

Circular Economy Convergence in the Visegrad Group: Regional Integration and EU Comparative Insights

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Abstract This study examines the progress of the Visegrad Group (Czech Republic, Hungary, Poland, and Slovakia) in implementing circular economy principles from 2015 to 2022, aligned with the EU Circular Economy Action Plan. Using Eurostat data and a quantitative methodology, comprising trend, descriptive, and correlation analyses, it evaluates twelve indicators, with emphasis on Material Footprint, Municipal Waste Recycling Rate, and Circular Material Use Rate. Results show partial convergence with the EU average, though significant national disparities persist. Slovakia leads in recycling, Poland excels in material productivity, and the Czech Republic shows steady progress in circular material use, while Hungary lags in waste management. The study underscores the need for targeted investment and policy harmonization within the V4 to support EU sustainability goals. It offers a novel regional perspective, contributing to the literature on circular economy transitions in geopolitically and economically integrated regions.

Keywords: Visegrad Countries, Circular Economy, Convergence Analysis, Sustainability, Regional Integration

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I. Introduction

In an era where sustainable development and environmental responsibility dominate global policy discussions, the circular economy has emerged as a strategic solution for the future. Unlike the traditional linear model of resource extraction, production, consumption, and disposal, the circular economy seeks to minimize waste and optimize resource efficiency, ensuring that materials and products remain in use for as long as possible. This transformation is essential for achieving long-term environmental sustainability, mitigating climate change, and reducing

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dependence on finite natural resources. Given the urgency of environmental challenges, assessing regional progress in adopting circular economy principles is crucial.

The European Union (EU) has been tracking circular economy indicators at the national level since 2015, revealing disparities among Member States. This presents an opportunity to analyze regions with shared geographical, cultural, and political characteristics - such as the Visegrad Group (V4) - and compare their performance against the EU average. The V4 formed in 1991 to support their integration into the European Economic Community. Since joining the EU in 2004, the V4 has evolved into a political bloc influencing EU policymaking (Hornat, 2021; Griessler, 2018; Jasiński, 2020).

Despite diverging political and economic developments, the V4 forms a compact cultural and economic unit shaping Central Europe (Vlackova, 2017). Measuring its progress in relation to Sustainable Development Goals (SDGs) and Environmental, Social, and Governance (ESG) criteria is increasingly relevant (Kozma, 2019; Nesiba & Cuhlova, 2021; Zvarikova et al., 2024; Hassan & Meyer, 2022). Each country's unique history, culture, and economic structure influences its capacity and willingness to implement circular economy principles.

While comparative studies on circular economy indicators across EU countries have increased in recent years, most analyses either focus on general EU-wide trends or adopt broad cross-country comparisons. What remains underexplored is a focused, region-specific assessment of the V4 countries as a cohesive unit, particularly in relation to their convergence with EU circular economy targets. This paper fills a gap by evaluating the progress of the V4 countries in integrating circular economy principles. It examines whether the V4 countries are converging with the EU average and assesses their alignment with circular economy targets established by the European Commission. The study analyses national policy frameworks, compares performance trends, and offers a broader view of regional sustainability alignment. It addresses the following research questions:

RQ1: How do V4 countries rank based on key circular economy indicators from 2015 to 2022?

RQ2: How do the V4 countries compare with the EU average between 2015 and 2022?

The first section provides a historical overview of each V4 country's approach to the circular economy since 2015, reviewing key national policies and strategic documents. The second section presents statistical research based on twelve circular economy indicators used in EU methodology. It applies correlation analysis to three key indicators: Material footprint, Municipal waste recycling rate, and Circular material use rate.

Using correlation convergence diagrams, the study evaluates distribution patterns and national differences. The final section compares the overall circular economy performance of V4 countries, deriving a comparative ranking based on Eurostat indicators. By integrating policy analysis with empirical data, this study contributes to a deeper understanding of the regional dynamics of

circular economy transitions within the EU and provides a valuable reference for policymakers, researchers, and stakeholders interested in sustainable development in Central Europe.

II. Circular Economy Implementation

The overview of circular economy implementation in V4 countries centers on a comparison of key elements in the circular economy as identified by the European Environment Agency (European Environment Agency, 2023). These elements include the establishment of a national circular economy strategy, the investment of financial resources into circular solutions, and the adoption of relevant legislative measures. Additionally, it encompasses monitoring the progress and setting targets for circular economy initiatives, as well as the involvement of both public and private institutions in its development. The association of stakeholders also plays a crucial role in advancing the circular economy.

A. Czech Republic

The Czech circular economy plays an important role in the National Recovery Plan (NRP), as the assessment of all projects involved in this programme is subject to the principle of 'no substantial harm', focusing on the environment. The NRP built on a number of strategic documents, one of which was 'Waste Management Plan for the period 2015-2024' (National Recovery Plan, 2023). NRP places emphasis on circularity principles, for example on the Investments in waste infrastructure; Waste recycling; Circular solutions in enterprises; Water savings in industry; Digitalization; Innovation and Education; and more (Ministry of the Environment of Czech Republic, 2021). One of the reforms of the NRP was precisely the completion and adoption of the 'Strategic Framework Circular Czech Republic 2040', which took place at the end of 2021 and was taken care of by the Ministry of the Environment, the strategy also includes specific measures to start implementing, such as "Promote the reuse of products through charities and reuse centres" (Ministry of the Environment of Czech Republic, 2023a). This is the first comprehensive strategy for the circular economy in the Czech Republic, which emphasizes the importance of promoting the principles of the circular economy and includes its implementation among the country's policy priorities, with the global goal of this strategy is 'Less waste and more value for the Czech Republic' (Ministry of the Environment of Czech Republic, 2023b). In addition to the NRP, the Czech Republic also reallocates resources and investments to various projects under operational programmes. Especially in the 2021-2027 EU programming period, programs are precisely oriented towards the promotion of circular solutions in enterprises, be it innovation, experimental development, consultancy, or cooperation with educational institutions

(Ministry of Industry and Trade, 2023). NGOs have gained prominence and have become advisory bodies in the formulation of the various steps, e.g. the 'Incien Institute for Circular Economy' or the 'Circular Academy' (Incien, 2024).

The Czech Republic has adopted several regulatory and legislative measures and changes in this area, mainly following the EU legislation from the 'Circular Economy Package'. The first is the update of the Waste Act No. 185/2001 Coll., which came into force in 2021. New regulations from European legislation have also been transferred to the 'Packaging Act' (Act No. 477/2001 Coll.) with the obligation to reduce, recycle and reuse packaging. Thanks to this law, the Czech Republic is obliged to launch a PET bottle and can backup system in 2025, which positively supports the ideas of circular economy. In addition, changes have also been made to the Energy Act No 469/2023 Coll. Adopted legislation linked waste sorting and management activities between municipalities and the state.

B. Hungary

In 2019 started project 'Implementing circular economy and addressing waste management challenges' under the auspices of the Ministry of Innovation and Technology. The 'Circular Economy Strategy' was launched in 2023 (OECD, 2023). It aims to make Hungary a more competitive and sustainable economy by 2040 and focuses on industry, agriculture and the service sector, divided into three priority areas where circular economy elements should be applied: biomass and food, construction industry, plastics (European Commission, 2024a). The 'National Waste Management Plan' for the period 2021-2027 plays an important role in the circular economy, focusing on the promotion of collection and recycling to increase recovery rates and, in turn, reduce landfilling as well as 'Climate and Nature Action Plan' adopted in February 2020 (European Environment Agency, 2022a).

In Hungary, cooperation between public policy and private companies focuses on finding solutions to general environmental risks (WasteRadar, Green Programme of the Hungarian Central Bank). The main role plays Circular Economy Platform with the official name the 'Business Council for Sustainable Development Hungary', founded in 2018, operates as a private institution working on this issue, bringing together companies and organizations to accelerate the transition to a circular economy model by sharing knowledge and creating joint projects and collaborations (Business Council for Sustainable Development in Hungary, 2024).

C. Poland

The Polish government initiated the implementation of a circular economy in 2015 with the adoption of the 'Circular Economy Action Plan'. In 2019, Poland adopted its national strategy, entitled 'Roadmap towards the transition to a circular economy'. The strategy encompasses a

wide range of policy areas, with nine ministries of the Polish government involved in its implementation. The Ministry of Entrepreneurship and Technology has been designated as the primary government body responsible for the implementation of the strategy (Avdiushchenko, 2021). The strategy encompasses over 40 activities, which have been categorized into four distinct areas: sustainable industrial production, sustainable consumption, bioeconomy and new business models. Each activity is associated with a competent ministry and a date of implementation, thereby ensuring that the objectives are met (Gospodarka o obiegu zamkniety, 2019). The monitoring system in Poland was implemented in 2021. The framework's development was an integral component of the adopted circular strategy. In addition to the indicators from the European Action Plan, the country employs eight indices to assess the degree of circularity at various levels. These include indices at the local level (e.g., the share of renewable energy or participation in circular economy campaigns), corporate level (e.g., the amount of waste disposed, the number of circular economy patents obtained), regional level (e.g., regional R&D expenditure), and national level (e.g., the share of renewable energy produced or the value of circular economy procurement in total public procurement) (European Environment Agency, 2022b).

The national environmental policy 2030, which includes changes in waste management towards a circular economy, is a key aspect of Poland's environmental policy. This policy is being implemented through the transformation of EU legislation and the correction of the waste management system. Poland's energy policy to 2040 encompasses alterations to the energy mix, the utilization of indigenous energy sources, a reduction in the utilization of coal, and an improvement in air quality. In 2022, the government adopted the 'National Raw Materials Policy 2050', which aimed to establish an efficient system for the management of secondary raw materials (Ministry of Climate and Environment Republic of Poland, 2022).

One of the largest European organizations engaged in the creation of a circular economy network across all countries is the Polish Circular Hotspot, in collaboration with the National Institute for Circular Economy. This initiative produces research and studies, promotes new business models, develops policies, and disseminates awareness about sustainability and circularity (National Institute of Circular Economy, 2020).

D. Slovakia

Slovakia has only recently started to integrate circular economy principles into its policies, because the first comprehensive strategy 'Closing the loop in Slovakia' was developed in cooperation with the OECD in 2022 (OECD, 2022), focusing on areas such as food and bio-waste, construction, sustainable production and consumption, with a focus on economic instruments (European Commission, 2023a). Slovakia, like the Czech Republic, has adapted the principles of the green economy, the transition to renewable energy and the promotion of science and

innovation through the EU-funded National Renewal Plan. One of these is the Slovak Ministry of the Environment's plan for the Slovakia by 2030, otherwise known as 'Envirostrategy 2030: A Greener Slovakia'. Overall, the plan aims to promote sustainability and combat environmental challenges. Regarding the circular economy, Slovakia has set itself several targets: to increase the recycling rate of municipal waste to 60%, to reduce landfilling to less than 25%, to ensure 70% green public procurement, and to ban the disposal of food waste for supermarkets. Thus, all these targets are mainly focused on waste management (Ministry of the Environment of Slovak Republic, 2022). The second general strategy in which elements of circular economy have appeared are a document issued in 2019 by the Ministry of Economy of the Slovak Republic, namely the 'Strategy of Economic Policy of the Slovak Republic until 2030', 'Waste Management Plan' and the 'Waste Prevention Programme of the Slovak Republic for 2019-2025' (Ministry of Economy of Slovak Republic, 2019). Similarly to Hungary, the Circular Slovakia platform has been operating in Slovakia since 2018, bringing together the public, private and non-governmental sectors with the ambition to accelerate the transition to a circular economy. It provides various educational activities, summits and working groups in this field (Circular Slovakia, 2024). The Incien Institute of Circular Economy, also operating in the Czech Republic, is involved in education and awareness-raising (Incien, 2024). Table 1 summarizes the attitudes of the V4 countries.

Table 1. Summary of V4 Policy Approaches

| | Czech Republic | Hungary | Poland | Slovakia |
|-------------------------------|--|--|---|--|
| Focus areas | Waste recycling, reuse, water savings, digitalization, education, circular solutions in enterprises. | Biomass & food, plastics, construction; industry, agriculture, service sector. | Sustainable production & consumption, bioeconomy, new business models, energy transition, secondary raw materials. | Waste management (recycling, landfill reduction), food waste, sustainable production and consumption. |
| Implementation tools | NRP funding, EU Operational Programmes, legislation updates (Waste Act, Packaging Act, Energy Act). | Circular economy platform (private sector cooperation), public-private partnerships. | Inter-ministerial coordination, detailed implementation timelines, circular economy monitoring system with 8 indices. | Targets set in Envirostrategy, economic instruments, education, public-private platform Circular Slovakia. |
| Main circular economy targets | Emphasis on "Less waste, more value" qualitative; PET/can deposit system. | No specific quantified targets stated. | Embedded in strategic documents; renewable energy share, procurement value. | 60% municipal waste recycling, <25% landfill, 70% green public procurement, ban on supermarket food waste. |

(Source) Own processing.

The basic discussion on the adoption of the circular economy in the EU is linked to the other background documents. Firstly, the 2015 Circular Economy Action Plan (CEAP) was adopted as the EU's first major strategy on the circular economy. It focuses on waste, recycling, product lifecycles and resource efficiency, and was revised in 2020 under the European Green

Deal. The CEAP is linked to a number of other documents (2018 - Plastics Strategy; 2020 - The New Industrial Strategy for Europe; 2020 - the EU Strategy for Sustainable and Circular Textiles; 2023 - the EU Batteries Regulation). The Circular Economy Strategies are linked to the Corporate Sustainability Reporting Directive (CSRD, 2022), which makes it mandatory for certain companies to report on their environmental, social, and governance (ESG) performance. Circular economy policies focus on transforming how the EU designs, produces, consumes and manages resources, targeting systemic change across entire sectors (e.g. packaging, textiles and electronics). ESG frameworks in the EU are driven by the need for transparency and accountability in the financial and corporate sectors. In terms of political negotiations within the EU between 2015 and 2022, the fundamental nature of discussions among the V4 countries (as well as the Baltic States) regarding the circular economy strategy can be identified. The V4 countries expressed concerns about a loss of competitiveness for the EU's less developed economies. Poland expressed concern that strict circular economy rules could burden coal-based industries and SMEs. Hungary warned against one-size-fits-all circular economy targets, requesting more technical and financial assistance for the transition to circular economy. Slovakia and the Czech Republic called for regional funding mechanisms to be strengthened and highlighted gaps in implementation capacity (Pomázi & Szabó, 2020; European Commission, 2022).

The V4 Common Strategy for CE was created at the time of the approval of the first version of the CEAP in 2015. It refers to the need to unify environmental commitments in view of geographical proximity. This resulted in the Ministerial Conclusions of the Ministers Responsible for Regional Development (Common Strategy, 2014). The V4 presidency rotates among the individual states for one year. For example, the Polish presidency was held in 2020/21, the Hungarian presidency in 2021/22, the Slovak presidency in 2022/23, and the Czech presidency in 2023/24 (and again). Since 2015, the countries that have chaired the V4 have coordinated their efforts to fulfil the commitments of the UN Agenda 2030 on sustainable development, as well as improving the implementation of the circular economy in national strategies (Visegrad Group, 2019, 2021). The Polish Presidency (2024/2025) has also declared its commitment to promoting the UN Agenda 2030 (V4 Presidency, 2024). Despite the decline in the intensity of political cooperation within the V4 since 2022 due to differing international policy orientations (e.g. regarding the war in Ukraine), joint coordination of circular economy initiatives continues (Borek et al., 2025). This cooperation and mutual comparison of individual circular economy indicators is seen as the reason for the growing trend of achieving individual CEAP targets within the V4 countries. According to a study by Stremikis et al. (2024), between 2010 and 2021, thirteen of the twenty CEAP criteria improved in all V4 countries, while seven deteriorated compared to the EU average. The Environmental Implementation Review (EIR) documents the efficiency of CEAP criteria implementation. The EIR is a regular reporting tool designed to improve the implementation of EU environmental laws and policies. Four editions of the report

have been published, in 2017, 2019, 2021 and 2025, and it is prepared by the European Commission. Reports on the V4 countries show declared commitments, but improvements only in specific individual areas of the circular economy compared to other EU countries (European Commission, 2025).

Based on cross-country comparisons, Lehmann et al. (2023) demonstrate that Eastern European countries, including those in the V4 group, are falling behind in terms of the key criteria required for the implementation of a circular economy. This is due to historical differences in political and social development. Comparative research between EU regions covers a wide range of political views and public attitudes towards EU policies. This includes the controversy surrounding the adoption of the circular economy as part of the Green Deal. (Leipold, 2021; Starke et al., 2022). This study focuses only on comparisons between the V4 and the EU as a whole rather than between different historical and geographical regions with different conditions for implementing the circular economy.

III. Research Methodology

The objective of this paper is to evaluate the progress of the V4 countries in the circular economy indicators. Based on a review of the literature, two research questions (RQ) are proposed:

RQ1: How do V4 countries rank based on key circular economy indicators from 2015 to 2022?

RQ2: How do the V4 countries compare with the EU average for the period 2015-2022?

The study employs a quantitative research approach that combines descriptive statistical analysis, trend analysis, and correlation analysis to evaluate the progress of the V4 countries in period from 2015 to 2022, as this was the period during which the first Circular Economy Action Plan was adopted by the V4 countries. The research is based on secondary data obtained from the publicly available European Eurostat Database (Eurostat, 2024), which provides standardized twelve circular economy indicators for each country, with a score for the entire period from 2015 to 2022. The analysis then focuses on three circular economy data indicators, namely material footprint, municipal waste recycling rate, and circular material use rate, which were selected based on the definition of the basic principles of the circular economy (Helander et al., 2019; Moraga et al., 2019; Mesa et al., 2020).

The results are evaluated through the application of trend analysis and correlation analysis between the V4 countries. The results can be used to ascertain whether countries will reach similar levels of observed circularity indicators in the future or whether they will diverge in their results. The average growth coefficient values were calculated from the country data,

comparing the initial value with the final value and measuring the average annual percentage change in the variables. To avoid the double counting of values in the calculations, the values for the EU average have not been taken into account. The final overview uses relative statistical comparison of twelve indicators compared to the EU average scores.

Additionally, the study also benchmarks V4 countries against explicit targets set by the European Commission (EC) in its Circular Economy Action Plan (2015, revised 2020). The EC's targets include a minimum 65% municipal waste recycling rate by 2035, no more than 10% landfilling of municipal waste, and a proposed doubling of the circular material use rate to approximately 22.4% by 2030 (European Commission, 2020). Although there have been strong calls from the European Parliament and environmental NGOs to set an EU-wide binding target for reducing the Material Footprint, no specific reduction target has not been adopted yet.

IV. Results

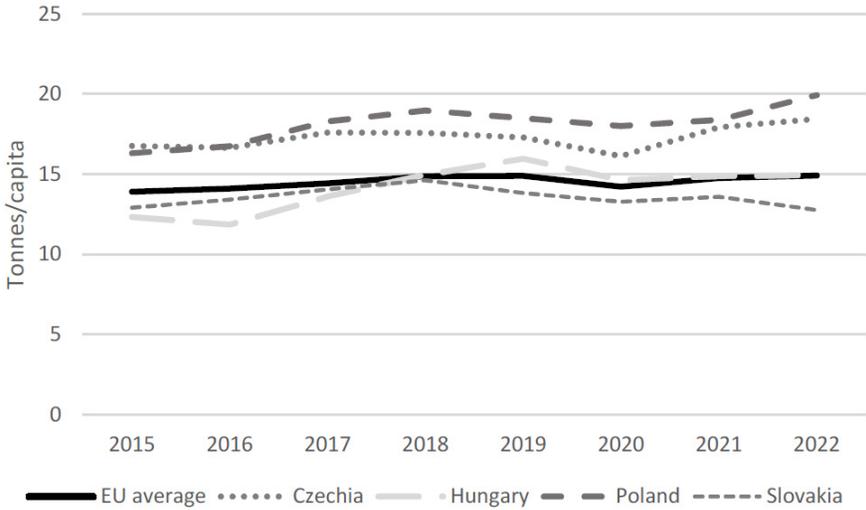
A. Material footprint

The material footprint indicator talks about the resource efficiency and the volume of materials that are used and consumed in a given area (according to ESMS Indicator Profile, see (European Commission, 2024b)). The EU has set a goal of gradually reducing this indicator to the lowest possible level and of increasing the use of renewable and recyclable materials. Figure 1 illustrates the evolution of material footprint values, which represent the quantity of anthropogenic materials consumed per capita per year in the production of goods and services. The higher value of material footprint variable indicates the greater amount of primary materials required along the supply chain to meet final demand.

The EU average material footprint has remained around 14 tonnes per capita, with a slight increase since 2015. Under a linear economy, this trend is expected to continue; according to the European Commission (2024), global material consumption is projected to double in the next 40 years. The EU consumes more materials than it produces, making European consumption a driver of emissions abroad.

A key factor influencing material footprint size is economic dependence on industrial production. A comparison of V4 GDP structures reveals a high degree of similarity, with industry contributing 25%-30% of GDP. In 2022, the Czech Republic had the highest share (30.69%), while Hungary had the lowest (24.61%) (Statista, 2022). Figure 1 shows Poland with the highest material footprint among the V4, increasing slightly over time. The Czech Republic and Hungary also exceed the European average.

Figure 1. Material footprint in V4 and EU countries 2015-2022, in tonnes per capita annually

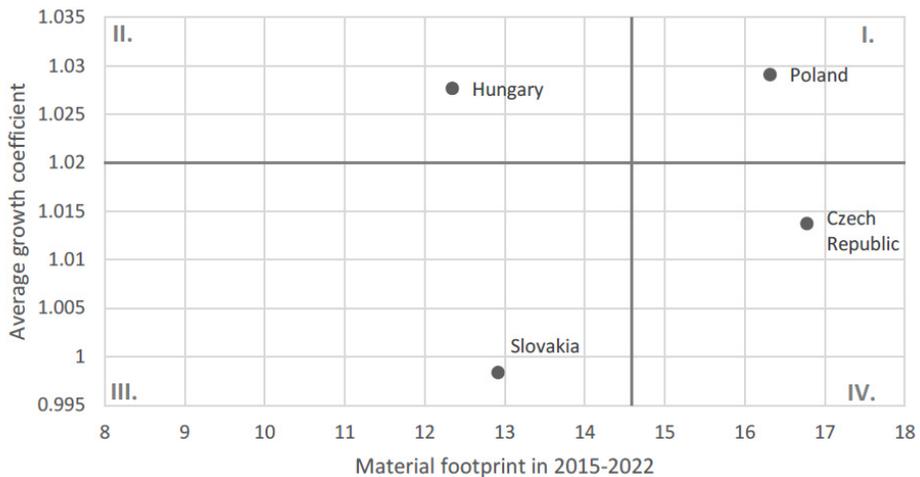


(Source) Own proceeding based on Eurostat (2024a), online data code: cei_pc020
 Note. Material footprint is calculated as domestic extraction of primary materials (biomass, fossil energy materials/carriers, metal ores and non-metallic minerals) plus raw material equivalent of imports, minus raw material equivalent of exports.

When comparing GDP per capita, Poland and Hungary are roughly equal (The World Bank, 2022), suggesting similar production per capita, though Poland is less resource-efficient—possibly due to its mineral extraction. Poland leads the EU in hard coal mining and is a major producer of metallic and non-metallic minerals. Most coal is consumed domestically, supplying a large share of the energy system (Circle Economy Foundation, 2024). Meanwhile, the Czech Republic has the highest population productivity relative to its material footprint.

In 2022, Slovakia exhibited the lowest value for this indicator, at 12.77 tonnes per capita, while simultaneously demonstrating the second highest GDP per capita among the selected countries. The Slovak trend has remained relatively consistent. The material footprint of Hungary is at a comparable level to Slovakia's, with both countries outperforming the European average. Consequently, it can be posited that Slovakia and the Czech Republic demonstrate the most favourable outcomes among the V4 countries in this domain.

A four-quadrant diagram of the correlation (Figure 2) between the Material Footprint 2015-2022 and the Average growth coefficient shows that Hungary is closest to quadrant II, i.e. Hungary started with lower values in 2015 and gradually improved (converged to the EU average). The Czech Republic is closest to quadrant IV, i.e. it started with good values and slowly improved over the following seven years. In both countries there is significant convergence compared to Poland and Slovakia. Therefore, Poland (quadrant I) and Slovakia (quadrant III) show the highest degree of divergence among the countries studied.

Figure 2. Correlation diagram of V4 countries' development in material footprint, 2015-2022

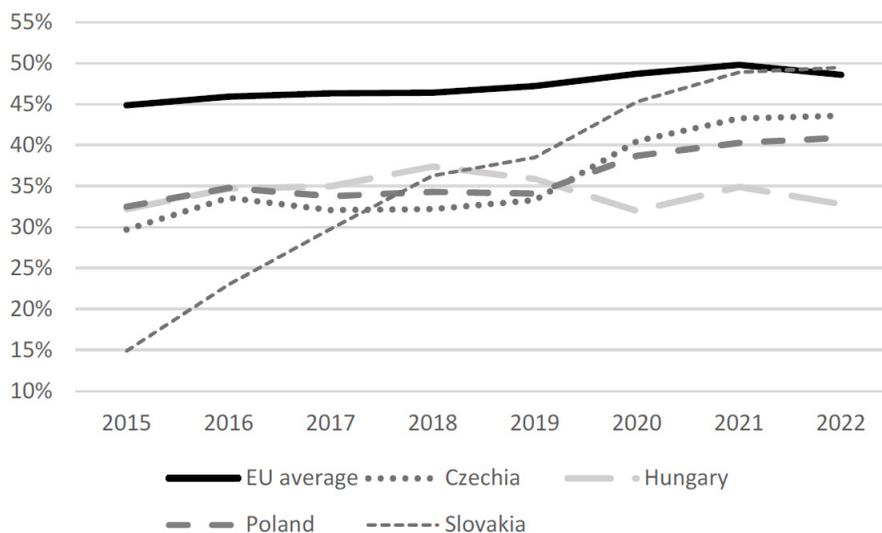
(Source) Own proceeding based on Eurostat (2024a), online data code: cei_pc020

B. Municipal waste recycling rate

The municipal waste recycling rate indicator provides insight into the utilization of waste from final consumers as a resource in the circular economy (Albizzati et al., 2024). Due to its heterogeneous composition, the thorough treatment of this waste stream is for a long period still challenging (Soukopova et al., 2022). Consequently, the municipal waste recycling rate serves as an effective indicator of the overall quality of the waste system. The EU has set a target of reaching a recycling rate of 65% by 2035. By 2020, this target has been set at 50% (European Commission, 2024). None of the V4 countries managed to meet the 2020 target.

Figure 3 illustrates the most pronounced shift in this area, which has occurred in the Slovak Republic. Since 2015, the municipal waste recycling rate in Slovakia has increased from below 15% to almost 50% in 2020. This places Slovakia above the EU average, which has been between 45% and 50% for a considerable period of time.

As part of the changes to legislation following the adoption of the EU Circular Economy Action Plan, the Slovak government has adopted two successive programmes to meet the European targets: the 'Slovak Waste Management Programme' for the period 2016-2020, and the 'Waste Prevention Programme of the Slovak Republic' for the period 2019-2025. The European Environment Agency, which assesses the pathway to achieving the EU's national waste sorting targets in a study, identifies several factors affecting recycling rates. Slovakia has a landfill tax since 2020, i.e. a ban on landfilling of bio-waste, door-to-door collection of cardboard, metals plastics and glass (European Environment Agency, 2022c).

Figure 3. Municipal waste recycling rates in V4 in 2015-2022 (in % annually)

(Source) Own proceeding based on Eurostat (2024b), online data code: cei_wm011

Note. It is calculated as a share of recycled municipal waste in total generated municipal waste (this represents the sum of municipal waste collected by units responsible for waste collection and the estimated mass of generated municipal waste not covered by waste collection).

Furthermore, municipal waste recycling rates in the Czech Republic have demonstrated a consistent and notable upward trajectory. Since 2015, the proportion of municipal waste recycled has increased from below 30% to approximately 43% in 2022, which is attributable to an expansion in composting activities. The Czech Republic has enacted a number of legislative measures pertaining to waste management since 2021, including the 'Waste Act' and the 'End-of-Life Products Act'. In the context of municipal waste recycling, this has resulted in a relatively modest increase of only three percentage points. The recycling of bio-waste, wood and textiles is not adequately addressed.

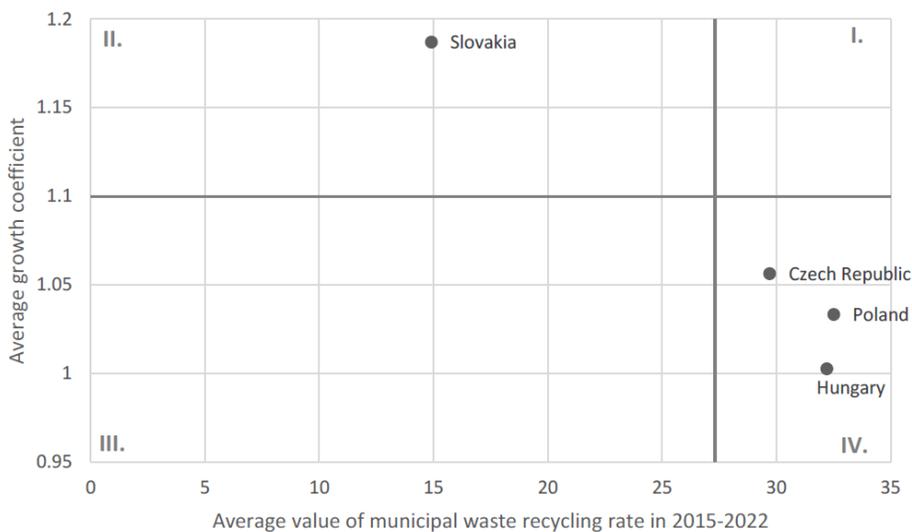
Poland, like the Czech Republic, has a long-term performance of 35-40% in terms of waste collection and recycling systems, using very similar elements as the Czech Republic and Slovakia. The country employs a landfill tax, has clearly defined support instruments to achieve the targets, bans the landfilling of bio-waste and combustible waste, and utilizes separate collection systems, with door-to-door being the predominant method.

As for Hungary, the municipal waste recycling rate has started to decline slightly since 2018, when it was at its highest (37%). This trend is only visible in the V4 grouping in this country. Hungary has the lowest municipal waste recycling rate among the V4 countries. Factors that may be influencing this trend are the following: responsibilities for achieving recycling targets are fragmented between several authorities, minimum recycling targets are defined which

service operators have to comply with, a ban on landfilling of untreated municipal waste has been in place since 2002, quality collection of paper, glass and plastic is not well established, there is no separate collection for food waste.

Figure 4 of the correlation between the Average municipal recycling rate 2015-2022 and the average growth coefficient shows that the Czech Republic, Poland and Hungary are in quadrant IV, i.e. the countries had high initial values in 2015, but convergence with the EU average was progressively lower in the following years. Only Slovakia had lower initial values but achieved the strongest convergence between 2015 and 2022. All countries converge upwards towards the EU average.

Figure 4. Correlation diagram of V4 countries' development in municipal waste recycling rate, 2015-2022



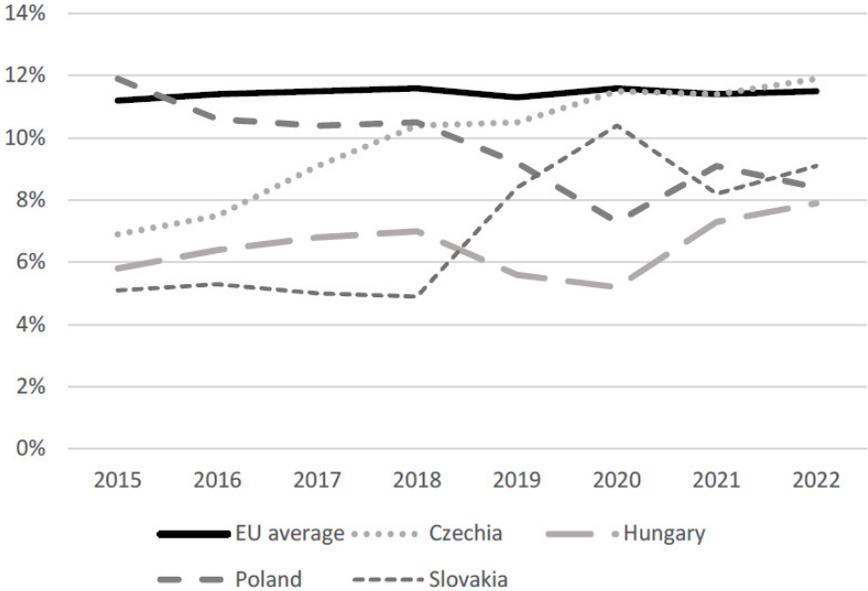
(Source) Own proceeding based on Eurostat (2024b), online data code: cei_wm011

C. Circular material use rate

The principles of the circular economy state that the more material is recycled and returned to the economy, the less waste is generated, and the less primary raw materials are extracted (Cullen, 2017; Skare et al, 2023). The circular material use rate, or circularity rate, is the proportion of recycled materials in the total demand for materials in a country. Countries with high rates of this indicator have either high levels of waste recycling or low levels of domestic materials consumption.

The circular material use rates across the V4 countries between 2015 and 2022 display significant variation, both in trends and in relation to the EU Member States average¹⁾, which remained relatively stable at approximately 11.7% throughout the period, as illustrated in Figure 5.

Figure 5. Circular material use rate in the V4 in 2015-2022, (in % annually)



(Source) Own proceeding based on Eurostat (2024c), online data code: cej_srm030

Note. It is calculated as the share of materials recovered and reintroduced into the economy as secondary raw materials (materials recovered through recycling processes and reintroduced into production and consumption systems) compared to the total material use (total quantity of materials used in an economy, including both primary or extracted raw materials and secondary or recycled and reused raw material).

Among the V4, the Czech Republic demonstrated the most consistent and significant improvement. Starting below the EU average in 2015, Czech Republic ultimately surpassed the EU benchmark by 2022. Slovakia also showed progress, particularly between 2018 and 2020, where its circular material use rate rose sharply to reach its highest recorded level. Although a slight decline followed in 2021 and 2022, Slovakia remained close to the EU average, suggesting that despite some volatility, the country has made meaningful strides in advancing circular economy practices. Hungary followed a more fluctuating path. After gradual improvement from 2015 onward, Hungary experienced a sharp increase in circularity in 2019 and 2020. Although this was followed by a brief downturn, the rate began to recover in 2022, indicating renewed efforts to bolster material reuse.

In contrast, Poland stands out as the only V4 country experiencing a long-term decline. Initially above the EU average in 2015, Poland’s rate steadily fell, reaching its lowest point around 2020. Although a modest rebound occurred in the final two years, Poland remains

1) The EU average circular material use rate is calculated as a weighted average based on each Member State’s Domestic Material Consumption. This reflects the proportion of recycled materials relative to total material use at the EU level, giving countries with larger economies proportionally greater influence in the aggregate figure (Eurostat, 2018).

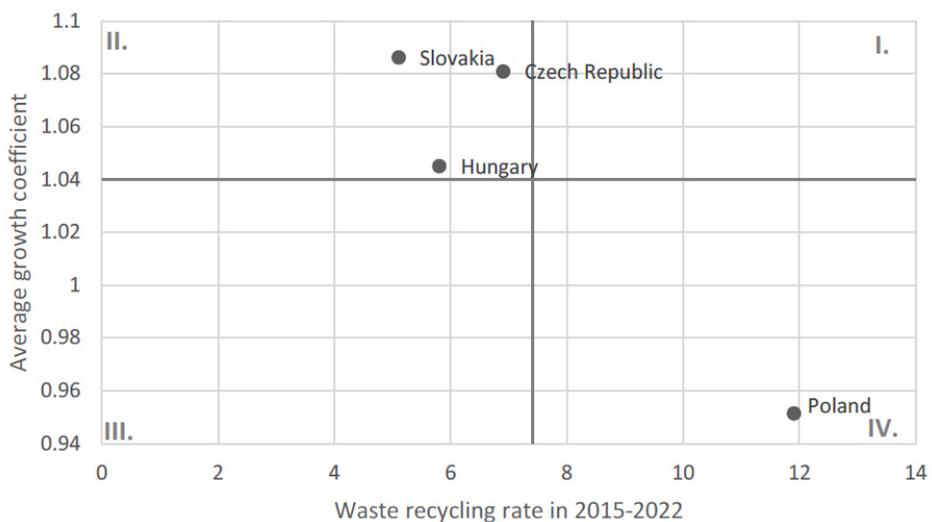
significantly below its 2015 level and below the EU average.

Among the eight most common recyclable materials, only aluminium, paper, and glass have well-functioning secondary markets (European Environment Agency, 2023). Competing with new materials remains a challenge, particularly for wood and textiles. A key barrier to greater uptake of recycled materials in the V4 countries is insufficient funding for waste processing. While all V4 nations have established municipal waste collection and sorting systems, they must advance beyond collection to actual material reuse.

In the Czech Republic, which has the highest recycling rate among the V4, EKO-KOM holds a monopoly on plastic collection. However, its revenues cover only basic collection and sorting, leaving other plastics to be incinerated or landfilled. Landfill fines remain lower than the cost of new recycling technologies, and domestic demand for recycled products is weak (Gosling, 2022). As a result, these materials are often exported to Germany, Scandinavia, or other Western countries, lowering the national circular material use rate.

These challenges extend beyond the Czech Republic. The V4 countries, with similar economic and policy frameworks, share common barriers: weak legislative pressure on product design and recycling, fluctuating waste material availability, strict product standards, and a lack of trust in recycled materials. This mistrust discourages investment and creates instability in demand. As shown in Figure 6, Slovakia, followed by the Czech Republic and Hungary, has made the most progress toward the EU average. Poland, initially performing well in 2015, has since lagged in convergence. Notably, none of the V4 countries fall into divergence quadrants I or III, indicating significant progress in waste recycling relative to the EU average.

Figure 6. Correlation diagram of V4 countries' development circular waste recycling rate, 2015-2022



(Source) Own proceeding based on Eurostat (2024c), online data code: cei_srm030

The largest changes can be predominantly seen in Slovakia and Poland. More significant changes can be observed in the recycling rate of municipal waste in Slovakia (1,187) and Poland (1,033). For material footprint the biggest differences are again between Slovakia (0,998) and Poland (1,029). Circular material use rate indicates also gap between Slovakia (1,086) a Poland (0,951). Czech Republic and Hungary stay in between in the middle (Eurostat (2024c).

The analysis shows that V4 countries are converging in circular economy performance, with initially weaker performers improving over time. Achieving a resource-efficient economy requires effective natural resource use and recycling, positively impacting circular material use, secondary raw material access, waste reduction, and job creation in the sector. Slovakia made the most progress from 2015 to 2022.

Table 2 summarizes each country's performance across selected indicators, assigning scores from 1 (best) to 5 (worst) using the Ordinal Function and Scoring Method. All indicators are part of the EU's Circular Economy monitoring framework that connects each of these variables to circular economy progress, with the framework distinguishing core circular activity indicators and the broader environmental and economic impacts stemming from a circular transition (European Commission, 2023b). These indicators are grouped into five areas: production & consumption, waste management, secondary raw materials, competitiveness & innovation, and global sustainability/resilience. The total score determines the best and worst-performing countries in circular economy integration. The results against European Commission circular economy targets reveal additional mixed performance among the V4 countries.

Table 2. Heat Map Scoreboard of the Circular Economy Results in the EU (2015-2022)

| Indicator | EU average | Czech Republic | Hungary | Poland | Slovakia |
|---|------------|----------------|-----------|-----------|-----------|
| Material Footprint | 2 | 4 | 3 | 5 | 1 |
| Resource Productivity | 1 | 3 | 4 | 5 | 2 |
| Municipal Waste Generation | 4 | 5 | 2 | 1 | 3 |
| Municipal Waste Recycling Rate | 2 | 3 | 5 | 4 | 1 |
| Electronic Waste Recycling | 4 | 2 | 5 | 3 | 1 |
| Circular Material Use Rate | 2 | 1 | 5 | 4 | 3 |
| Private Investments to Circular Economy Sectors | 1 | 5 | 3 | 2 | 4 |
| Employment in Circular Economy Sectors | 4 | 2 | 3 | 1 | 3 |
| Gross Added Value Related to Circular Economy Sectors | 1 | 4 | 3 | 2 | 5 |
| Consumer Footprint Index | 1 | 3 | 2 | 5 | 4 |
| Greenhouse Gas Emissions from Production | 3 | 4 | 1 | 5 | 2 |
| Dependence on Material Imports | 2 | 4 | 3 | 1 | 5 |
| Result | 27 | 40 | 39 | 38 | 34 |

(Source) Own processing based on Eurostat (2024d)

Note. The colour scale of heat map follows the semaphore principle, where green represents the highest-performing values, yellow indicates moderate or average performance, and red signals the least favourable outcomes.

Values for calculation of each indicator are presented in online Appendix 1.

A comparative analysis of key circular economy indicators reveals that Slovakia currently leads the V4 group in overall performance, despite having only recently adopted a formal circular economy strategy in 2022. Slovakia ranks first on Municipal Waste Recycling Rate indicator, reflecting recent gains in waste sorting and recycling capacity. This performance complements Slovakia's strengths in resource productivity and a low material footprint, positioning the country favourably in terms of waste minimization and material efficiency. However, these surface-level gains mask deeper structural issues as Slovakia continues to struggle with converting collected waste into high-quality secondary raw materials, limiting the effectiveness of its recycling system. Furthermore, despite improvements in selected indicators, Slovakia still lags behind the EU average in several broader areas, such as circular material use and value-added contributions from circular sectors.

Poland ranks second among the V4 in circular economy performance, demonstrating a more structured and policy-driven approach to sustainability. The country has adopted a comprehensive national circular economy strategy, accompanied by monitoring systems, research initiatives, and supportive legislation. These institutional efforts have begun to translate into practical applications at both municipal and corporate levels, where circular solutions are gradually being integrated into waste management, production, and consumption systems. Poland is also undergoing a transition toward a more sustainable energy system, which is expected to reduce its environmental footprint by improving resource efficiency, lowering greenhouse gas emissions, and minimizing the consumption footprint. However, several structural challenges persist. Material processing and recycling rates remain below the EU average, hindering the country's progress in achieving higher circular material use. Poland's resource productivity and municipal waste recycling rate also fall short of the levels required to meet the EC's 2030 and 2035 targets. Despite these limitations, Poland performs well in low municipal waste generation and benefits from a relatively self-sufficient circular industry, which has begun to attract foreign investment in sustainable technologies and infrastructure.

Hungary ranks third, benefiting from low greenhouse gas emissions and a relatively clean energy mix, which positively impacts consumption behaviour and ecological footprint. The country also generates significantly less municipal waste than the EU average, which positions it well in waste prevention and reduction metrics. However, these advantages are undermined by persistent weaknesses in waste processing capacity and the transformation of waste into secondary raw materials. Hungary consistently lags behind both V4 counterparts and EU standards in recycling infrastructure and material recovery, making it one of the least prepared to meet the EU's binding circular economy targets in their current form. Although Hungary has laid out clear intentions in its waste management strategy (through 2027) and circular economy roadmap (to 2040), progress is hindered by political and institutional uncertainty. Governance challenges may affect access to EU funding, which is essential for the implementation of large-

scale circular economy initiatives. Without enhanced policy enforcement, investment incentives, and infrastructure development, Hungary is unlikely to reach the EC's municipal waste recycling rate target or to significantly improve its circular material use rate by the 2030 deadline.

The Czech Republic leads the V4 on the Circular Material Use Rate aiming to double the share of recycled materials in the economy, from ~11.2% to 22.4% by 2030. As the only V4 country currently exceeding the EU average, Czechia's sustained growth in Circular Material Use Rate between 2015 and 2022 underscores its success in integrating recycled content into production and manufacturing. This places the country in a favourable position to approach the 2030 target. Recent progress, supported by EU funding, has advanced eco-friendly solutions, secondary raw material use, and green infrastructure. A circular economy roadmap to 2040 was introduced in 2021, with private sector involvement in research and education. However, major challenges include high municipal waste generation, inefficient resource use, and reliance on non-renewable energy sources. The country's dependence on material imports and high emissions further limit progress. Nevertheless, given its economic growth, investment climate, and proactive policies, the Czech Republic is well-positioned to improve its circular economy ranking within the V4. The Czech Republic, which ranks third among the V4 in municipal waste recycling, demonstrates a steady upward trend and stronger policy continuity. While its current recycling rate is not yet at the 65% threshold, Czechia's progress aligns relatively well with EU trajectories. Its established infrastructure and long-term policy planning suggest that it is well-positioned to meet the EU target if investment and public engagement continue to expand.

V. Discussion and Conclusions

The EU countries are divided into two distinct groups according to their performance in the circular economy indicators set by the European Commission (Mazur-Wierzbicka, 2021). There is a growing perception that Europe is moving at two different speeds in terms of countries' progress in the circular economy. The group of more advanced countries comprises Germany, Belgium, Spain, France, Italy and the Netherlands. Consequently, other European countries have the potential to emulate the exemplary practices observed in these countries and to be motivated to implement similar practices. The fostering of collaboration and knowledge sharing is of paramount importance (Mondal et al., 2023; Mishra et al., 2019). This is particularly evident when considering the macro perspective between leading and lagging countries. The V4 often presents a united front in broader EU matters (e.g. energy security, sovereignty-related issues), however evidence suggests that they do not consistently act as a cohesive bloc in the realm of circular economy policy. Moreover, there is no formal V4 environmental negotiation framework akin to their collaboration in foreign policy. Their attitudes in EU negotiations on this topic

tends to be fragmented and nationally driven, rather than strategically aligned. When comparing the circular economy in different EU countries, it is important to consider both regional policy approaches and integrative Europe-wide objectives. While some studies provide a quantitative analysis of structural differences between countries and categorise elements hindering sustainability (Lehmann et al., 2023), others focus on the need for standardisation in performance assessment and the development of a common performance measurement framework in the EU (Pakuła et al., 2025; Colivicchi et al., 2025). These kinds of studies adopt different approaches to the circular economy. Ultimately, political decision-making must uphold the principles of subsidiarity and proportionality as enshrined in the Treaty on European Union.

The research revealed that not all countries surveyed are making comparable efforts to implement new solutions in the circular economy. This is despite the topic having been discussed in the EU since 2015, when the Circular Economy Action Plan was adopted and the EU began to develop strategies for its implementation. The Czech Republic and Poland are the countries in the V4 group that are making the most significant efforts in this area. They have both adopted national circular strategies and are working to meet their goals, while making heavy use of EU funding, such as the NextGenerationEU fund for the national recovery plans of member countries. In addition, these countries have incorporated circularity elements into other strategic plans and documents, are engaged in intensive research and development in this field, and are facilitating the collaboration of stakeholders, public actors, and entrepreneurs to enhance cooperation and progress on circular solutions. Hungary has only recently commenced its circular activities, with the development of a national strategy in collaboration with the OECD in 2023. This strategy is comprehensive, with specific targets, responsibilities, and an elaborate monitoring system. Slovakia has the least activity in the field of circular solutions and does not even have an adopted national strategy on the circular economy.

The scoreboard provides key insights into the progress of the analysed countries in their transition to a circular economy. Slovakia ranks highest, demonstrating strong performance in resource management, waste reduction, and circular economy development. In contrast, the Czech Republic and Hungary would benefit from greater focus on optimizing material use, improving recycling rates, and reducing reliance on imported materials to enhance their circular economy strategies. While all V4 countries show varying degrees of progress in the transition to a circular economy, Czechia and Slovakia appear best positioned to meet EU targets, albeit for different reasons - proactive policy in the former, structural efficiencies in the latter. Poland and Hungary, although making strides, face more substantial obstacles in aligning with EU benchmarks. Achieving full compliance with the EC's circular economy goals will require not only national commitment but also targeted support to address capacity gaps, infrastructure investment, and cross-sector coordination across the V4 region. The countries' specificities need to be considered while forming environmental strategies (Bilas & Franc, 2024).

Achieving full compliance with the EC's circular economy goals will require not only national commitment but also targeted support to address capacity gaps, infrastructure investment, and cross-sector coordination across the V4 region. In the future, continued monitoring and refinement of the circular economy monitoring framework will ensure that progress is tracked and focus areas are identified. The implementation of targeted policies and the promotion of consumer behaviour shifts towards circular practices will enable countries to significantly accelerate its transition to a more resource-efficient future and fulfilling the SDGs.

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