

## WASTE MANAGEMENT AS A CIRCULAR ECONOMY TOOL IN THE CONDITIONS OF COUNTRIES AND CAPITALS OF V4 COUNTRIES

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**Abstract:** *The circular economy is the most common synonym for measuring countries or cities to achieve the goals of sustainable goals aimed at transforming them into the image of a circular economy. The primary goal of the contribution is to determine the state of application of waste management conditions within the V4 countries, but also in their capital cities, with their subsequent comparison. To better grasp the primary objective, we used research questions, focusing not only on the V4 countries but also on the capitals of the V4 countries. To achieve the primary goal, we used several statistical data taken from official statistical offices and annual reports. We processed these statistical data using mathematical-statistical and theoretical-general methods and compared them with the monitored countries and cities. Despite this, we were confronted with several limitations of data or publications for this monitored region. Nevertheless, we know that Budapest produced the most municipal waste in 2019 at the level of 680,400 tons, followed by Prague. On the contrary, Prague produced the most municipal waste per inhabitant each year in a volume of 510 kg per capita. However, the following year, Warsaw was already at the level of 707,364.05 tons of municipal waste, followed by Budapest. This year, Bratislava produced the most municipal waste per inhabitant, an average of 487 kg of municipal waste per capita. To achieve the circular economy and, therefore, the 2030 Agenda, it is essential to understand the given parameter in this region.*

**Keywords:** Waste management, Visegrad Group, Circular economy

### 1 INTRODUCTION

Based on mathematical and statistical predictions, it is assumed that the world population will increase to 8.5 billion people by 2030. In another 20 years, it is expected to increase to 9.7 billion people. Related to this is the expected doubling of global GDP (almost every two decades) with a significant increase in per capita income. This will have an almost directly proportional effect of doubling the material used and the resulting waste, which impacts the overall environment (climate change, pollution, erosion, land use change). Annual waste production is expected to increase by 70% by 2050. Of this, plastics would account for 15% of the global carbon budget and 20% of oil consumption by 2050 [35].

The circular economy aims to maintain the total value of resources for as long as possible, emphasizing social, technological, and economic parameters with an environmental undertone (minimization of generated waste). Author Geissdoefer defines the circular economy as: “a regenerative system in which resource input and waste, emissions and energy leakage are minimized by reducing, closing, and narrowing material and energy cycles. This can be achieved by setting up the necessary design, then maintaining, repairing, reusing, repurposing, renovating, and recycling”. In turn, the author [29] defines the circular economy as “an economic system that is based on business models that replace the concept of “end of life” by reducing, possibly reusing, recycling and regenerating materials in production/distribution and consumption processes, which works micro and macro level to achieve sustainable development”. The aim of

the circular economy is to preserve as much value as possible from resources, products, parts, and materials, to create a system that enables long life, optimal reuse, renovation, re-production and recycling [24]. The achievement of the circular economy goal is the key to fulfilling the 2030 Agenda for Sustainable Development (SDG 12) and the EU vision until 2050. Based on the first action plan of the circular economy [9], according to the established legislation, clear goals were set for revised waste, such as waste management methods [8]. At the same time, within the circular economy action plan framework, they addressed the issue of recycling together with the pan-European strategy for plastics, aiming to change how plastics are used and recycled. The circular economy monitoring framework, added to the resource and raw material efficiency scoreboard, included ten indicators in 4 areas to improve progress monitoring and identify positive trends and areas that require more action by the European Union [10].

The created EU Circular Economy Action Plan (CEAP) until 2020 is an integral part of the European industrial strategy that helps to fight climate change as well as its overall natural environment. Within this industrial strategy, the EU is trying to ensure that products entering the single European market are designed so that their life cycle is primarily focused on usefulness, easier reuse, and the possibility of recycling or repair [10]. It is estimated that the circular economy, made possible by the technological revolution in crucial sectors (mobility, food, and the built environment), will increase the European area's

resource productivity by up to 3% per year. The GDP is expected to increase by 7% compared to the baseline values, with a positive impact on employment [5]. With the simultaneous fulfilment of the 2030 Agenda and the expected reduction of raw material consumption by another 10%, or greenhouse gas emissions by another 17%, this ultimately brings total annual savings of EUR 1.8 trillion, which by 2030 will also increase the disposable income of households in EU by 11% [10]. Focusing public investment on the circular economy, public procurement and subsidies in critical sectors can raise €320bn (30-35bn p.a.) of private capital by 2025: €135bn in mobility, €70bn in food and €115bn in the built environment. Employment effects, at least +700,000 FTE by 2030, amount to 2 million additional jobs with faster technology and productivity change, moving up the “circularity hierarchy” [6]. It should not be forgotten that the circular economy is created in cities, which are the primary carriers of the current situation in the given countries. By using the circular economy, the city tries to offer residents better access to housing, goods and services, ensure sustainable prosperity, or reduce the consumption of limited resources [25]. Nevertheless, the introduction of a circular economy is a challenging task for a large part of cities. There can be several reasons, but the biggest reason is the historical status of the city and the community of people used to the local lifestyle.

The author Hillier characterizes the city’s introduction of the circular economy as: “systemic changes in a large socio-technical system. A city can be considered a socio-technical system formed by (at least) two main interacting systems. A physical system comprises buildings with connected streets, roads, and infrastructure. The human system consists of people, their movement, interactions, and activities in each city” [22]. Systemic change can only be promoted by approaching the entire socio-technical system and not just its elements separately. The systems will then be comprehensively resilient, adaptable, modular, waste-free, and easy to maintain, with reusable components and materials [2].

When understanding waste management within the European Union, it is necessary to perceive the overall layering according to the type and material of the given waste. Therefore, the European Union considers packaging waste one of the best recyclable wastes. He also refers to this as “one of the central pillars of the circular economy, as the possibility of reprocessing returns the material back into the economy and prevents waste from being sent to a landfill or incinerated.” This captures the value of this type of materials as much as possible and reduces losses”. A critical but challenging type of waste is electronic waste, also known as a waste of electrical and electronic equipment (WEEE). It deals with recycling computers, televisions, refrigerators, and mobile phones and recovering critical chemical elements and metals essential in producing new (cadmium, lithium, mercury). As rightly pointed out by [34], e-waste is the fastest-growing waste stream in the

EU. It, therefore, represents a paradigm as a significant emerging problem and a business opportunity. The exact impact of electronic waste on the environment is devastating from the point of view of the contained heavy metals or elements that have a long decomposition process. It also happens that e-waste is not recycled in the country where the original product was purchased and used but is very often sent illegally to developing countries where controls are weaker and often controlled by criminal organizations [1]. We must not forget an essential type of waste in the form of construction waste, which has one of the highest % possibilities for processing or reuse. Among the last most important types of waste is biological waste, which has the best elements and possibilities of ecological decomposition with the lowest negative impact. The European Union has been increasingly focusing on managing biological waste in recent years. The leading cause is the mixing of biological waste in landfills, significantly contributing to climate change [1]. That is why waste management has become a symbol of the applicability and evaluation of the conditions of the circular economy. We can therefore understand waste management as a hierarchy or a sequence to the sustainable evaluation of individual types of materials, which we have graphically illustrated in figure 1.

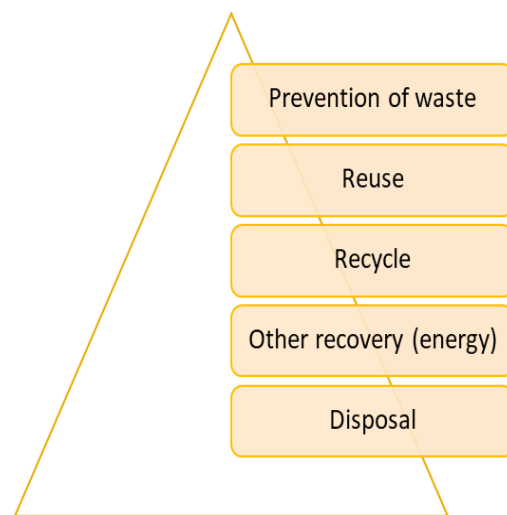


Figure 1 Hierarchy of waste management

Source: own processing based on <https://www.nulaodpadu.sk/co-je-obehove-hospodarstvo>, 2022

Its applicability in specific countries or cities points to a trend that took on a more positive trend after the adoption of the Paris Climate Agreement. However, we must not forget the clearly defined goals intended to reverse the overall negative phenomenon of climate change. This is also an important phenomenon that several leading authors are investigating. Therefore, we will also follow it at the level of the main cities of the Visegrad region to understand the given issue.

## 2 METHODOLOGY

The primary goal of the contribution is to determine the state of application of waste management conditions within the V4 countries, but also in their capital cities, with their subsequent comparison. To achieve the goal of the contribution, it was necessary to use various background materials consisting primarily of the study of professional domestic and foreign literature.

Selected methods using the principles of logical thinking, such as abstraction, comparison, analysis, synthesis, induction, deduction, or subsequent evaluation, were also used in the paper. We used the abstraction method to single out the essential facts to process the knowledge base consisting of domestic and foreign sources. Using the comparison method, individual data were evaluated together with the respective countries. We used mathematical and statistical methods to process the results from statistical portals and annual reports. Mathematical-statistical methods worked with homogenized data on V4 countries with a subsequent concrete expression of selected parameters within waste management. Among the specific parameters, we include the total number of waste production, municipal waste, and municipal waste per inhabitant and the method of processing the given waste. To obtain the necessary statistical data, data from local statistical portals, annual reports, as well as from Eurostat, as well as other professional publications, which became the basis for the research of our chosen problem, were necessary for this contribution. To obtain and process the necessary statistical data, the author used the method of analysis and synthesis in this paper. Using the general theoretical methods of induction, deduction, and evaluation, we unified the knowledge gained and reached our chosen research questions. Using the scientific method of research questions, we achieved the primary goal of the paper we chose. These statistical data were graphically represented in eight tables, nine figures to better understand.

We will first define the basic parameters of the individual examined V4 countries and their capitals to anchor the examined parameters.

*Table 1 Geographic specifics of V4 countries and their capital cities*

Indicator / Country	Slovakia	Czechia	Hungary	Poland
Area in km <sup>2</sup>	49 035	78 866	93030	312 696
Population in mil.	5.459	10.7	9.75	37.95
Capital City	Bratislava	Prague	Budapest	Warsaw
Area in km <sup>2</sup>	367.6	496	525.2	517.2
Population	475503	1259079	1744665	1735442

*Source: own processing based on data from Eurostat, 2022*

The author of the paper focused on answering the selected research questions (RQ), which will help to fulfil the primary goal of the paper.

*RQ1: What is the status of the application of waste management within the V4 countries?*

*RQ2: How do capital cities of V4 countries apply waste management policies as part of their plans to become world Smart Cities in the field of circular economy?*

## 3 RESULTS AND DISCUSSION

*RQ1: What is the status of the application of waste management within the V4 countries?*

We expressed the examined parameters in individual countries from the point of view of the environmental, economic, technological, or social spectrum and their impact on the state and the citizen. To better understand, we expressed the given countries separately with a subsequent mutual comparison.

### *Slovakia*

In 2020, Slovakia produced a total of 2,611,556 tons of municipal waste, a municipal increase of 241,830.9, representing a nominal increase of 9.3% of municipal waste produced. Of this, in 2020, 662,866.9 tons were energetically recovered by recovering organic substances, while 1,189,238.5 tons were disposed of by landfilling and 355,130.9 tons by composting [31]. In both cases, it was a significant increase. In the case of energy recovery by recovering organic substances by 33.34%, landfilling in 2020 decreased by less than 0.01%, but composting by 24.2%. According to the forecast of the Ministry of the Environment from 2020, it said that in 2035, with the specified rate of preparation for reuse and the rate of recycling of municipal waste, the share of these wastes should represent 1,815,591 tons of municipal waste. Energy recovery is expected at 254,000 tons in existing facilities for energy recovery of waste. The forecast for 2035 also included the acceptable amount of landfilled municipal waste, which represents 10%. For the remaining municipal waste, which represents the amount of 244,304 tons, it is necessary to expand or use the capacities for the production of substitute primary fuel for waste-to-energy facilities in existing waste-to-energy facilities and existing operations of sources for the combined production of electricity and heat after their modernization, if the rate of preparation for reuse and the rate of recycling of municipal waste does not increase [27].

On November 27, 2019, an amendment to the Waste Act was adopted, which set waste management goals in packaging waste management [26]:

- By December 31, 2025, achieve a recycling rate of at least 65% of the total weight of packaging waste.
- By December 31, 2030, achieve a recycling rate of at least 70% of the total weight of packaging waste.

- Achieve the recycling rate for individual packaging materials (waste streams) at least.

### **Czechia**

In 2020, a total of 38,486,186 tons of waste was produced in the Czech Republic, representing a difference of 1,175,247 tons of waste compared to 2019, when 37,310,939 tons of waste were produced municipally. From a nominal point of view, it is an annual increase of 0.03%. In 2020 alone, 48.2% was recycled, 33.8% was buried, 10.9% was landfilled, 3.9% was used for energy, or 2.9% was composted [4]. On the contrary, the Czech Republic disposed of 49.4% of municipal waste by landfilling, 22.4% by recycling materials, 15.2% by using it as energy, and 12.4% by composting [4]. Up to 43% of waste in 2020 came from the construction industry, 12% from the processing industry, or 5% from wholesale and retail trade. The production of municipal waste per inhabitant was 506 kg in 2020, which was 6 kg higher than in 2019. The highest level of generated municipal waste was recorded in 2020 in the Central Bohemian Region at 590 kg per inhabitant. At the end of 2020, a new law was adopted, with its subsequent effect from January 2021, which establishes the maximum fee rate, which is 6 CZK per kg, if the basis is the weight of the waste or 1 CZK per litre if the basis is the volume of waste or the capacity of the collection facilities resources [7].

### **Hungary**

In Hungary in 2019, the total amount of waste for recovery or disposal was at the level of 3,261,644.7 tons, while the following year, 2020, we recorded an increase of 0.01% to the level of 3,310,572.5 tons of produced waste. Of the given number, 958,264.2 tons of waste were intended for recycling and subsequent use. However, despite the increase in total waste in 2020, it decreased by 0.03% to 926,392.8 tons. The same applies to waste intended for composting. In 2019, up to 352,887.8 tons of waste were designated for this act, and in 2020 it decreased by 0.01% to 349,986.5 tons [23]. When converting municipal waste per inhabitant, we recorded it at 387 kg per inhabitant in 2019. In 2020, on the contrary, it was already at the level of 364 kg per inhabitant (Eurostat, 2022). The price charged for residual waste is approximately €20 per m<sup>3</sup> and €30 per m<sup>3</sup> of compacted waste. According to data compiled by the EU statistical agency Eurostat, Hungarians generate about 364 kg of municipal waste per person annually, among the lowest levels in the European Union. The amount of garbage generated by Hungarians was well below the 505 kg per person average for the EU, the data from 2020. Rates were lower only in Poland (346 kg) and Romania (287 kg). Eurostat noted that the amount of municipal waste generated by Hungarians has fallen by 21% since 1995, among the steepest drops in the EU, where declines were seen in just seven member states during the period [2].

### **Poland**

Approximately 127 million tons of waste were produced in Poland in 2019. Furthermore, when converted per inhabitant, it came out to 332 kg. The lowest level of waste production per capita was 272 kg per capita in 2014. Overall, the production of municipal waste in Poland per capita is lower than the European average of 502 kg per year. Total waste production in Poland had an upward trend between 2010 and 2018. From a more detailed overview, the largest waste producer is the mining and quarrying sector, with a share of around 55.8%, followed by the general industry at 23.8% and then the energy industry with a 12.3% share of total waste production. From the latest data from the Statistical Office of Poland, we identified the phenomenon that 49% of the total waste was recycled, then 43% of the waste was landfilled, and 5% was processed outside the territory of Poland. Approximately 545,000 tons of waste were imported from international politics in 2019 [33].

From an economic point of view, there are new fees for the management of municipal waste from January 1, 2022, while the rates are at the level of PLN 85 (€17.51, the exchange rate was 12.10.2022) for a household with several units and PLN 107 (€22.04 the exchange rate was 12.10.2022) for a household with one family. The last amount can be reduced by PLN 9 (€1.85 was the exchange rate as of 12/10/2022) if bio-waste is composted at home. There is a risk of an increase in the fee in case of proof of non-separation of waste. According to the latest information, 259 projects were started in the Polish waste sector last year. At the end of 2019, 286 legal landfills and 1,868 illegal landfills were counted nationwide [33]. Waste disposal fees charged by local councils have more than doubled in Poland over the past two years, growing at the fastest rate in the European Union. According to Eurostat, the prices charged in Poland rose 31.3% in 2019, then a further 53.6% in 2020 up to the end of November. That was the highest rise of any EU member state in the two years, representing a total increase in prices of over 100% since the beginning of 2019. By contrast, across the EU, waste disposal prices rose only 10.6% [28].

To answer this research question, we will focus on the individual components of waste management with a comparison between V4 countries and EU-27 countries. First, we will focus on the indicator of the share of recyclable municipal waste in the total production of municipal waste. Recycling includes material recycling, composting and anaerobic digestion. For a more detailed explanation, let us look at figure 2.

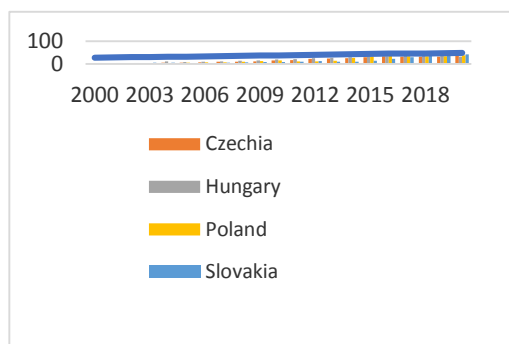


Figure 2 Recycling rate of municipal waste in V4 countries in time 2000 to 2022 (%).

Source: Author's own processing based on data from Eurostat, 2022

The expressed data from figure 2 evaluates the current state of recycled municipal waste in V4 countries against the European average. From this point of view, we can see the given situation, when since 2000, a significant step has been taken in all V4 countries to reach the average of this indicator. This is most noticeable in the Czech Republic, where the share of municipal waste recycling in total municipal waste increased from 0.9% to 45.4% over these 20 years. Poland improved from the original 2.1% to 38.7%, and

Slovakia, during this period, improved from a value of 5.2% to 42.2% in 2020. We can clearly say that until 2004 Slovakia was the best in the given parameter among the countries studied. At the same time, Hungary had the lowest increase, when it grew from the original value of 1.6% to a value of 32% in 2020. The overall European average is at the level of 48.6% of the share of municipal waste treatment in total municipal waste. The initial average European value in 2000 was at the level of 27.3%.

An essential element in achieving a circular economy is the degree of reprocessing of products and their return to the market. The indicator is the share of recycled packaging waste in all produced packaging waste. Packaging waste includes waste material used for the packaging, protection, handling, delivery, and presentation of goods, from raw materials to finished goods, from the producer to the user or consumer, excluding production residues. In this discussion, we must focus on the products' packaging and reprocessing in the examined V4 countries. In Table 2, we will focus on individual packaging materials in the countries and the European average. We will focus more closely on types of packaging such as paper and cardboard, metal, glass, and wooden and plastic packaging.

Table 2 Recycling rate of packaging waste by type of packaging in V4 countries in time 2010-2019 (%.)

Material	Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Glass	EU	71.2	72.3	73.1	73.4	75.3	74.2	75.3	75.8	75.8	75.4
	Czechia	73.1	74.4	81.1	75	71.6	72.6	72.8	72.3	74.8	76.4
	Hungary	35.4	41.2	34.2	32.4	36.3	50.5	34.6	34.2	35.3	28.7
	Poland	45.6	45	51.2	43.6	60.2	57.2	59.6	63	61.8	67.1
	Slovakia	55.7	63.9	69.4	72.9	67.7	66.2	62.2	68.7	68.6	69.7
Metallic	EU	74.6	75.7	76.6	77.8	78.5	79.3	80.2	80.6	82.9	77.4
	Czechia	64	68	69.2	58.5	65	58.6	63.4	67.8	67.6	65
	Hungary	75.7	83.5	80.8	94.6	83.5	79.7	71.8	70.4	71.2	68.8
	Poland	45.9	45.1	46.9	34.5	52.9	62	59.4	62.6	75.5	84.2
	Slovakia	40.6	58.4	67.8	68.9	70.8	73.5	80.4	86.1	75.4	72.4
Wooden	EU	35.3	36.6	37.5	35.2	39.3	41.4	40.7	41.2	34.7	31.1
	Czechia	36.3	27.6	25.7	35.6	66.1	68.7	63.9	49.3	45	42.3
	Hungary	34.2	34.7	18.1	7.5	18.1	19.9	20.1	24.1	23	24.5
	Poland	21	27.2	28.5	21.9	48.6	50.5	40.8	32.4	29.1	27.3
	Slovakia	8.3	26.3	36.7	36.4	37.2	42.1	55.3	47.2	53.4	55.7
Plastic	EU	34.1	35.6	37	37.5	39	40.5	42.4	41.7	41.4	40.6
	Czechia	54	57	58.2	59.7	58.2	61.7	59.2	58.6	57	61
	Hungary	32.5	22.4	27.8	30.8	36.8	27.4	31.4	32	30	33
	Poland	20.1	22.5	21.9	19.7	28.3	30.8	46.9	34.6	35.7	31.5
	Slovakia	44.9	49.9	57	55.1	55.9	54.4	51.7	52.4	51.4	52.8
Paper and cardboard	EU	83.8	82.7	83.5	84	84.1	83.9	85.4	85.4	84.2	82
	Czechia	93.5	90.5	85.9	87.6	88.6	90.1	93.7	90.2	85.6	88.2
	Hungary	94.7	94	73	78.3	66.2	75.8	77	74.5	67.5	70.5
	Poland	57.1	58.7	53.1	50	72.8	77.6	73.8	82.2	88.2	79.9
	Slovakia	50.8	80.2	84.7	79.7	79.9	76.8	78.4	74.2	76.7	77.7
Σ	EU	64	64.2	65.2	65.4	66.5	66.6	67.6	67.5	66.4	64.4
	Czechia	70	69.7	69.9	69.9	73	74.3	75.3	72.3	69.6	71.2
	Hungary	58.7	59.3	48.5	49.2	48.4	50.1	49.7	49.7	46.1	47.3
	Poland	38.9	41.2	41.4	36.1	55.4	57.6	58	56.7	58.7	55.5
	Slovakia	45.7	62.4	68.1	65.9	65.4	64.3	65.8	65.7	66.6	67.5

Source: Author's own processing based on data from Eurostat, 2022

From the data presented in Table 2, we can see, from an overall perspective, above-average recycling in the Czech Republic and Slovakia for the year 2019, reaching 71.2% in the case of the Czech Republic and 67.5% in the case of Slovakia. The average of the countries of the European Union is at the level of 64.4%. We recorded a significantly below-average level in Hungary at the level of "only" 47.3% and in the case of Poland at 55.5%. In the Paper and cardboard category, only the Czech Republic reached the above-average European level of 82% at 88.2%. On the contrary, the Czech Republic and Slovakia significantly dominate in Plastic, while in the case of the Czech Republic, the recycling rate of the Plastic area is at 61%. In Slovakia, this recycling rate is 52.8%. The European average is at the level of 40.6%. The Wooden category is in a similar situation, while Slovakia dominates over other countries in this case. Again, in the case of the Metallic area, only Hungary reaches an above-average level at 84.2%, while the European average is 77.4%. In the last area, only the Czech Republic was above the average, by 1% above the pan-European average.

The following important category of waste management is the rate of recycling of electrical equipment within the European area. In this case, we have marked it in figure 3.

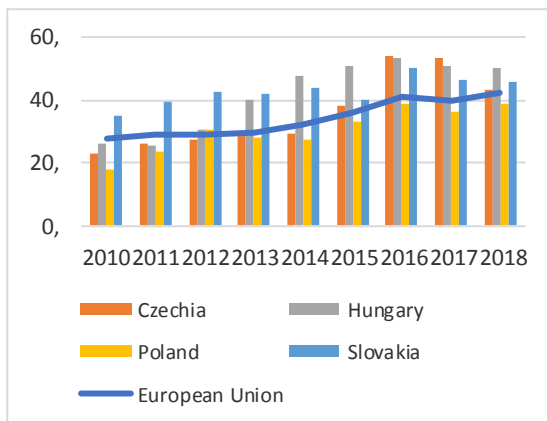


Figure 3 Recycling rate of e-waste in V4 countries in 2010-2018 (%).

Source: Author's own processing based on data from Eurostat, 2022

In this case, we see almost all V4 countries reaching the European average in 2018. Only Poland, below the average by 3%, did not achieve this that year. This year, the pan-European average was at 42.1%, while Hungary reached the highest level among the V4 countries at 50.5% that year. In the case of Poland, it managed to reach the European average only in 2012. The Czech Republic has reached this level continuously since 2015, but between 2017 and 2018, a significant decrease of 9.6% was recorded. Slovakia was the only country that reached this level throughout the period under review.

For the subsequent indicator in figure 4 of biowaste recycling, we will deal with the countries

examined from 2000 to 2020. This indicator is indirectly measured as the share of composted municipal waste to the total number of inhabitants. The ratio is expressed in kg per inhabitant.

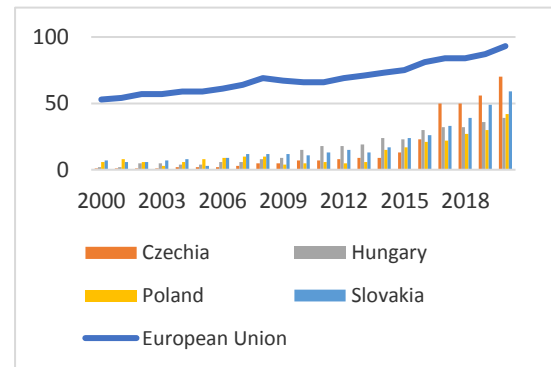


Figure 4 Recycling of biowaste in V4 countries 2000-2020 (%)

Source: Author's own processing based on data from Eurostat, 2022

In this parameter, all countries significantly lag the pan-European average, when in the observed year 2000, this average was at the level of 53%, and the V4 countries reached the maximum level of 7% in the case of Slovakia and 1% in the case of the Czech Republic. During the entire period, not a single country managed to reach the required pan-European average, when in 2020, it was at 93%, while the "closest" to this was the Czech Republic at 70%. The worst is Hungary, which reached the level of bio-waste processing at 39% and Poland at 42%.

Subsequently, we will deal with the construction and demolition waste category, which is the most polluting category within the environment and the most frequently used category within the circular economy. The indicator is the ratio of construction and demolition waste ready for reuse, recycled or subject to material recovery, including backfill operations, divided by construction waste and demolition waste processed according to European Union standards. We have the exact data displayed in the table for the monitored countries V4.

Table 3 Recovery rate of construction and demolition waste in V4 countries in 2010-2020 (%)

TIME	2010	2012	2014	2016	2018	2020
EU	:	:	89	89	90	:
Czechia	91	91	90	92	:	96
Hungary	61	75	86	99	99	98
Poland	93	92	96	91	84	74
Slovakia	:	:	54	54	51	81

Source: Author's own processing based on data from Eurostat, 2022

The European average was at the level of 90% in 2018, while only Hungary achieved this that year, up to the level of 99%. In 2020, we did not have a determined reference value for the European average. Therefore, assuming the data from 2018, the Czech Republic also reached this level, which has moved by 4% to 96% since 2016. The worst is Poland, which has dropped by 10% since 2018 to 74%. On the other hand, Slovakia achieved an increase of 30% from 2018 to 81% in 2020.

In the following graph 4, we will deal with the Recycling rate of all waste, excluding significant mineral waste in 2010-2018. The indicator is calculated as the share of recycled and total processed waste, except for the main mineral waste, and then multiplied by 100 to the total share. Recycled waste is processed waste sent to a recovery operation other than energy recovery and backfilling (referred to as recycling for simplicity). Waste data are adjusted for waste collected in one country and recycled in another. The indicator includes hazardous and safe waste from all sectors of the economy and households, including waste from waste processing, but excluding most mineral waste.

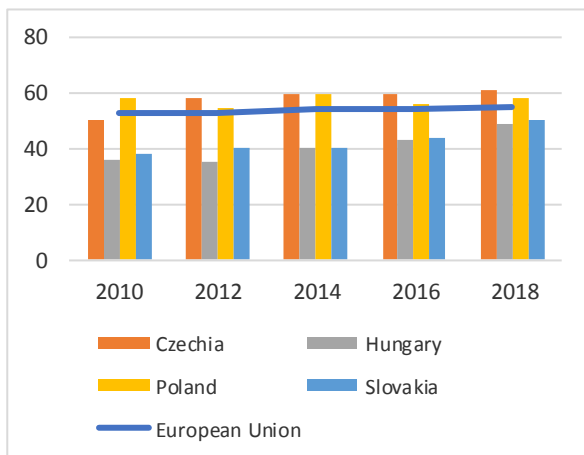


Figure 5 Recycling rate of all waste excluding major mineral waste in V4 countries in 2010-2018 (%)

Source: Author's own processing based on data from Eurostat, 2022

In the presented figure 5, only two V4 countries (the Czech Republic and Poland) managed to reach the pan-European average during the observed period (the Czech Republic only from 2012), which was at an average level of 54%. In 2018, it reached the highest level in the Czech Republic at 61%. On the other hand, Hungary achieved the lowest at 49%.

In the following figure 6, we will focus on the Generation of waste, excluding significant mineral wastes by hazardousness in V4 countries in 2004-2020. The indicator measures all the waste produced in the country. Due to strong fluctuations in waste production in the mining and construction sectors and their limited data quality and comparability, large mineral wastes, mining tailings and soils are excluded. This exclusion improves comparability between countries, as some countries with critical economic activities, such as

mining and construction, account for large amounts of mineral waste.

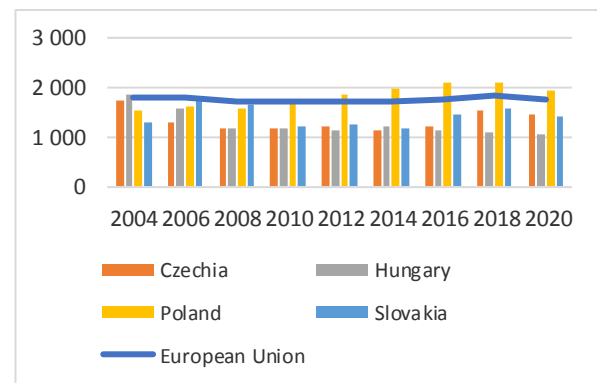


Figure 6 Generation of waste excluding major mineral wastes by hazardousness in V4 countries in 2004-2020 (tons)

Source: Author's own processing based on data from Eurostat, 2022

We expressed the differences between the countries in figure 6 for the period 2004-2020, where Poland stands out from a geographical point of view with a long history in the given economy. Since 2010, it has been the only one to reach the European average, while Hungary was the first to do so in 2004, and Slovakia was the first to do so in 2006. However, since then, the given countries have not reached the parameters. In 2020, the European average was at 1745 tons, while Hungary achieved the lowest at 1045 tons, and on the contrary, Poland at the level of 1940 tons.

In the following figure 7, on the contrary, we will focus on the overall state of circular material use rate in V4 countries in 2010-2020. economy on the general use of material. Circular material use is the ratio of circular material use to total material use. Total material consumption is measured by the sum of total domestic material consumption and circular use of materials. Domestic material consumption is defined in the national accounts of material flows within the economy. The circular use of materials approaches the amount of waste recycled in domestic recovery facilities minus the imported waste destined for recovery plus the exported waste destined for recovery abroad. A higher Circular material use value means that more secondary materials replace primary raw materials, reducing the environmental impact of primary material extraction.

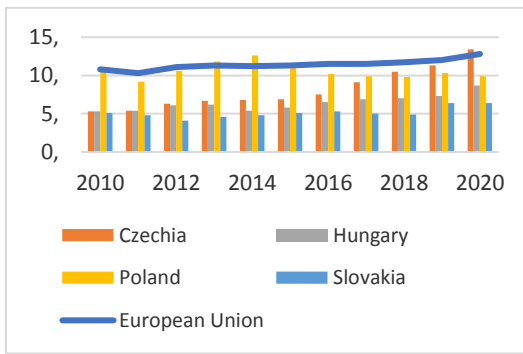


Figure 7 Circular material use rate in V4 countries in 2010-2020 (%)

Source: Author's own processing based on data from Eurostat, 2022

In the final statement in graph 6, we noted the rare phenomenon of reaching the pan-European average across all V4 countries in the monitored period. Poland achieved this average in 2010, 2013-15 and the Czech Republic in 2020. The most significant percentage is in the case of the Czech Republic, which in 2020 was at 13.4%, while the pan-European average was 12.8%.

*RQ2: How do capital cities of V4 countries apply waste management policies as part of their plans to become world Smart Cities in the field of circular economy?*

To answer the author's research question, it is first necessary to isolate the current state of produced municipal waste within the population of specific cities. We obtained this data from the Statistical Offices of the individual V4 countries, and thanks to this, we can determine the status and trend for 2019-2021. We have detailed it in table 4.

Table 4 Municipal waste generated per person in V4 countries

City / Time	2019	2020	2021
Bratislava	487	487	-
Prague	510	467	-
Budapest	389	371	365
Warsaw	375	394	415

Source: Own processing based on data from the Statistical Offices of V4 countries, 2022

To better understand the state of waste management in the capital cities of the V4 countries, we will express them separately. At the same time, we will express waste management's environmental, economic, technological, and social impact on each capital city.

### Bratislava

In the year-end statistics for 2019, the capital of Slovakia reported a population of 437,725 inhabitants, while they produced a total of 213,047.58 tons of municipal waste, which represents 487 kg/year per inhabitant. The total level of municipal waste sorting for 2019 was at the level of 31.3%. In 2020, the

number of inhabitants increased to the level of 440,845 inhabitants, while they produced a total of 1,432.53 tons more of municipal waste, which in total amounts to 214,480.11 tons. Nevertheless, this represents the same level of municipal waste production at the value of 487 kg per inhabitant per year. In this case, the municipal waste sorting level was 37.1% [20]. The level of municipal waste sorting for 2019 was 31.33%. The most common type of waste in Bratislava in 2019 was mixed waste, which comprised 53% of the waste. Sorted collection in the capital makes up 14%. In Bratislava, in 2019, waste was managed in the following way:

- 56% of waste was recovered for energy.
- 9% of the waste was placed in a landfill.
- Recycling was at the level of 25%.
- Recovery of biodegradable kitchen waste represented 8%.
- 2% was handed over to another entity.

The most represented type of waste by weight in Bratislava in 2020 was mixed waste comprising 51% of the waste [20].

Currently, there are six landfills in Bratislava (there are 80 landfills in total in Slovakia), three incinerators, but 1 of them is under repair (there are 20 incinerators in total in Slovakia) and 13 collection yards (out of a total of 63). The average rate for 1 litre for a 1,100-liter container is €0.01509. A rate of 0.02413 euros per 1 litre for a 110-litre or 120-litre collection container for two people living independently in a family house, or a rate of 0.078 euros per kilogram of small construction waste without harmful substances [20]. The most represented type of waste in Bratislava in 2020 was a mixed waste, which comprised 51% of the waste. Up to 49% of the waste was processed in an incinerator, 9% was processed for energy, and 31% of the waste was recycled. The other 11% of the waste was sent to the landfill.

The capital city of Bratislava has long been among the cities with the lowest rate of landfilling. Thanks to the facility for energy recovery of waste, only a tenth of all municipal waste is landfilled in Bratislava, which is significantly less than 50% of the national average. The goal of Bratislava is to keep the rate of landfilling at a level of up to 10%. According to the Institute of Environmental Policy (IEP) "What about waste in Bratislava", between 2025 and 2045, the production of municipal waste in Bratislava will grow by an average of 2.5% year-on-year, and the rate of recycling will increase. The growth of municipal waste production will be driven by higher household consumption and a higher population. The introduction of measures also changes the waste management structure and will increase the recycling rate. Increasing the targets for sorted collection, the obligation for sorted collection of kitchen bio-waste and the backup of disposable beverage packaging reduces the production of unsorted mixed municipal waste and, at the same time, increases the rate of sorting and recycling.

We know from the specific form that in 2020,

34% of waste was metal, 18% was paper, 11% was glass, and 9% was plastic. Between 2025 and 2045, municipal waste production in Bratislava will grow by an average of 2.5% year-on-year, and the recycling rate will rise to 36%. The growth of municipal waste production will be driven by higher household consumption and a higher population. The introduction of measures also changes the waste management structure and will increase the recycling rate. Increasing the targets for sorted collection, the obligation for sorted collection of kitchen bio-waste and the backup of disposable beverage packaging reduces the production of unsorted mixed municipal waste while increasing the rate of sorting and recycling. We estimate that the recycling rate will increase mainly until 2027 and reach 36% by 2045 [26]. We can take a closer look at this forecast in figure 8.

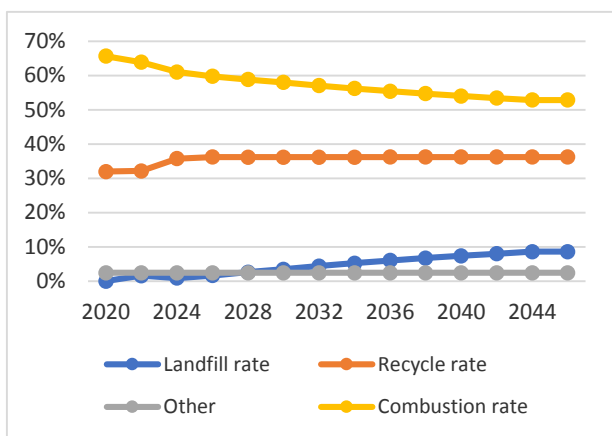


Figure 8 Forecast of the rate of landfilling, incineration, and recycling within Bratislava until 2045

Source: Taken from the document of the Ministry of the Environment of the Slovak Republic, 2020

On figure 9, we have the expected forecast of the development of the number of inhabitants with a contrast to the expected development of municipal waste production by the inhabitants.

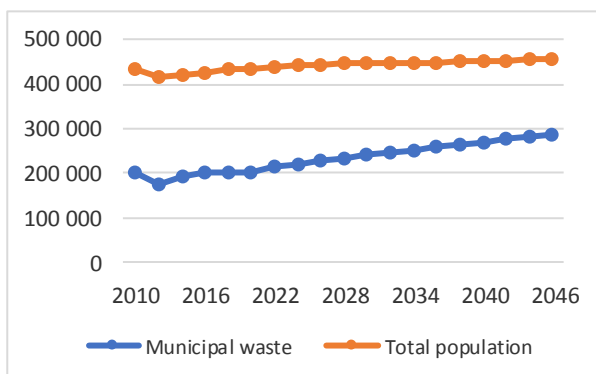


Figure 9 Forecast of municipal waste development in Bratislava

Source: Taken from the document of the Ministry of the Environment of the Slovak Republic, 2020

In this forecast from the Ministry of the

Environment of the Slovak Republic, a more significant increase in the generation of municipal waste by residents is expected than the overall increase in the number of residents within the city. This results in calls for the city to process municipal waste more efficiently or create less space for residents to consume. It is this forecast that gives a signal that the municipality should react to the given situation to achieve the desired goals of Agenda 2030.

### Prague

In 2019, the capital Prague had approximately 1,309 mils. Inhabitants, while it produced 5,030,625 tons of waste. Conversely, in 2020, Prague 1 had 306 mils. Inhabitants, i.e. a decrease of approximately 3,000 thousand inhabitants and a decrease of produced waste by 306,042 tons of waste to the level of 4,724,583 tons. When converted per inhabitant, in 2019, it amounts to 3,825 kg per capita, and in 2020, it represents a value of 3,560 kg per capita waste per inhabitant of Prague. From the specific point of view of municipal waste, we recorded 670,776 tons of municipal waste produced in 2019. At the same time, the year-on-year decrease in 2020 by 51,247 tons of municipal waste established a value of 619,529 tons for 2020. In nominal terms, this means a decrease of 7.7%. This amounts to 510 kg of municipal waste per inhabitant in 2019, with an annual decrease in 2020 to 467 kg per year [4]. When processing waste, the share of used waste based on the material and energy spectrum (% waste weight) was 83.6% in 2019 and 83.4% in 2020. In 2020, 64.3% of the total waste was disposed of by landfilling, an increase compared to the year 2019 by 0.5%. There are currently 19 collection yards in the city of Prague. A total of CZK 951,381 was collected in 2020 as the total sum of municipal waste fees in Prague. The result of this indicator is 31% higher than in 2019 when CZK 725,806 was obtained. In municipal terms, this represents a difference of CZK 225,575. At the same time, the total income of the city of Prague for the year 2020 from the area of waste management was at the level of CZK 1,125,296, which was a year-on-year increase of CZK 225,873, which represents an increase of 25.11%. However, the total costs were CZK 1,717,577 in 2020, which was CZK 116,664 higher than in 2019. Overall, the city of Prague achieved a negative balance.

Most of the produced waste is used for energy. It is mainly mixed municipal waste. While this waste represents 58% of the total waste produced, 93% is used for energy, and thanks to this, the overall rate of energy use of all waste is high. Material utilization represents 28% of all waste produced by the city in 2020. Since 1998, material utilization has gradually increased, but in recent years, the amount of materially utilized waste has stagnated. To increase the material utilization of municipal waste, the city introduces new methods of collection, such as the collection of the organic waste directly in households or the collection of gastrointestinal waste. In 2020, only about 14% of reported waste was deposited in landfills. This is part of the production of mixed waste, bulky waste, and street litter. 2% of all waste was removed by other

means, of which about 0.03% was removed thermally. This is the removal of hazardous waste handed in by citizens at the collection yards of the capital. m. of Prague, during the mobile collection of hazardous waste, medicines in pharmacies or injections collected during the activities of the city police.

*Table 5 Production of mixed municipal waste from citizens from containers in household equipment or in front of the house*

Year	Amount of waste in thousand tons	Year-on-year increase	Number of inhabitants	Landfilling (kt)	Energy use (kt)
1998	210.5	-	1 193 270	81.4	129.1
1999	208.6	-0.85 %	1 186 855	15	193.6
2000	209.9	0.57 %	1 170 476	43.1	166.8
2001	211.8	0.95 %	1 160 118	15.5	196.3
2002	226.7	6.99 %	1 161 938	25.6	201.1
2003	230.2	1.54 %	1 165 581	26.6	203.6
2004	231.0	0.35 %	1 170 571	24.8	206.2
2005	234.7	1.02 %	1 181 610	33.5	201.2
2006	237.7	1.29 %	1 188 126	35.7	200.5
2007	240.3	1.11 %	1 212 097	43	197.3
2008	243.1	1.16 %	1 233 211	52.3	190.8
2009	244.6	0.62 %	1 249 026	53.4	191.2
2010	245.1	0.20 %	1 234 037	44.7	200.4
2011	246.8	0.69 %	1 241 664	26.2	220.6
2012	247.3	0.20 %	1 246 780	21	226.3
2013	246.3	- 0.41 %	1 243 201	24.2	222.1
2014	246.2	-0.04 %	1 259 079	11.4	234.8
2015	247.2	0.40 %	1 267 449	3.6	243.6
2016	249.2	0.80 %	1 280 508	12.5	236.8
2017	250.2	0.40 %	1 294 513	19.6	230.6
2018	253.8	1.42 %	1 308 632	17.6	236.2
2019	255.5	0.67 %	1 324 277	14.8	240.7
2020	257.8	0.90 %	1 335 084	18.3	239.4

Source: Taken from the Statistical Office of the Czech Republic, 2022

The amount of mixed municipal waste handed over to SKO containers has increased from 210,500 tons in 1998 to 257,754 tons in 2020. The increase in the weight of the handed-over mixed municipal waste correlates with the increasing number of Prague. Mixed municipal waste is mainly used for energy. In 2020, a total of 239,429 tons of mixed municipal waste was handed over by citizens to SKO containers, i.e. 92.9% of this waste was processed in the waste-to-energy facility. In addition to mixed waste from citizens from containers in household appliances or on the streets, i.e. mixed waste that is subject to a fee, in 2020, Prague was the originator of mixed waste from businesses involved in the city's system (in 2020, it amounted to 1,323.8 tonnes), further mixed waste originating from the buildings of the Municipality and the city police, from the waste bins of the city districts or the activities of other entities. A total of 5,116.3 tons of this mixed municipal waste was recorded in 2020. The total reported amount of mixed waste in 2020 was 264,194.3 tons.

### **Budapest**

The capital Budapest had over 1,750,000

million in 2019. inhabitants. Of this, the city produced 680,400 tons of municipal waste. In 2020, we recorded a decrease of 31,600 thousand tons of municipal waste, which represents a decrease of 4.64%. This positive downward trend is also confirmed by the data for 2021 when it decreased by 9,700 tons of municipal waste compared to 2020.

In comparison with 2019, it decreased 41,300 tons of municipal waste for 2021, which in nominal value represents a decrease of 6.06 %. Thus, in 2020, 648,900 tons of municipal waste were produced, and in 2021, it represented 639,200 tons of municipal waste. Comparing previous years (since 2015), we found that the given the year 2019 was the highest value for Budapest's capital. In 2018, this amounted to 670,800 tons of municipal waste (Statistical Office HU, 2022). In a closer analysis from the point of view of the circular economy, in 2021, waste for energy recovery made up 50% of the total produced municipal waste, 31% of waste disposed on landfill sites and 18% for material recovery. Compared to 2020, it was an increase of 1% in Waste for energy recovery, or on the contrary, a decrease of 2% in Waste disposed on landfill sites. We have significant differences compared to 2019, primarily in the year-on-year decrease compared to 2020 in the Waste for material recovery area, where the decrease was 8%. There are currently 17 waste collection yards in Budapest. From a per capita perspective, we can confirm the general position of Hungary, which is one of the lowest producers of municipal waste in the European Union.

*Table 6 Generation of municipal waste transported in the framework of public services by Budapest in thousand tons*

Parameters/Year	2015	2016	2017	2018	2019	2020	2021
Waste removed from households	376	383	393	394	401	390	389
Separately collected waste fractions removed from households	55	55	61	65	75	83	81
Waste removed from other organisations	217	222	215	214	209	194	193
Separately collected waste fractions removed from other organisations	2	3	4	4	4	4	5
Removed waste derived from public area cleaning	21	19	17	30	31	35	29
Separately collected waste in public area	21	25	28	33	39	30	28

Source: Author's own processing based on data from the HU Statistical Office, 2022

At the same time, Budapest belongs to the best cities ever on the old continent and in the competition of V4 capitals, it ranks first. In 2019, an average of 389 kg of municipal waste was produced per inhabitant, with a downward trend in the following years. In 2020, this represented 371 kg of municipal waste per

inhabitant, and in 2021 the level 365 kg of municipal waste per inhabitant. The fee is based on the container size (110 l, 120 l, 240 l, 770 l, 1100 l) and the frequency of its collection. The introductory price is given as one collection per week and costs depending on the size of the container: from €2.46 for residual waste and €1.62 for separated waste (110 l) to €24.64 for residual and €16.18 for separated waste (1100 l).

In the following table, we will characterize Budapest's collection of municipal waste in 2015-2021 from households, organizations, or public spaces. The city of Budapest received the most municipal waste from households in 2021, while households accounted for up to 60.86% of the total waste produced within the city of Budapest, while compared to 2020 it was an increase of municipal waste produced by households by 0.76%. Waste removed from other organizations accounted for 29.74% in 2020, and in 2021 it increased by 0.61% to 30.35% of the total municipal waste produced within Budapest.

### Warsaw

The capital Warsaw had over 1,776,000 inhabitants in 2019. Of this, the city produced 668,569.37 tons of municipal waste. When converted per inhabitant, it represented 375 kg/year. The following year, 2020, Warsaw already produced 707,364.05, representing a 5.8% increase compared to 2019. The burden of the city's inhabitants was at the level of 394 kg/year. This trend continued in 2021, when 743,758.94 tons of municipal waste were produced, which represents 415 kg/year produced by the inhabitants of the city of Warsaw. Compared to 2019, it was an increase of 75,189.57 tons, which represents an increase of 11.2% in nominal value. We can conclude from the monitored medium-term period that the least produced waste was in 2019 and the most in 2017 at 777,184.78 tons of municipal waste (Statistical Office PL, 2022). In Warsaw, the paying for waste model applies, as was enacted throughout Poland. For a more specific breakdown of the waste management of the capital city of Warsaw, we determined for the monitored period 2017-2021 within the basic monitored categories determined in table 7.

*Table 7 Waste collected separately during the 2017-2021 in thousand tons*

Type/Year	2017	2018	2019	2020	2021
Paper and cardboard	434.50	682.45	15 020.34	45 568.19	35 480.49
Glass	14 296.27	13 972.19	17 114.30	37 737.09	34 733.01
Plastics	453.32	655.68	201.77	494.43	422.40
Metals	97.84	82.83	23.95	122.65	101.49
Textiles	4.60	18.19	22.25	52.28	125.67
Hazardous	46.32	733.91	366.76	305.69	203.19
Waste electrical and electronic equipment	11 122.37	5444.03	1680.78	232.82	185.99

*Source: Author's own processing based on data from the Statistical Office PL, 2022*

In 2021, residents produced 10,087.70 less paper waste and 3004.08 less glass waste than in 2020 in the city of Warsaw by residents. In addition to the Textiles category, we also recorded a decrease in other categories. This category produced 73.39 more tons of waste than in 2020. 2020 was a breakthrough from the point of view of waste in almost all categories (except Hazardous, where a 100% decrease compared to 2019 was recorded). We significantly increased precisely in these categories focused on paper and glass. In 2020, produced paper waste increased by over 203.4% and glass waste by 102%. The year 2020 is a breakthrough in several of these categories. We can perceive it because of the worsened epidemiological situation, which resulted in higher household activity in waste production.

Finally, we will summarize the most critical findings in a separate table 8, where we will see more clearly the states of total and per capita municipal waste within the capital cities of the V4 countries in selected parameters.

*Table 8 Comparison of the main cities in the parameters of total or per capita municipal waste produced in the period 2019-2021 by the capital cities of the V4 countries*

City / Parameter		2019	2020	2021
Bratislava	Municipal waste per capita	487	487	-
	Total of municipal waste (t)	213 047.58	214 480.11	-
Prague	Municipal waste per capita	510	467	-
	Total of municipal waste (t)	670 776	619 529	-
Budapest	Municipal waste per capita	389	371	365
	Total of municipal waste (t)	680 400	648 900	639 200
Warsaw	Municipal waste per capita	375	394	415
	Total of municipal waste (t)	668 569.37	707 364.05	743 758.94

*Source: Author's own processing, 2022*

## 4 CONCLUSION

With this article, we pointed out the environmental, economic, and social, but also the technological impact of waste management on the countries, as well as the capital cities of the V4 countries. At the same time, we managed to achieve the primary goal, which was supported by the author's research questions. With its strong interaction, the circular economy to achieve the goals of the 2030 Agenda and thus ensure the sustainable development of the given geographical regions creates the necessary

trends and challenges to the subsequent achievement of the set goals. Therefore, this issue is analysed in many forms with several statistical data in several parameters, but often in the absence of mutual interaction with similar data from other regions. Most of all, in the given area, there is no connection to the urban units, which, apart from general characterization, do not develop the given areas into a more significant analysis, which causes limitations in the mutual comparison in established measures. Understanding these quantities helps to further explore the given regions from the point of view of the circular economy.

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## REFERENCES

- [1] Agovino, M., Matricano, D., & Garofalo, A. (2020). Waste management and competitiveness of firms in Europe: A stochastic frontier approach. *Waste Management*, 102, 528-540.
- [2] Arup and Ellen MacArthur Foundation. (2019). Circular economy in cities. Retrieved 05.10.2022, from <https://www.ellenmacarthurfoundation.org/our-work/activities/circular-economy-in-cities>
- [3] Budapest Business Journal. (2022). Waste generation among lowest in EU. Retrieved 14.10.2022, from <https://bbj.hu/economy/environment/pollution/waste-generation-among-lowest-in-eu>
- [4] Český statistický úřad. (2022). Produkce, využití a odstránění odpadů 2020. Retrieved 08.10.2022, from <https://www.czso.cz/csu/czso/produkce-vyuziti-a-odstraneni-odpadu-2020>
- [5] Dodick, J., & Kauffman, D. (2017). A review of the European Union’s circular economy policy. Report from Project The route to circular economy. Project funded by European Union’s Horizon.
- [6] Econometrics, C. (2018). Impacts of circular economy policies on the labour market: final report and annexes.
- [7] Epravo.cz. (2021). Poplatky za odpady od roku 2021 – zjednodušení, nebo komplikace?. Retrieved 07.10.2022, from <https://www.epravo.cz/top/clanky/poplatky-za-odpady-od-roku-2021-zjednoduseni-nebo-komplikace-112556.html>
- [8] European Commission. (2018). Circular economy indicators. Retrieved 04.10.2022, from Monitoring framework - Circular economy - Eurostat (europa.eu)
- [9] European Commission. (2018). Directive 94/62/EC on packaging and packaging waste. Retrieved 04.10.2022, from <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L:2018:150:TOC>
- [10] European Commission. (2021). Circular economy fact sheet. Retrieved 04.10.2022, from <https://op.europa.eu/en/publication-detail/-/publication/8ea1b114-a639-11eb-9585-01aa75ed71a1/language-en/format-PDF/source-269577244>
- [11] Eurostat. (2022). Circular material use rate. Retrieved 09.10.2022, from [https://ec.europa.eu/eurostat/databrowser/view/sg\\_12\\_41/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/sg_12_41/default/table?lang=en)
- [12] Eurostat. (2022). Generation of waste excluding major mineral wastes by hazardousness. Retrieved 10.10.2022, from [https://ec.europa.eu/eurostat/databrowser/view/SDG\\_12\\_50\\_custom\\_3532326/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/SDG_12_50_custom_3532326/default/table?lang=en)
- [13] Eurostat. (2022). Municipal waste generation up to 505 kg per person. Retrieved 08.10.2022, from <https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220214-1>
- [14] Eurostat. (2022). Recycling rate of all waste excluding major mineral waste. Retrieved 08.10.2022, from [https://ec.europa.eu/eurostat/databrowser/view/cei\\_wm010/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_wm010/default/table?lang=en)
- [15] Eurostat. (2022). Recycling rate of biowaste. Retrieved 07.10.2022, from [https://ec.europa.eu/eurostat/databrowser/view/cei\\_wm030/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_wm030/default/table?lang=en)
- [16] Eurostat. (2022). Recycling rate of construction and demolition waste. Retrieved 09.10.2022, from [https://ec.europa.eu/eurostat/databrowser/view/cei\\_wm040/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_wm040/default/table?lang=en)
- [17] Eurostat. (2022). Recycling rate of e-waste. Retrieved 09.10.2022, from [https://ec.europa.eu/eurostat/databrowser/view/cei\\_wm050/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_wm050/default/table?lang=en)
- [18] Eurostat. (2022). Recycling rate of municipal waste. Retrieved 10.10.2022, from [https://ec.europa.eu/eurostat/databrowser/view/cei\\_wm011/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_wm011/default/table?lang=en)
- [19] Eurostat. (2022). Recycling rate of packaging waste by type of packaging. Retrieved 09.10.2022, from [https://ec.europa.eu/eurostat/databrowser/view/cei\\_wm020/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_wm020/default/table?lang=en)
- [20] Friedrich-Ebert-Stiftung (FES). (2021). Analýza odpadového hospodárstva v ôsmich najväčších mestách Slovenska. Retrieved 08.10.2022, from <https://slowakei.fes.de/e/publikacia-analyza-odpadoveho-hospodarstva-v-osmich-najvaecsich-mestach-slovenska>
- [21] Geissdoerfer, M. et al. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757-768.
- [22] Hillier, Bill, 2019. The city as a socio-technical system: a spatial reformulation in the light of the levels problem and the parallel problem. Keynote paper Conference on Spatial Information Theory
- [23] Hungarian statistical office. (2022). Environment, public utilities. Retrieved 09.10.2022, from <https://www.ksh.hu/environment-public-utilities>

- [24] Lehmann, M., et al. (2014). Circular economy. Improving the management of natural resources. In World Resources Forum: Bern, Switzerland.
- [25] Marchesi, M., Tweed, C., & Gerber, D. (2020, November). Applying circular economy principles to urban housing. In IOP Conference Series: Earth and Environmental Science (Vol. 588, No. 5, p. 052065). IOP Publishing.
- [26] Ministerstvo životného prostredia SR. (2020). Čo s bratislavským odpadom? Retrieved 11.10.2022, from <https://www.minzp.sk/iep/publikacie/ekonomicke-analyzy/co-bratislavskym-odpadom.html>
- [27] Ministerstvo životného prostredia SR. (2020). Program odpadového hospodárstva SR na roky 2021– 2025. Retrieved 10.10.2022, from <https://www.enviroportal.sk/eia/dokument/319112?uid=7928a4a5c95cda1bacf9de9b09b647e55327af4d>
- [28] Notes from Poland. (2021). Poland has EU's fastest growing waste disposal fees for second year running. Retrieved 13.10.2022, from <https://notesfrompoland.com/2021/01/12/poland-has-eus-fastest-growing-waste-disposal-fees-grow-for-second-year-running/>
- [29] Ruiz-Real, J. L., Uribe-Toril, J., De Pablo Valenciano, J., & Gázquez-Abad, J. C. (2018). Worldwide research on circular economy and environment: A bibliometric analysis. *International journal of environmental research and public health*, 15(12), 2699.
- [30] Statistical office of Poland. (2022). Množstvo komunálneho odpadu. Retrieved 13.10.2022, from [https://datacube.statistics.sk/#!/lang/sk/?utm\\_source=susr\\_portalHP&utm\\_medium=page\\_database&utm\\_campaign=DATAcube\\_portalHP](https://datacube.statistics.sk/#!/lang/sk/?utm_source=susr_portalHP&utm_medium=page_database&utm_campaign=DATAcube_portalHP)
- [31] Statistical office of Slovakia. (2022). Produkce, využití a odstránění odpadů 2020. Retrieved 08.10.2022, from <https://www.czso.cz/csu/czso/produkce-vyuziti-a-odstraneni-odpadu-2020>
- [32] World population prospects. Retrieved 04.10.2022, from [https://population.un.org/wpp/Publications/Files/WPP2019\\_Highlights.pdf](https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf)
- [33] WEKA Industrie Medien (2022). Recycling: Poland is slowly catching up. Retrieved 09.10.2022, from <https://waste-management-world.com/artikel/recycling-poland-is-slowly-catching-up/>
- [34] Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., & Böni, H. (2005). Global perspectives on e-waste. *Environmental impact assessment review*, 25(5), 436-458.
- [35] World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. (2016). The New Plastics Economy — Rethinking the future of plastics. Retrieved 04.10.2022, from <http://www.ellenmacarthurfoundation.org/publications>

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