Institute for Environmental Policy

How to get out of the Wasteland

Waste Management Model of the Slovak Republic

September 2023
Economic analysis 16

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Ministry of Environment of the Slovak Republic

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List of Abbreviations

MBT	Mechanical biological treatment
PRO	Producer Responsibility Organisation
EPR	Extended Producer Responsibility
SO SR	Statistical Office of the Slovak Republic
RDF	Residual Derived Fuel
WtE	Waste to Energy Plant
MF SR	Ministry of Finance of the Slovak Republic
MoE SR	Ministry of Environment of the Slovak Republic

Summary

Waste management in Slovakia continues to lag behind most EU countries. In 2021, the recycling rate for municipal waste approached the EU average, but with a landfill rate of 41%, Slovakia significantly falls short of the EU average of 23%. This disparity puts Slovakia at risk of failing to meet the targets of increasing recycling to 65% and reducing landfill to a maximum of 10% of municipal waste by 2035.

The absence of a long-term strategy in waste management and the lack of data have led to a confusing situation. An example is the ban on landfilling untreated municipal waste, which has been postponed multiple times due to insufficient processing capacities. Currently, there are plans to significantly increase capacities for waste-to-energy plants and waste treatment plants. The planned Waste management information system, in preparation since 2017, is intended to provide a central record of data on waste material flow and processing capacities. However, the full launch date of the system remains unknown.

Planned measures will increase the annual costs of waste management by 16 million euros, but they will not suffice to meet the municipal waste recycling targets. The target for landfilling is expected to be met. According to current legislation, the waste management sector plans to implement mandatory waste treatment before landfilling and the sorted collection of textiles. The increase in costs will primarily come from the mandatory treatment of waste before landfilling. If these measures are substantially implemented, the municipal waste recycling rate is projected to rise to 53%, and the landfill rate is expected to drop below 10%, aligning with the 2035 target.

Adopting additional measures could raise the recycling rate to 62%, requiring an extra 10 million euros. Compared to the planned measures, we propose additional actions such as more convenient collection of kitchen biowaste and the implementation of a nationwide pay-as-you-throw system. The increase in costs compared to the scenario with the planned measures would mainly result from higher costs for re-sorting, electronic record, and providing bins and bags for kitchen biowaste collection. The most significant savings would be achieved through reduced costs for managing non-recyclable waste. Consequently, the local fee per capita would be slightly lower compared to the planned measures due to higher sorting rates and the shift of a larger portion of costs to producers.

The planned initiatives for building waste-to-energy plants exceed Slovakia's needs. The total capacity for direct waste-to-energy facilities may increase from the current 254,000 tonnes to over 1.1 million tonnes. Additionally, plans for cement and heating plants will lead to an increase in co-incineration capacities for low-calorific residual derived fuel from the current 84,000 tonnes to 302,000 tonnes. Currently, mechanical biological treatment facilities are insufficient, but the total planned capacity reaches nearly 1.5 million tonnes. Assuming the use of cement and heating plants for processing residual derived fuel (RDF), capacities of nearly 600,000 tonnes would be needed for the production of RDF via mechanical biological treatment and 375,000 tonnes of capacity for energy recovery from waste.

Excess capacities for waste-to-energy create a dependency on waste production and imports, hindering the growth of recycling. Countries like the Netherlands and Sweden have energy recovery capacities more than double their needs and depend on waste imports. In the Netherlands, an agreement between the state and the private sector was reached in 2009 to halt further capacity expansion. Furthermore, the European Commission emphasizes the need to avoid overbuilding infrastructure for residual waste treatment, including mechanical biological treatment facilities.

To achieve stability and predictability, it is necessary to develop a clear waste management strategy for Slovakia. A key part of the strategy should be an Action Plan for practical implementation within a specific timeframe. Implementing the action plan and adhering to scheduled deadlines can enhance the credibility of the sector in policy-making related to waste management. Currently, market players often assume that legally set deadlines will be postponed, as is commonly the case. **The strategy should also define and establish the required capacities and locations for waste processing facilities in Slovakia.**

Improving waste management will require significantly better data availability and quality. Inadequate or missing data pose a major limitation for any estimates and calculations. Data on waste processing capacities are mostly available only in paper form at the relevant district offices, making it time-consuming to verify the accuracy and currency of these data. A functional waste management information system is needed to centrally record all necessary data electronically. Due to the lack of data, much of the analysis relies on data from the private sector.

Introduction

In recent years, Slovakia's waste management has significantly improved but still lags behind most EU countries. The municipal waste recycling rate approached the EU average in 2021, largely due to changes in reporting methodology. Additionally, with a landfill rate of 41%, Slovakia lags considerably behind the EU average of 23%. Without further measures, Slovakia risks failing to meet the targets of increasing recycling to 65% and reducing landfilling to a maximum of 10% of municipal waste by 2035 (European Commission, 2023).

The lack of a unified waste management strategy and insufficient data have led to a confusing situation. An example is the ban on landfilling untreated municipal waste, which has been repeatedly postponed due to a lack of processing capacity. Currently, there are plans for a significant increase in capacities for energy recovery and waste treatment facilities. The total planned capacities of these facilities exceed Slovakia's needs. The planned Waste Management Information System, under preparation since 2017, is intended to provide a central database on waste material flows and processing capacities. However, the full launch date of the Waste Management Information System is unknown.

The aim of this study is to create a waste management model that provides estimates of municipal waste management development following the implementation of various measures. Based on the estimated impacts of these measures, scenarios of future municipal waste production and management were developed, considering the implementation of planned measures according to current legislation and additional measures to meet waste management targets. Each scenario estimates the financial costs and benefits, as well as environmental externalities. The scenarios also predict the rates of sorting, recycling, and landfilling of municipal waste and the distance from achieving the targets.

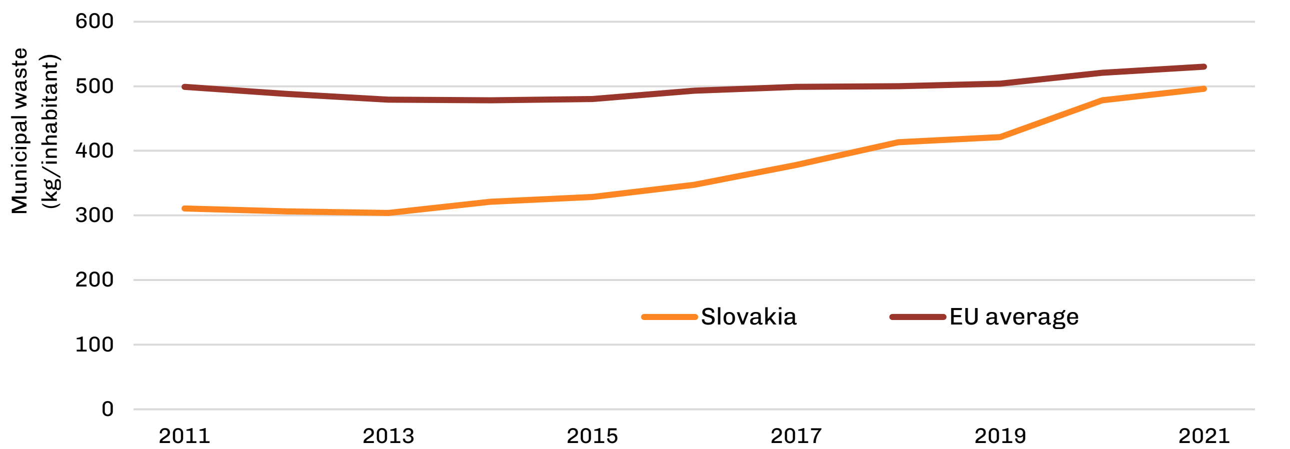
This model can subsequently serve as a tool in preparing strategic documents and other decision-making processes in the field of waste management. The estimated development of municipal waste management will allow for the identification of future processing capacity needs and potential issues in achieving key recycling, recovery, and disposal targets. To achieve stability and predictability, it is necessary to develop a clear waste management strategy for Slovakia. The study results would provide an analytical basis for the part of the strategy focused on municipal waste.

1 Our Daily Waste

1.1 How much Waste we have and what Happens to It

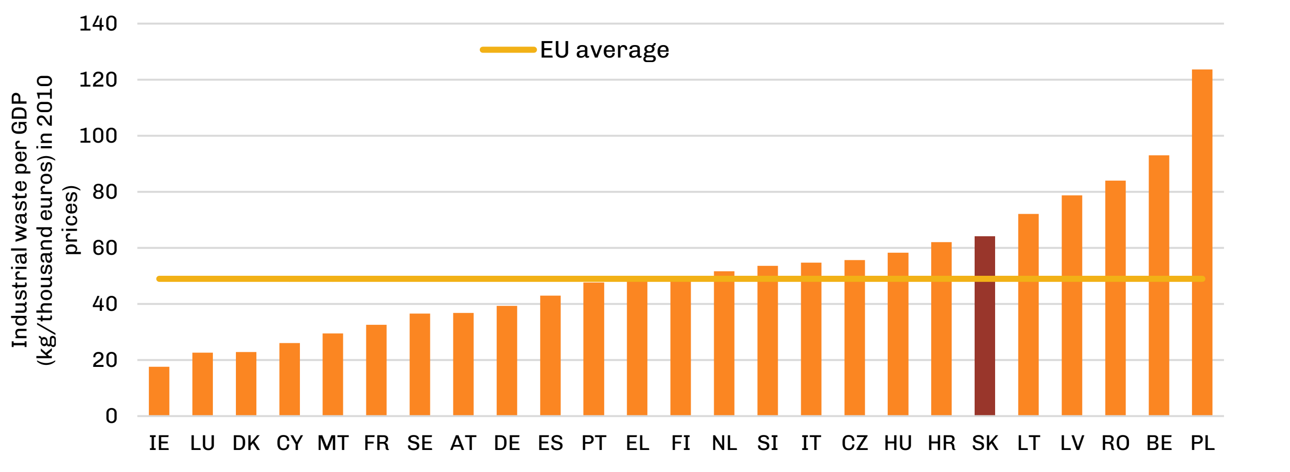
In 2021, Slovakia produced 12.7 million tonnes of waste. Municipal waste accounted for 496 kg per capita, while industrial waste production was 64 kg per unit of GDP. The production of municipal waste in Slovakia is still lower compared to the EU average, but it is increasing more rapidly year-on-year. This rise is attributed to the increasing standard of living and changes in waste reporting (see Box 1 for more details). Conversely, Slovakia ranks among the countries with the highest production of industrial waste[1] per GDP. This may be due to the lower share of the service sector in the overall economy, as the service sector typically generates less waste.

Graph 1: Development of municipal waste production



Source: IEP based on data from Eurostat

Graph 2: Development of industrial waste production

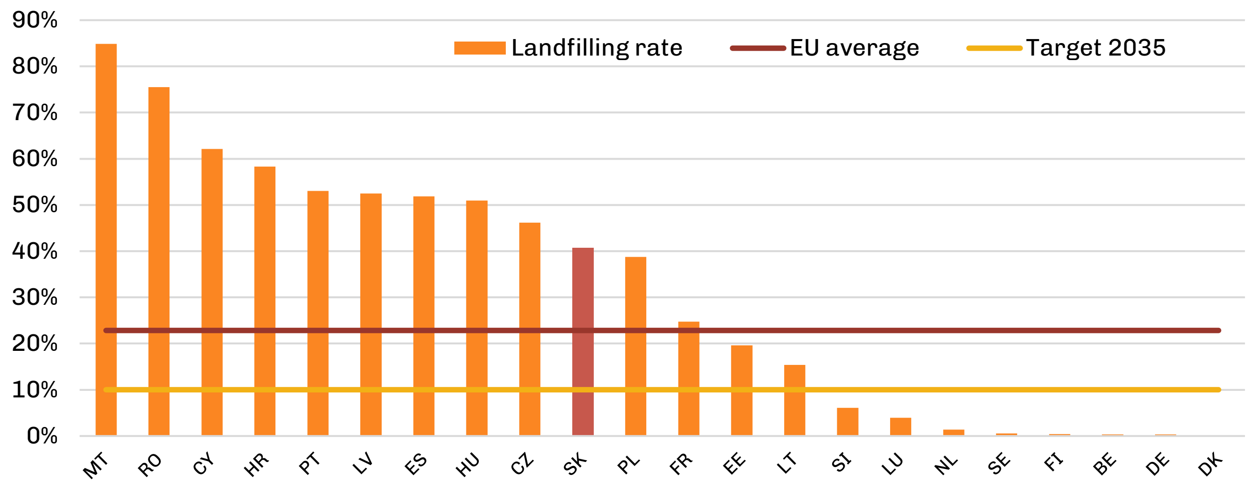


Source: IEP based on data from Eurostat

[1] Mineral waste is mostly not reported because it mainly comes from the construction and mining sectors and is significantly specific to a particular country. For better comparability and tracking of trends, it is therefore excluded from comparative statistics.

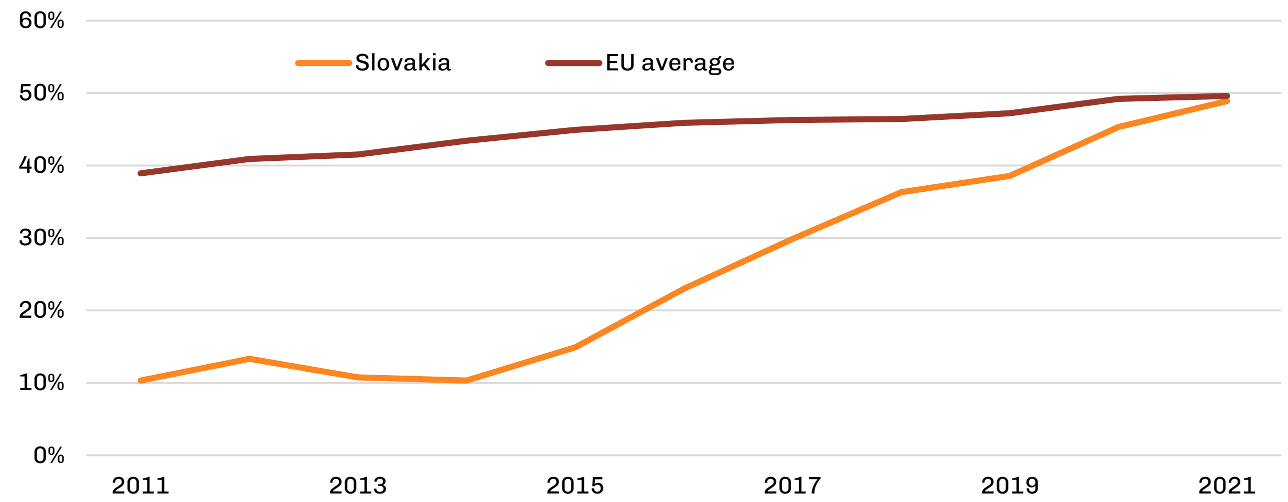
In terms of municipal waste management, Slovakia lags behind most EU countries. The recycling rate increased from 9% to 49% between 2010 and 2021, reaching the EU average. A more significant growth in recycling has occurred since 2016, primarily due to the introduction of the Extended Producer Responsibility (EPR) system for the sorted collection of packaging and non-packaging products, the increase in landfill fees since 2019, and the obligation to sort or compost biowaste. As the recycling rate has risen, landfilling has decreased from 81% in 2010 to 41% in 2021. However, compared to the EU average of 23%, Slovakia remains in the lower half of EU countries.

Graph 3: Landfilling of municipal waste in 2021



Source: IEP based on data from Eurostat

Graph 4: Trends in the municipal waste recycling rate



Source: IEP based on data from Eurostat

Different methodologies for data processing complicate the comparability of recycling rates over time and across EU countries. A significant portion of the increase in municipal waste production and recycling rates in Slovakia is also linked to changes in reporting methodologies in 2015 and 2020 (see Box 1). Additionally, countries calculate recycling rates differently, often based on the total amount of waste collected separately. However, not all waste from separate collection is recyclable due to technical or economic reasons. Moreover, collection bins for separate waste often contain impurities, accounting for 5 to 25% of the weight. According to the European Commission[2], the calculation should use the amount of waste entering the recycling process or the amount from separate collection after deducting losses due to processing before recycling (see Box 1).

Slovakia is struggling to meet the main targets for managing municipal waste. According to EU targets, the recycling rate for municipal waste should reach at least 55% by 2025 and gradually increase to 65% by 2035. In 2020, the target was 50%, while Slovakia achieved 45%. Additionally, the amount of municipal waste disposed of in landfills must be reduced to a maximum of 10% by 2035. The recent growth in recycling rates is unlikely to continue at the same pace, as it was driven by the implementation of significant measures and changes in methodology (see Box 1). Furthermore, there are specific targets for different types of municipal waste, detailed in Appendix A.

In contrast, Slovakia has consistently exceeded targets in the area of packaging waste recovery, possibly due to "free riders" who do not report data. While the recycling rates for paper and glass packaging in Slovakia are at the EU average, the recycling rate for plastic packaging in Slovakia reaches 60%, compared to the EU average of only 38%. This discrepancy may be due to underreported packaging production caused by free riders among producers. Comparing data from the extended producer responsibility (EPR) organizations and municipal waste data reveals a discrepancy in plastic packaging production of more than one-third. Part of this difference can be attributed to insufficient data on waste and missing data on private exports and imports.

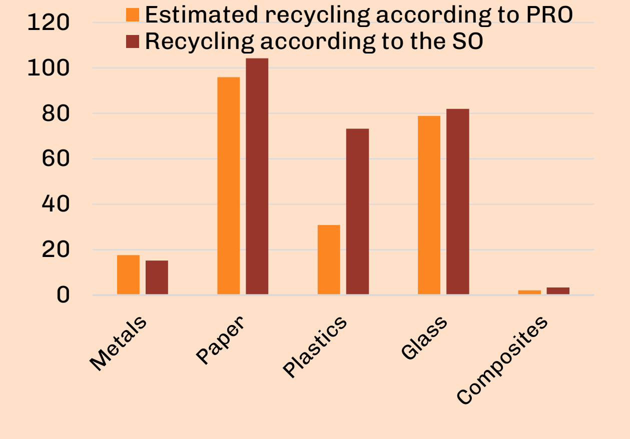
Box 1: Actual recycling rate of municipal waste

The recycling rate of municipal waste is calculated based on data from the Statistical Office of the Slovak Republic. According to these data, all waste collected separately is considered recycled, which is not the case in reality. This issue is particularly problematic for plastics, a significant portion of which are not technically or economically recyclable. This is confirmed by data from Producer Responsibility Organisation, indicating that the amount of recycled waste is lower than the amount of collected segregated waste.

A comparison of data from Producer Responsibility Organisation organizations and the Statistical Office of the Slovak Republic suggests that in 2021, only approximately 42% of sorted plastic waste was actually recycled. This estimate aligns with a report from the Supreme Audit Office of the Slovak Republic, which states that 62% of sorted plastic waste cannot be recycled, and more than 30% of sorted plastic waste ends up in landfills (Supreme Audit Office of the Slovak Republic, 2020). More than 90% of sorted paper and glass waste was recycled. The remaining waste, after sorting, was either recovered for energy in waste-to-energy plants or ended up in landfills. In this case, the municipal waste recycling rate for the years 2020 and 2021 would have decreased by 5 percentage points compared to the official figures.

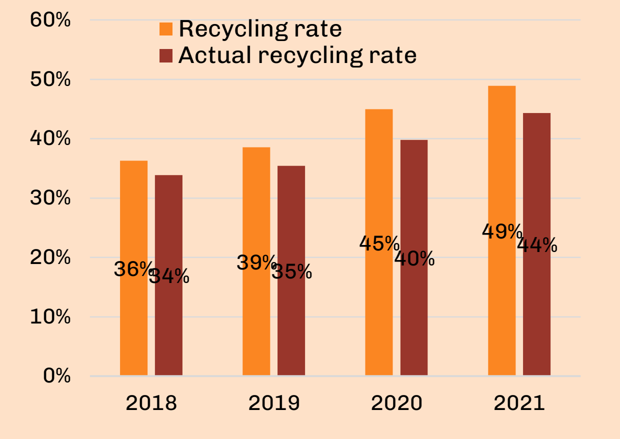
[2] COMMISSION IMPLEMENTING DECISION (EU) 2019/1004 establishing rules for the calculation, verification, and reporting of data on waste.

Graph 5: Comparison of recycling components of sorted collection in 2021 (thousand tonnes)



* only household waste

Graph 6: Estimated actual recycling rate of municipal waste



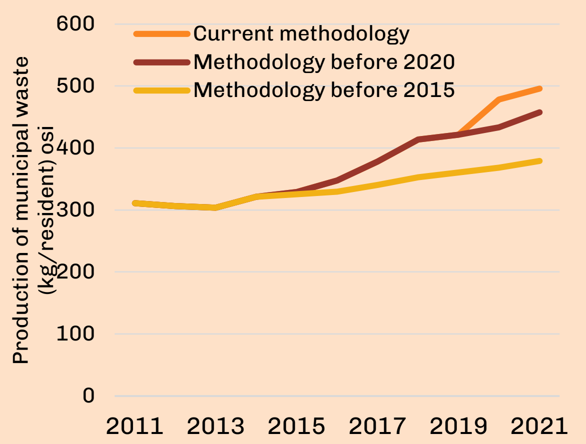
Source: IEP

Changes in the reporting of municipal waste

In 2015, a change in the reporting of metal waste from civic amenity sites led to a significant increase in reported metal waste. Metal waste increased from an average of 2.2 kg per capita between 2010 and 2014 to 82 kg per capita in 2021. Additionally, between 2016 and 2018, the recycling rate jumped by an average of 7 percentage points annually, with nearly half of this increase attributed to the rise in metal recycling. Various cities progressively reported more metal waste each year to boost their sorting rates and reduce landfill fees.

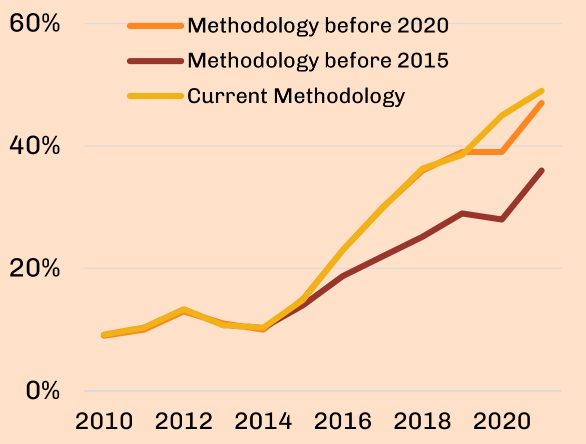
Since 2020, municipal waste in Slovakia has included waste from restaurants and food service establishments and packaging waste not only from separate collection of municipal waste but also from other sources that have a similar nature and composition to household waste[3]. This change in methodology increased the reported production of municipal waste per capita by approximately 9%. Furthermore, the recycling rate of municipal waste also rose significantly by 2 and 3 percentage points in 2020 and 2021, respectively, since most newly recorded types of waste were recycled. If metal production accounted for only 0.65% of the total municipal waste production, as it did between 2010 and 2014 before the 2015 methodology change, the production of municipal waste per capita in 2021 would have been just 379 kg, and the recycling rate would have been 36%.

Graph 7: Development of municipal waste production according to methodology



Source: IEP calculations

Graph 8: Development of municipal waste recycling according to methodology



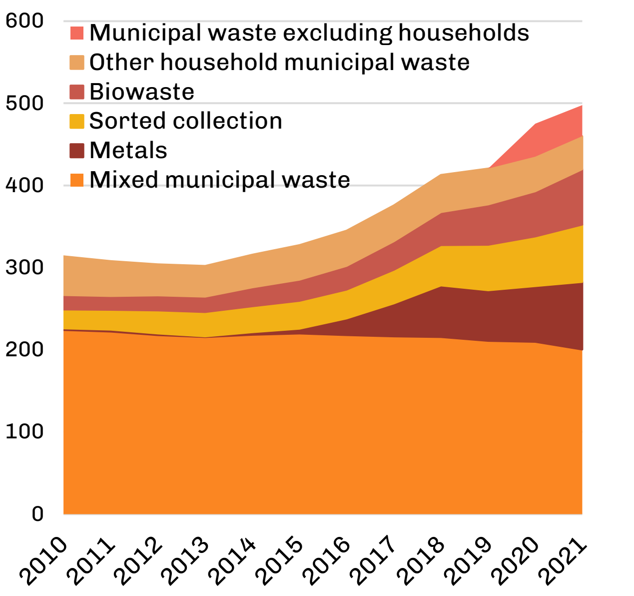
Source: IEP calculations

[3] According to Directive (EU) 2018/851 of the European Parliament and of the Council

Mixed municipal waste still constitutes the largest portion of municipal waste. In 2021, mixed municipal waste amounted to 200 kg per capita, approximately 10% less than in 2010. Preliminary data for 2022 indicate a decrease in mixed municipal waste to 189 kg per capita. Conversely, the amount of waste collected through separate sorting, including biowaste, increased more than threefold between 2010 and 2021, reaching 137 kg per capita. In 2020 and 2021, there was also an increase in non-household municipal waste recorded (see Box 1), which amounts to approximately 40 kg per capita.

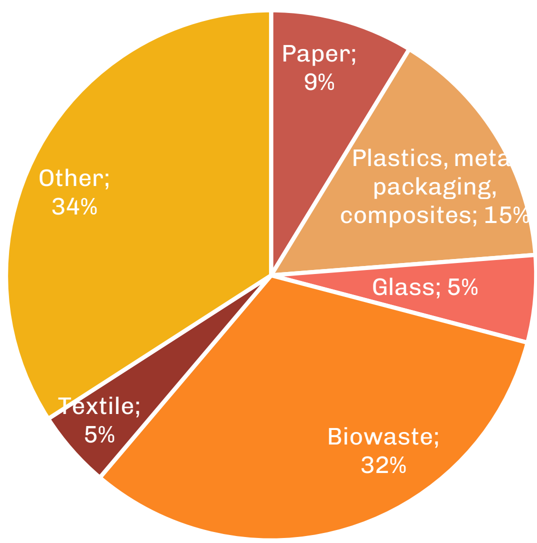
Biowaste constitutes the largest portion of mixed municipal waste, although the introduction of kitchen biowaste collection has been reducing this share. According to composition analyses from 2020 to 2023, garden, kitchen, and food biowaste together accounted for one-third of mixed municipal waste. Waste from packaging and non-packaging products, which should be part of sorted collection in the EPR system, comprised just under 30%.

Graph 9: Development of municipal waste composition (kg per capita) [4][5]



Source: IEP based on data from Statistical Office of the SR

Graph 10: Estimated composition of mixed municipal waste in 2020

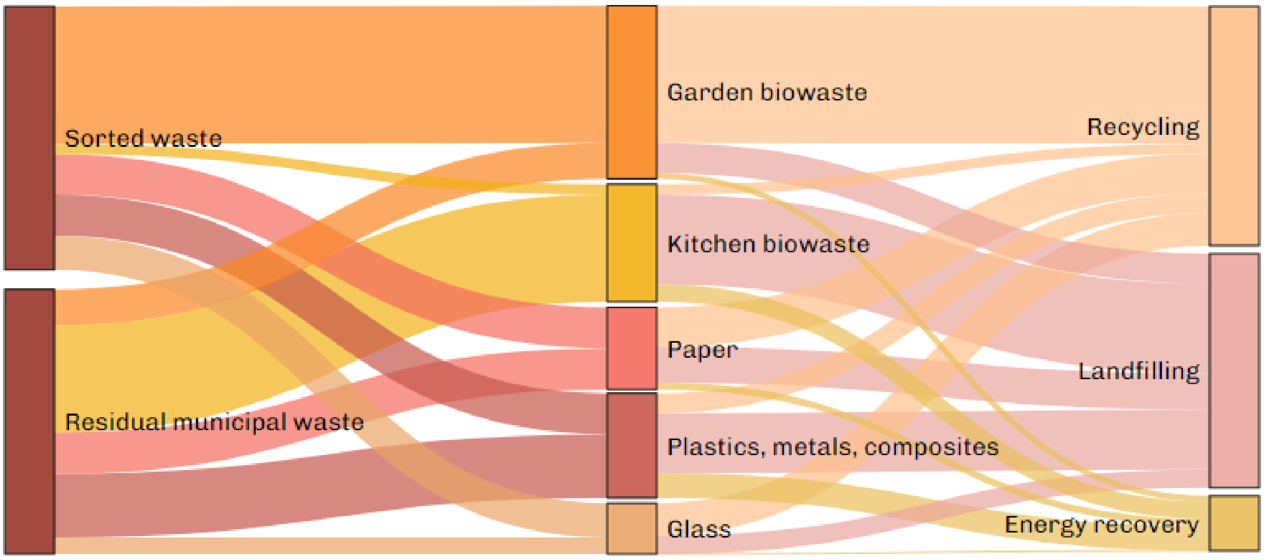


Source: IEP based on data from JRK

Not all components of municipal waste are sorted and recycled to the same extent. In 2021, as much as 57% of biowaste ended up in a landfill or a waste-to-energy plant, as part of mixed municipal waste. For other household waste collected separately, up to 61% ended up in a landfill or an energy recovery facility. The reasons for this include not only low sorting rates but also the non-recyclability of some wastes in the separate collection. We estimate that the highest recycling rates are for glass and paper waste, at 64% and 48%, respectively. Conversely, only 39% of plastic, metal packaging, and multilayer composite packaging waste is sorted, and less than half of this is recycled.

[4] The item 'sorted collection' includes all components of municipal waste with catalogue numbers starting with 20 01, except for kitchen biowaste, which is included under the item 'biowaste.'
[5] Municipal waste excluding minor construction waste, septic tank sludge, soil and aggregates, and waste from sewer cleaning.

Graph 11: Estimated management of selected components of municipal waste in 2021



Source: IEP

1.2 Where Waste ends up

In Slovakia, waste was deposited in 81 landfills in 2022. Of these, 62 landfills were designated for non-hazardous waste, which includes the majority of municipal and industrial waste. Another 8 landfills were for hazardous waste, and 11 for inert waste. Since 2015, the total number of landfills has decreased by almost one-third.

The estimated remaining capacity of landfills for non-hazardous waste at the end of 2022 was 12.9 million tonnes (more details in the technical appendix). Currently, it is not possible to open new landfills, but the capacities of existing landfills can be expanded. This expansion occurs every year, with permits issued by Slovak Environmental Inspectorate or the relevant district office.

There is no centralized system currently in place to maintain records for all landfills. These data can only be obtained by directly contacting landfill operators, Slovak Environmental Inspectorate, or district offices. Operators are also required to submit data on available capacity to the Ministry of Environment every year; however, these data are often incomplete, exhibit high error rates, and are inconsistent over time. Therefore, the exact capacities of landfills in Slovakia are not known.

Table 1: Capacities of active landfills

	Number	Estimated available capacity at the end of 2022 in mil. tonnes
Landfill for non-hazardous waste	62	12.9
Landfill for hazardous waste	8	0.5
Landfill for inert waste	11	9.5

Source: IEP

Landfills are not evenly distributed throughout Slovakia. The largest capacities are found in landfills for non-hazardous waste in the Banská Bystrica and Košice regions, each exceeding 2 million tonnes. In contrast, landfills in the Bratislava region have capacities of less than

125,000 tonnes. In 2020, several municipalities in this region reported regional shortages in landfill capacity for municipal waste. Increasing the rate of sorting and subsequent recycling is therefore crucial for maintaining functional waste management.

Regarding some older landfills, Slovakia faces lawsuits from the European Commission for their failure to close. Currently, 21 landfills in Slovakia are under European Commission proceedings, which are in the stage of initial legal action. Waste is no longer deposited at these landfills, so their closure does not result in a loss of landfill capacity. In most cases, restoration has already been completed or is ongoing. Intensive negotiations are underway with operators of other landfills aimed at achieving their swift restoration.

An alternative for processing non-recyclable waste in Slovakia is through facilities for energy recovery, some of which require waste treatment. Energy recovery from waste in Slovakia takes place in waste-to-energy (WtE) facilities and in co-incineration plants, such as cement and heating plants. While waste is directly recovered in WtE facilities, co-incineration plants require the waste to be processed into residual derived fuel (RDF) through mechanical or mechanical biological treatment (MBT), depending on the type of waste. Unlike waste-to-energy plants, co-incineration plants are not bound by regular and long-term waste disposal obligations for RDF. Capacity expansion or new facility construction is planned within waste-to-energy plants to process waste.

Current capacities of MBT facilities are insufficient to meet the landfill ban requirement, effective from 2024, for untreated municipal waste. Existing treatment capacities cover only one-third of the necessary capacity. A significant increase in MBT capacities is expected in 2024, which would fulfil three-quarters of the municipal waste management needs. However, construction may be hindered by lengthy approval processes, and regional-level capacity shortages may also pose challenges.

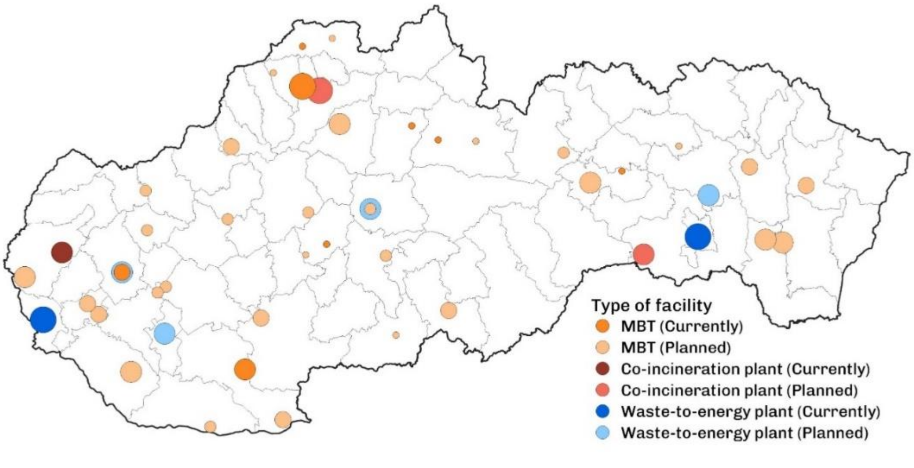
Table 2: Capacities of waste-to-energy plants

	Number of facilities	**Capacity (thousand tonnes/year)**	
	Current	Current	Planned
Waste-to-energy plants	2	254	1,135
Cement plant	4	350	500
which use RDF with low calorific value		85	150
Heating plant			
which use RDF with low caloric value	-		109-152
Mechanical biological treatment	8	293	658 – 1 469

Source: IEP

The lack of a coherent strategy can lead to excessive capacities or uneven distribution of capacities across regions. An example of this is the plan for a significant increase in waste-to-energy and mechanical biological treatment facilities, which exceed Slovakia's needs. The European Commission's report in 2019 highlighted the necessity of preventing overdevelopment of such infrastructure (European Commission, 2019). Conversely, some regions have historically experienced shortages in landfill capacity for municipal waste without viable alternative waste management options. The planned Waste Management Information System, in preparation since 2017, is expected to provide centralized records of waste material flow and processing capacities. However, the full implementation timeline for the system remains uncertain.

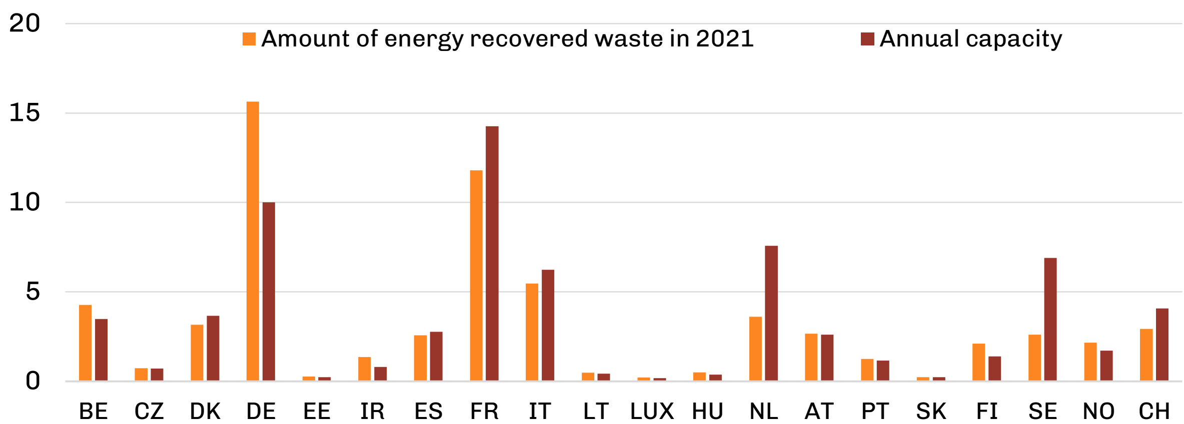
Graph 12: Map of current and planned facilities for waste treatment and energy recovery



** one company plans to build 3 more waste-to-energy plants without specified locations yet* *Source: IEP*

Excess capacities for energy recovery from waste create a dependency of the country on waste production and imports, while also hindering the growth of recycling (OECD, 2019). In most EU countries, capacities are approximately aligned with the production of non-recyclable waste (CEWEP, 2020). In contrast, energy recovery capacities in the Netherlands and Sweden are currently more than double their needs, making these countries reliant on imported waste. In the Netherlands, an agreement was made between the state and the market as early as 2009 to halt further capacity expansion (NL Agency, 2011). The country also anticipates that waste imports will increase in line with the transition to a circular economy and the decreasing availability of waste. In Sweden, the rate of energy recovery reached 60% in 2020, more than double the EU average. Consequently, the European Commission recommends reducing the country's dependency on energy recovery by developing recycling infrastructure (European Commission, 2023).

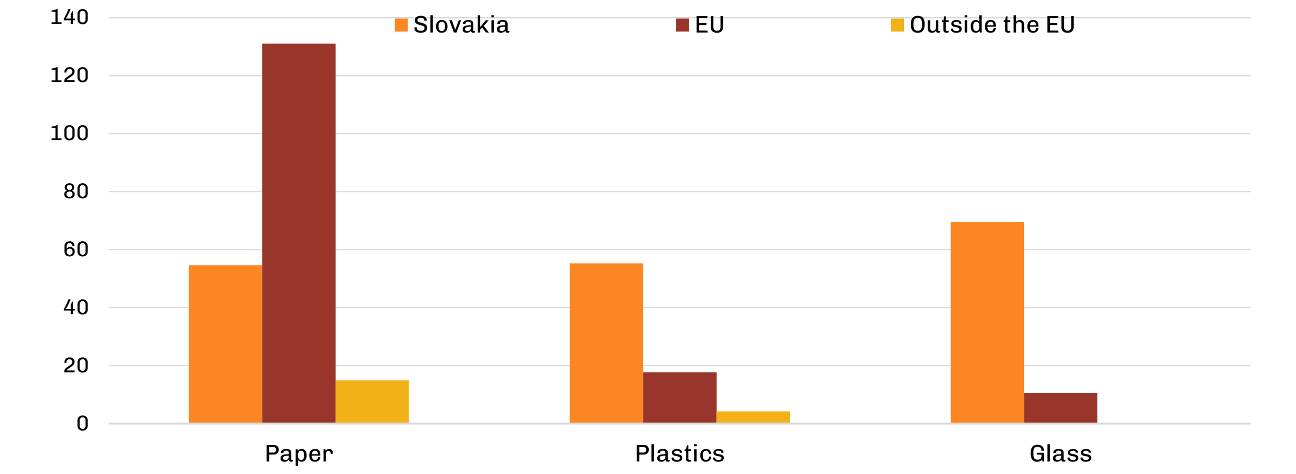
Graph 13: Comparison of capacities and energy recovery for municipal waste (in mil. tonnes)



Source: Eurostat

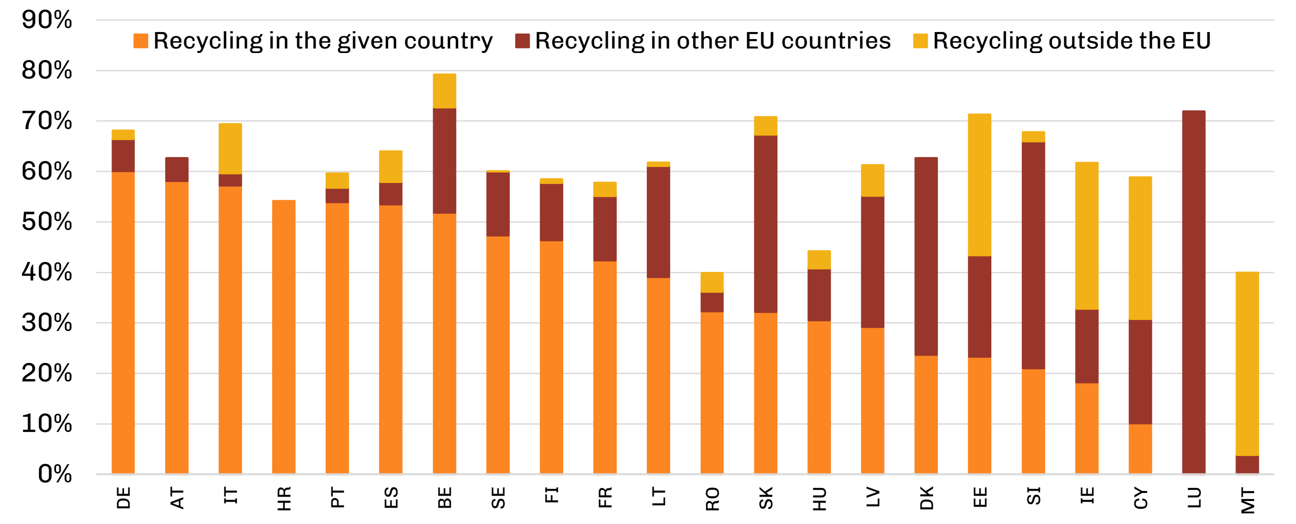
Capacities for recycling municipal waste are lacking at the regional level, with a significant portion being recycled abroad within the EU. Sorted biowaste is primarily processed in composting plants and biogas stations in Slovakia. Facilities for processing kitchen biowaste are unevenly distributed, leading to capacity shortages in some regions. For material recycling, nearly half of the waste, particularly paper, is recycled abroad. A country does not need to have the capacity to recycle all its waste. The decision on where waste is recycled depends not only on the availability of capacities but also on the distance and the purchase prices of secondary materials offered by processors.

Graph 14: Recycling of packaging waste from Slovakia in 2021 (in thousand tonnes)



Source: IEP based on data from PRO

Graph 15: Recycling of packaging waste in the EU in 2020



Source: Eurostat

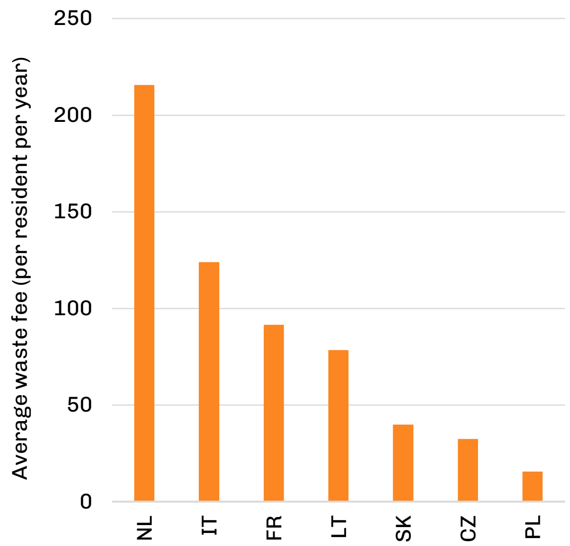
The exact capacities of all current waste processing facilities are not known. Currently, there is no unified electronic database of the number and capacities of facilities that is regularly updated. This information is only available in paper form at respective district offices, where requests can be made for its provision. Due to the lack of electronic records, verifying the accuracy and timeliness of this data is time-consuming. When estimating the number of facilities and their capacities for waste processing, we relied on multiple available sources.

1.3 Who Pays for Waste and how much

While non-sorted waste and sorted biowaste are funded by citizens, the costs associated with sorted collection are borne by producers. The costs of collection and disposal of municipal waste are covered by citizens through a local waste fee set by individual municipalities. An exception is the cost of sorted waste collection, which falls under the EPR system. These costs are covered by producers through fees to the EPR system. This system encourages producers to design products that are more easily recyclable and provides a financial incentive for consumers to sort waste.

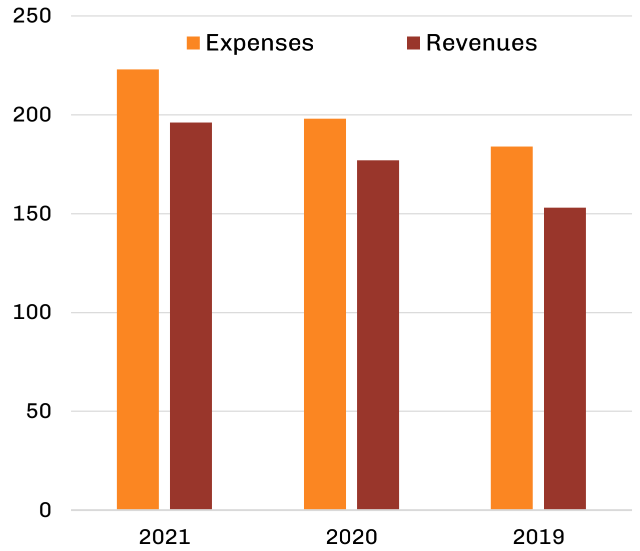
The amount of the municipal waste fee in Slovakia is one of the lowest in the EU. The average local waste fee has increased by 44% over five years and reached approximately 26 euros per inhabitant in 2022. In eight major cities in Slovakia, the average fee reached 40 euros per inhabitant. Nevertheless, Slovakia, along with the Czech Republic and Poland, has some of the lowest fees. In contrast, residents of cities in Lithuania, the Netherlands, France, or Italy pay 2 to 5 times more, taking into account purchasing power parity. The reasons for low fees in Slovakia may include low landfill costs, as well as cross-subsidization of waste management (Instite for Environmental Policiy, 2019).

Graph 16: Comparison of fees in the EU



Source: IEP

Graph 17: The amount of revenues and costs for waste management in Slovakia (mil. €)



Source: IEP

Currently, municipalities partially subsidize waste management, which reduces residents' motivation to sort waste. A comparison of data on costs and revenues from waste management shows that fees have been collecting on average 13% less than the actual costs over the long term. Residents of these municipalities do not bear the full costs associated with waste, and thus, municipalities subsidize waste management.

2 How to Dispose of Waste

Increasing the recovery and recycling of municipal waste requires implementing several measures. These include pay-as-you-throw collection, door-to-door sorted collection, sorted collection of kitchen waste and textiles, and deposit-refund systems for beverage containers. Fees for landfilling or energy recovery, as well as waste treatment before landfilling, directly impact waste management.

To achieve a circular economy, actions focusing on each phase of a product's life cycle are necessary. Market and regulatory tools can include changes in taxes on primary materials or stringent product content requirements to stimulate demand for secondary materials. Governments can promote sustainable products through mandatory green public procurement.

Behavioural measures are essential complements, such as providing environmental education to increase awareness. People's behaviour is also influenced by the availability and suitability of infrastructure, the way measures are communicated, their significance, and the behaviour of others in the vicinity. Ensuring compliance monitoring and potential penalties is crucial.

Estimated effects of these measures represent average values; in specific cases of municipalities, the effects may be higher or lower depending on the implementation of the measure. A municipality with higher fees, a straightforward system with appropriate collection frequency, higher environmental awareness, an active mayor in environmental issues, or better information campaigns and record-keeping can achieve better results. For example, in the village of Šútovce, a bagged sorted/bag-based sorted collection system with QR code monitoring was introduced in 2020, resulting in a 38% decrease in mixed municipal waste production and a 180% increase in sorted collection. This was facilitated by a discount system that reduced fees for higher sorting rates, as well as providing composters to every household.

2.1 Measures Focused on Waste Collection

Pay-as-you-throw

Measures aimed at volume-based collection is a fee collection method for waste that applies the principle of "pay as you throw" and encourages higher rates of sorting (Eunomia, 2003). Most municipalities charge residents an annual flat fee that is the same for all regardless of the amount of waste produced. The costs of waste from households that produce more waste are thus partially subsidized by households with lower waste production. An alternative is a fee differentiated by the amount of waste produced ("pay-as-you-throw collection"), which represents an effective tool for increasing sorting and recycling rates while reducing the amount of waste sent to landfills or incinerator plants. According to estimates from Slovak data, pay-as-you-throw collection reduces mixed waste production per capita by an average of 22% (Institute for Environmental Policy, 2019).

Table 3: Effect of pay-as-you-throw (percentage change compared to flat fee)

	Mixed municipal waste
Pay-as-you-throw – average	-22.3%
Tag-based	*-31.0%*
Volume-frequency based	*-11.3%*

Source: IEP

The interest of municipalities in pay-as-you-throw waste collection is increasing. While in 2018, this system was implemented in 167 municipalities, by 2022, the number had risen to 284. Consequently, 16% of the population now pays fees based on the amount of waste they generate. The most commonly used method is volume-frequency collection, where the fee is calculated in advance according to the frequency of pickups and the size of the container. The second most common type is tag based collection or collection using electronic record of containers, where residents pay according to the number of emptied containers. A few municipalities determine the fee based on the weight of the waste in the container using a weighing system. The law's amendment[6] anticipates the mandatory introduction of pay-as-you-throw collection in family houses from 2025 and in apartment buildings from 2030.

Introducing pay-as-you-throw collection must be preceded by the proper setup of infrastructure and an information campaign. Efficient operation of pay-as-you-throw collection requires creating a system that is sufficiently convenient and motivational for residents and providing them with necessary information before the system is implemented. Along with pay-as-you-throw collection, preventive measures against illegal dumping must be introduced, such as installing cameras with notices of possible fines. Another option is to introduce a discount system for higher sorting or a two-part fee with a minimum fixed fee and a variable fee depending on the amount of waste.

Implementing pay-as-you-throw collection in apartment buildings is more complicated. Lockable containers appear to be a suitable solution. In comparison to family houses, where each household has its own collection containers, multiple residents in apartment buildings share a common infrastructure. Unlocked stands, which can be used by residents of other apartment buildings, also pose a problem. In apartment buildings, it is advisable to build a lockable stand, where opening can be done using a chip or card with a specific identifier for each resident or household.

Door-to-door Sorted Collection

Sorted waste collection can be conducted in various ways – door-to-door collection, from curbside collection points, or from civic amenity sites. In door-to-door collection, each household or family house has its own containers for sorted waste. Recycling yards are primarily used for collecting bulky waste or small construction waste, but any type of sorted waste can be handed over there.

[6] LP/2022/725 Act amending and supplementing Act No. 39/2013 Coll. on Integrated Prevention and Control of Environmental Pollution

In Slovakia, sorted waste collection in apartment buildings is carried out using curbside collection points. For family houses, door-to-door sorted collection has been mandatory since 2023. According to information from PRO, 100% of municipalities have implemented door-to-door sorted collection. The exception is glass, which is mostly collected through curbside collection points. In apartment buildings where door-to-door collection is not attainable, the place of mixed waste collection is considered an appropriate distance for sorted waste collection[7] from 2023 onwards. However, according to PRO Naturpack, it is not possible to evaluate if this obligation is fulfilled 100% due to a lack of data from collection companies.

Implementing a door-to-door collection system increases the sorting rate and improves the quality of recyclable materials (Seyring, et al., 2016). Curbside points are usually located further from homes, which demotivates citizens from sorting. Additionally, shared infrastructure leads to higher contamination levels in sorted waste. This is confirmed by PRO data, with the average contamination level difference ranging from 35% to 72% against curbside collection in apartment buildings (Naturpack, 2022).

Table 4: Contamination rate of sorted waste by collection type

	Curbside collection points	**Door-to-door collection**
Paper and cardboard	10%	6%
Plastics, Composite packaging, and metal packaging	27%	19%
Glass	7%	2.5%

Source: IEP based on data from Naturpack and Envipak

The analysis results indicate that door-to-door sorted waste collection significantly reduces mixed municipal waste production by 15% compared to collection at curbside collection points in Slovakia. This reduction is achieved through the sorting of paper, plastics, multilayer composite packaging, and metal packaging, facilitated by changes in collection infrastructure. Since glass is almost exclusively collected through common containers, its sorting rate is presumed to remain unchanged.

Table 5: Effect of door-to-door collection on waste production

	Mixed municipal waste
Effect of door-to-door sorted waste collection	-15%
The combined effect of door-to-door sorted waste collection and pay-as-you-throw system	-25%

Source: IEP

The door-to-door sorted waste collection system in Italy has had a significant effect, with mixed municipal waste production dropping by nearly two-thirds. However, the conditions of the system in Italy differ substantially. The implementation of door-to-door collection is accompanied by informational campaigns, and each household is provided with small 30-40 litre bins for paper, plastics, glass, and biowaste, with a high collection frequency. For biowaste, the collection frequency is two to three times a week, while mixed municipal waste is collected once or twice a week. Households dispose of mixed municipal waste on average only once or twice a month. Additionally, the average municipal waste fee in Italy is around 100

[7] Waste Act No. 79/2015 Coll.

euros per capita compared to 26 euros in Slovakia. These factors significantly influence and change residents' motivation for higher sorting.

Sorted Collection of Kitchen Biowaste

Since mid-2021, municipalities in Slovakia are required to ensure sorted collection of kitchen biowaste. Before 2021, this collection was only operational in a few dozen municipalities. Consequently, an average of 24% of kitchen biowaste was found in mixed municipal waste, amounting to 51 kg per capita in 2019. According to the Waste Act, from 2021, all municipalities must ensure the sorted collection of kitchen biowaste, with exceptions only for municipalities that can prove that 100% of their residents compost[8].

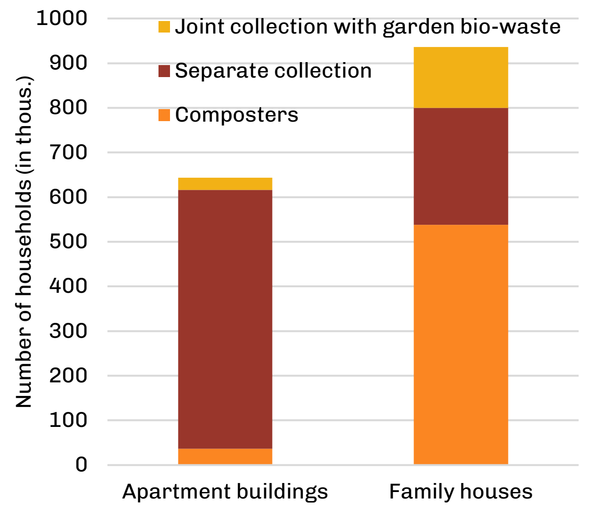
In apartment buildings, separate collection is predominantly done using collection bins, while in family houses, kitchen biowaste is mainly collected in home composters. According to data from the Statistical Office of the Slovak Republic, municipalities and towns opted for separate collection of kitchen biowaste for 90% of households in apartment buildings. Conversely, more than half of the family houses use home composters. By utilizing home composting, municipalities save costs on the collection and processing of biowaste. The data also show that approximately 11% of households in apartment or family houses did not have infrastructure for sorted collection of kitchen biowaste in 2022, with no infrastructure reported in 317 municipalities.

In 2022, about 37 thousand tonnes of kitchen biowaste were sorted from households, averaging 14 kg per capita. From the total potential in mixed municipal waste, we estimate a sorting rate of 23%. These estimates are based on municipalities where sorted collection of kitchen biowaste using collection bins was implemented. We assumed that the reported kitchen biowaste comes only from households with collection bins, not from home composters, as composting is not recorded.

We estimate that the impact of introducing kitchen biowaste collection in apartment buildings reaches 13%, with collection baskets for each household achieving up to 19% sorting from the potential in mixed municipal waste. This is based on data on kitchen biowaste sorting for 2022 (more in the technical appendix). A simple collection type involves only providing bins for sorted biowaste collection. A more comfortable system involves providing baskets or buckets and bags to each household, along with information on how to sort correctly. In these cities, the sorting rate reached approximately 19% in 2022. The results align with foreign practices (VANG, 2020) and the findings of a Slovak study from 2022 (ZOH, 2022).

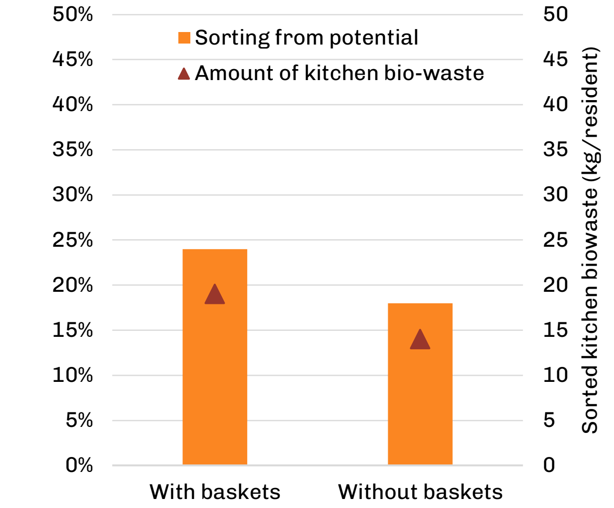
[8] Decree 348/2020 and Waste Act No. 79/2015

Graph 18: Methods of kitchen biowaste collection in Slovakia



Source: IEP

Graph 19: Sorting of kitchen biowaste (kg /capita)



Source: IEP

We estimate that implementing separate collection of kitchen biowaste through composting or door-to-door collection in family houses will result in a 40% sorting rate of the potential, based on the experiences from the town of Topoľčany. For comparison, municipalities where family houses constitute over 99% of the development and where non-zero amounts of garden biowaste are recorded, achieved a garden biowaste sorting rate of approximately 62% in 2019. A similar sorting rate can be expected for kitchen biowaste in the case of sorting kitchen biowaste in family houses. When kitchen biowaste is composted at home, the sorted amount does not enter the municipal waste records, resulting only in a decrease in mixed municipal waste.

Best practices from abroad demonstrate nearly complete sorting of kitchen biowaste. Collection of biowaste door-to-door combined with pay-as-you-throw collection in Italy's Treviso region led to an increase in sorted kitchen biowaste to 82 kg per capita annually (Contarina Spa, 2016). According analyses, biowaste constitutes less than 1% of mixed municipal waste. A Dutch study indicates that additional measures such as adjusting infrastructure distances, providing information on the importance of sorting, setting group targets, and offering feedback can further improve the separation of kitchen biowaste.

Deposit refund systems for plastic beverage containers

Since 2022, Slovakia has implemented a deposit refund system for single-use plastic and metal beverage containers. The deposit refund system in Slovakia operates similarly to centralized systems common in Scandinavian countries, involving unions and associations of producers. The central system's role is to coordinate activities, finance the system, and act as a clearing centre for participating parties. The entire system is funded by producers through an administrative fee per bottle/can. Costs associated with collection via manual or automated methods are covered through a handling fee (Deposit return system Administrator, 2023).

In the first year, the return rate of deposit-refunded containers reached 72%, with a projected increase to 90% over time. With a deposit set at 15 cents (Deposit return system Administrator, 2023), a return rate exceeding 90% is anticipated based on data from other countries with established deposit systems (Institute for Environmental Policy, 2018). Prior to the implementation of the deposit system, the estimated recycling rate for beverage PET bottles was 62%. The increase in return rates has led to a reduction in the proportion of deposit-refunded containers in mixed municipal waste. According to waste composition analyses for the years 2020-2021 and 2022-2023, the proportion of PET in mixed municipal waste decreased from 1.32% to 0.07% following the introduction of the deposit system.

Table 6: Results of the deposit refund system for single-use beverage containers in 2022

	Return rate		Recycling rate
	2022	**Target 2025**	**2022**
Plastic beverage containers	73%	90%	65%
Aluminium beverage containers	68%	90%	59%

Source: Deposit return system administrator

Selective Collection of Textiles

From 2025, EU member states must ensure sorted collection of textiles, currently implemented in only 2 countries. The collected textiles are primarily intended for reuse or recycling. The European Commission also proposes to introduce mandatory Extended Producer Responsibility (EPR) for textiles, which would help member states meet the target of implementing sorted collection (European Commission, 2023).

Currently, mandatory sorted collection for textiles is only in place in France and Estonia (Joint Research Institute, 2021). EPR for textiles has been operating in France for a long time (more details in the technical appendix), and it has been implemented in the Netherlands since 2023 (Government of the Netherlands, 2023) with plans to implement it in Sweden (European Environmental Agency, 2022). In France, the goal is to collect 50% of the equivalent volume of textiles placed on the market, while the Netherlands has set a target of recycling or reuse of 75% by 2030.

Currently, sorted collection of textile waste in Slovakia is not mandatory but operates on a voluntary basis. Overall, only 13% of textiles are successfully collected. According to a representative sample, 77% of Slovak municipalities participate in the selective collection of textile waste (MoE SR, 2022). Collected textile waste, after sorting of reusable textiles, is subsequently transported to neighbouring countries for further re-sorting. According to data from the Statistical Office of the Slovak Republic, 9,410 tonnes of textile waste were sorted in 2022. According to composition analyses, textile waste constitutes just under 5% of mixed municipal waste. The total household textile waste production in Slovakia is estimated at 58,000 tonnes, or 10.5 kg per capita. The average production in the EU is similar, around 11 kg per capita (European Commission, 2022).

Upon the introduction of EPR for textiles in Slovakia, we estimate a gradual increase in sorting by 20% to 40%. This estimation is based on the experience of the system in France, which has been operational since 2007. Initially, 20% of textiles were successfully collected, increasing to nearly 40% by 2020. In Slovakia, this would equate to approximately 2.7 kg, or 5.4 kg per capita annually. Since data on the costs of collection, re-sorting, and recovery of textiles are not available, we estimated the total costs of the EPR system for textiles based on costs in France. After adjusting for purchasing power parity, we estimate costs at 57 euros per tonne.

2.2 Waste Management Measures

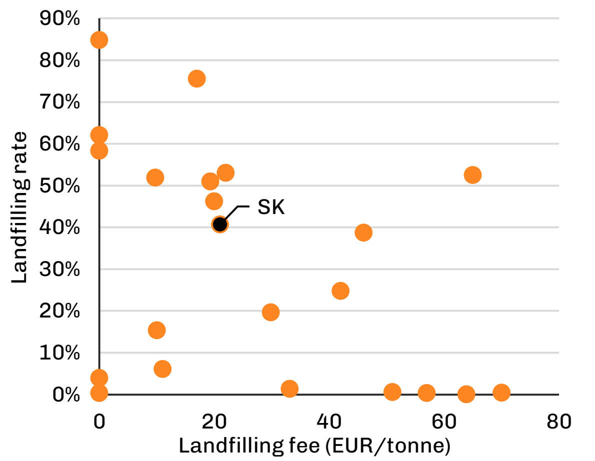
Landfill Fee

Landfill fees in Slovakia continue to rank among the lowest in the EU, which insufficiently incentivizes waste sorting. In 2018, Slovakia had one of the lowest landfill fees for municipal waste, amounting to just 7 euros per tonne, while also being one of the worst countries in terms of landfill rates. Since 2019, landfill fees have gradually increased, contingent upon the municipality's waste sorting rates from the previous year. Between 2019 and 2021, the average landfill fee rose from just under 10 to 21 euros per tonne. However, in 2022, the weighted average fee decreased to just under 19 euros per tonne due to higher sorting rates and unchanged rates compared to 2021.

Several studies indicate a significant correlation between higher landfill fees and municipal waste landfill rates (Bartelings & Linderhof, 2000). A meta-analysis by Acil Allen Consulting (2014) estimates an arc elasticity of landfilling at -0.11, implying that a 1% increase in landfill costs reduces the amount of waste landfilled by -0.11%.

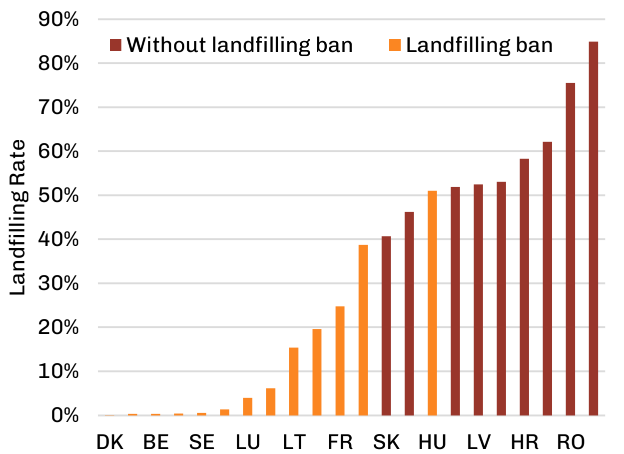
In addition to landfill fees, landfill bans can also be implemented. Nine EU countries have banned landfilling of combustible waste with a total organic carbon content averaging over 5%, which correlates with waste calorific value (CEWEP, 2022). Five countries have implemented bans on landfilling of unsorted and untreated waste. The average municipal waste landfill rate in these countries was 10% in 2021. Poland stands out, having implemented a ban on landfilling waste with high calorific value in 2016 without sufficient time to build capacity for its recovery. In other EU countries without landfill bans and with low landfill fees, the average landfilling rate was 58% in 2021. Slovakia plans to introduce a ban on landfilling of untreated municipal waste from 2024 onwards, although this ban has been postponed several times already[9].

Graph 20: Landfilling rate and landfill fees in 2021



Source: IEP based on data from Eurostat, CEWEP

Graph 21: Bans on landfilling waste with high calorific value



Source: IEP based on data from CEWEP

[9] Waste Act No. 79/2015 Coll.

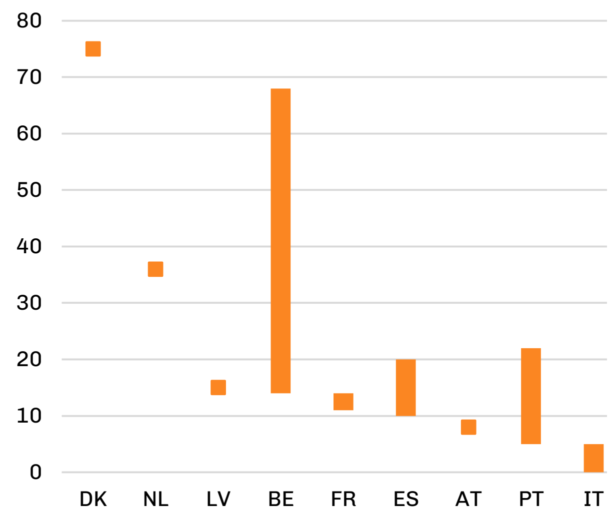
Energy Recovery Fee

Within the EU, 9 countries have implemented a fee for energy recovery or waste incineration, ranging from 5 to 75 euros per tonne, with some countries adjusting the fee based on the type of waste and method of handling (European Environmental Agency, 2023). In Belgium, lower fees apply to energy recovery incineration, while higher rates are for incineration without energy recovery. France offers tax relief for incineration with high energy recovery efficiency. Spain applies a lower fee for outputs from mechanical biological treatment. Latvia and Italy have this fee exclusively for waste incineration. Sweden had a fee for energy recovery for 2 years, but it was abolished in 2023 due to changes in the European electricity market conditions (IEA Bioenergy, 2023).

The purpose of this fee is to promote recycling, although current studies have not confirmed a direct impact on recycling rates (OECD, 2019). Additionally, in none of the countries has the fee led to a decrease in energy recovery. Belgium and the Netherlands use the fee for energy recovery to promote recycling and reduce dependence on energy from waste. Despite a significant increase in the fee in the Netherlands in 2019 from approximately 13 euros per tonne to 33 euros per tonne, the energy recovery rate only decreased by 1 to 2 percentage points. Conversely, in Belgium and Denmark, the energy recovery rate continues to rise. Sources confirm that tax rates must be set based on market conditions and considering the marginal costs of alternative waste management options (Weerdt, 2022).

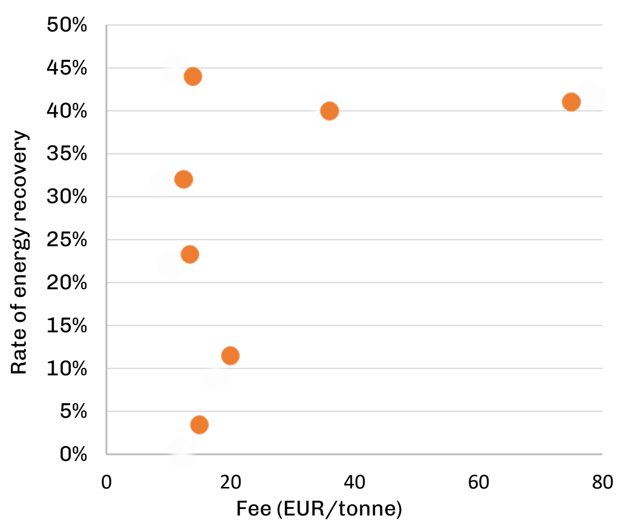
Furthermore, the fee aims to account for the impacts of pollutants and emissions from energy recovery and incineration (Freire-González, et al., 2022). In Denmark, the tax for energy recovery depends on the calorific value of the waste and the amount of heat produced. The goal is to limit the energy recovery of highly calorific waste, such as plastics, which contribute to air pollution and high emissions. Additionally, Denmark has a CO_2 emission tax amounting to 24 euros per tonne of CO_{2eq}.

Graph 22: Fees for energy recovery of municipal waste (€/tonne)



Source: IEP based on data from EEA

Graph 23: Rate of energy recovery and the level of fees for energy recovery



Source: IEP

The European Commission plans to integrate energy recovery into the EU Emissions Trading System (ETS). In line with the European Green Deal, the European Commission aims to include waste-to-energy plants into the ETS. From 2024 onwards, member states will be required to monitor and report emissions generated from fuel incineration in municipal waste incineration plants[10]. By 2026, the European Commission will assess the feasibility of integrating municipal waste incinerators into the EU ETS starting from 2028, with the possibility of implementation postponement for member states until 2030.

Mandatory Treatment of Waste before Landfilling

The mandatory treatment of waste before landfilling aims to stabilize the organic fraction in municipal waste, thereby reducing greenhouse gas emissions released from landfills and overall landfill waste volumes. According to an amendment to the Waste Act, starting from 2024[11], only waste that undergoes treatment can be landfilled. This measure aligns with the EU Directive[12], which mandates countries to decrease the proportion of biodegradable waste sent to landfills. Mechanical biological treatment (MBT) is primarily considered suitable for such treatment. In Slovakia, MBT facilities will need to meet oxygen consumption (AT_4) and methane production (GS_{21}) parameters.

It is anticipated that 45% of the waste will be utilized as low-calorific RDF in cement plants for energy recovery. This is driven by lower costs associated with selling such fuels to cement plants compared to landfilling. Additionally, after 2027, it will no longer be allowed to dispose of the calorific portion of treated waste in landfills. According to facility operators, the remaining stabilized waste will be deposited in landfills.

The obligation to treat waste before landfilling has been repeatedly postponed. The ban on landfilling untreated waste has been deferred multiple times, in both 2021 and 2023, due to insufficient capacity and inadequate readiness of facility operators.

2.3 Non-quantified Measures

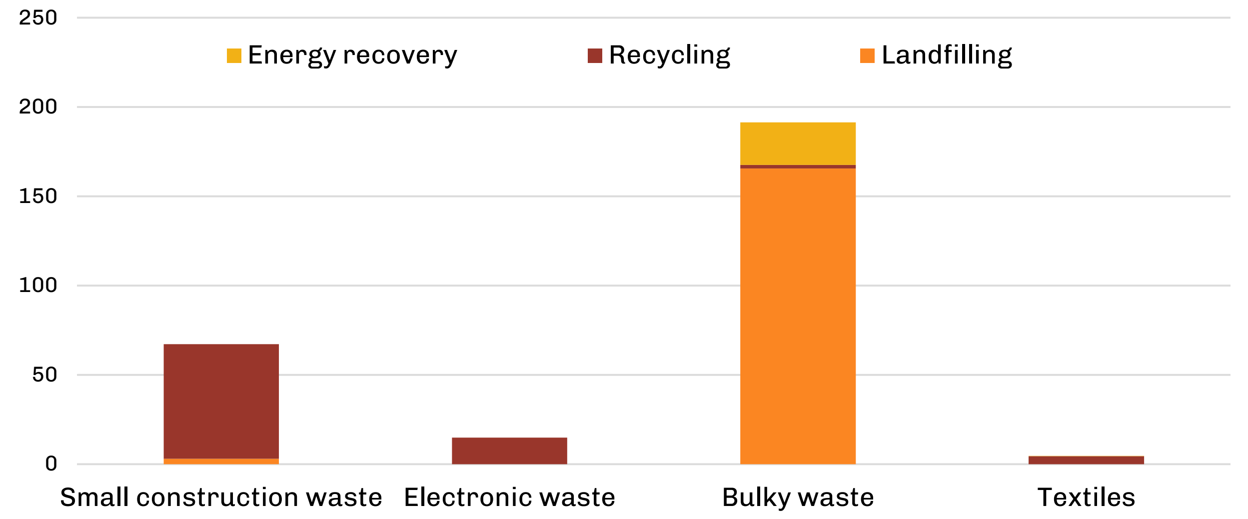
For several measures that could significantly impact the generation of municipal waste and the rate of sorting, there is currently no comprehensive literature with measured impacts. Examples include changes in taxes favouring secondary materials, mandatory green public procurement, expansion of extended producer responsibility systems to include additional waste types, differentiation of fees based on their environmental impact, and support for more environmentally friendly product design. Improving waste collection and management requires increasing public awareness through education, providing information, comfortable infrastructure, and additional incentives such as feedback, eliminating anonymity, and monitoring compliance with obligations. Measures focused on waste prevention and reuse also play an indispensable role.

[10] Directive 2003/87/EC
[11] The obligation applies from 2021, but until 2023 there is an exemption for municipalities that ensure the implementation of separate collection. This includes practically all municipalities in Slovakia.
[12] Directive 2018/850

Waste Prevention and Reuse

Waste prevention and reuse have significant potential to improve waste management. Bulky waste, such as old furniture, carpets, and flooring, accounts for up to 9% of municipal waste production in Slovakia, with 90% of it ending up in landfills. This waste is considered a priority for reuse (MoE SR, 2018). According to a British study, up to 32% of bulky waste can be reused without any modifications (WRAP, 2012). After minor repairs, up to 51% of bulky waste can be reused. Other waste suitable for reuse includes small construction waste, waste from electrical and electronic equipment, textiles, and clothing.

Graph 24: Selected types of municipal waste suitable for reuse (thousand tonnes)



Source: IEP

Residents can bring functional and well-preserved items to reuse centre for further utilization. In Bratislava, such a centre was established in 2022, and within less than half a year, it was visited by 50,000 people, resulting in the saving of 100 tonnes of potential waste (Odpady portal, 2023). One of the most effective systems for reuse operates in the Flemish region of Belgium (OVAM, 2015), where 31 reuse centres annually collect an average of 10 kg of products per capita, with 50% being reused and 50% recycled. Second-hand products can be purchased in up to 127 shops, with approximately 22% of sales in these stores coming from furniture, amounting to 19,000 tonnes (European Environmental Agency, 2018).

Internet marketplaces also have significant potential for further utilization of products. On the two largest Slovak internet marketplaces in 2021, there were over 600,000 products categorized as municipal waste items, totalling nearly 4,200 tonnes (more details in the technical appendix). This includes predominantly electrical appliances and furniture. For instance, in Germany, through the largest portal for the sale of used items, eBay, approximately 120,000 tonnes of electrical appliances, 18,000 tonnes of furniture, and 15,000 tonnes of clothing are reused annually (European Environmental Agency, 2018).

Currently, Slovakia reports zero values for waste reuse. According to a decision by the European Commission[13] on the methodology for reporting reuse, data on reuse will be

[13] Decision No. C (2020) 8976 establishing a common methodology and format for reporting on re-use in accordance with Directive 2008/98/EC of the European Parliament and of the Council.

reported for the first time from mid-2023 retroactively for 2021. Reporting on reuse data will include information from stores, online platforms, donations, and other channels. According to available information from the Slovak Environmental Agency (SEA), zero values were reported for 2021 across all four product categories[14] due to the lack of methodology for data collection at the national level.

Taxes

Market instruments such as taxes or subsidies are commonly used to stimulate the transition to a circular economy (OECD, 2020). To enhance the market for recycled plastics, OECD recommends increasing taxes on primary materials or reducing taxes on recycled plastics. In 2017, Sweden reduced VAT on the repair of bicycles, clothing, shoes, and electrical appliances from 25% to 12% to support reuse (European Environmental Agency, 2019). In the UK, a tax on plastic packaging containing less than 30% recycled plastics was introduced in 2021 (UK Government, 2021). The EU has also set minimum recycled material content requirements for PET beverage containers at 25% by 2025 and 30% by 2030.

Additionally, the European Union introduced a so-called plastic levy on non-recycled plastic packaging for all member states starting in 2021. Consequently, several countries are implementing additional taxes on plastics. Spain implemented a consumption tax on single-use plastic packaging starting in 2023, set at 0.45 euros per kg (Ferriz, 2023). Italy plans to introduce a tax on primary plastics used in the production or import of single-use plastic items in January 2024, with a rate similar to Spain's (Krahl, 2022). From mid-2023, the Netherlands introduced a charge for customers picking up or receiving food and beverages in disposable plastic containers, ranging from 5 to 50 cents per item. Moreover, businesses must offer reusable containers or allow customers to fill their own containers or cups (Scheuchzer, 2023). **Currently, in Slovakia, this levy is covered by the state budget,** and there is no mechanism through which producers responsible for introducing plastic packaging contribute to financing this levy. **Slovakia thus allocates just under 30 million euros annually in this manner.**

Littering

The European Commission is implementing measures to involve producers in the costs of removing litter. Member states, including Slovakia, are required to implement extended producer responsibility for tobacco products with filters by January 5, 2023, and for single-use plastics by December 31, 2024. Manufacturers will be responsible for reimbursing municipalities for the costs associated with the collection, transportation, and processing of this waste.

Slovakia has yet to decide how to implement this directive. A suitable solution would be to integrate this obligation into the existing extended producer responsibility system for packaging, primarily to save on administrative and transaction costs. In the first phase, manufacturers would pay fees to the producer responsibility organizations (PROs) at rates specified in the waste legislation, based on international practices (more details in the technical annex). These funds would then be distributed to municipalities based on population.

[14] These product categories are textiles, electrical and electronic equipment, furniture and building materials and products under Commission Decision 2021/19.

Subsequently, a litter analysis would be conducted to assess the actual volume and costs of litter. In the second phase, fees would be adjusted according to the results of this study.

Ecomodulation and Ecodesign

The fee rates for producers under the EPR scheme should be differentiated based on environmental criteria, such as recycled content, biodegradability, the availability and complexity of processing capacities, or recyclability information directly on the packaging (Watkins, et al., 2017). This differentiation of fees is known as ecomodulation. Initial results from the French system indicate a reduction in the proportion of products incurring penalties.

Belgium and France have the most advanced ecomodulation systems in the EU. In France, a system of bonuses and penalties is used, where producers earn points based on various criteria. Bonuses are awarded for actions like providing proper sorting information on packaging or through campaigns, reducing packaging production, and enhancing the recyclability of packaging. Penalties are primarily assigned based on packaging properties that limit recyclability[15]. In Belgium, packaging fees range from 49 euros per tonne for glass packaging to over 1,000 euros per tonne for certain types of plastics (Institute for Environmental Policy, 2020).

Fee modulation also encourages greener product design, which can improve the quality of secondary materials (OECD, 2020). The design of a product determines up to 80% of its environmental impact (European Commission, 2020). In 2023, Slovakia will begin collecting data through PROs on the material composition of packaging and non-packaging products, including the share of recycled content, to better implement ecomodulation in the country[16].

Green Public Procurement

Green public procurement refers to the purchase of goods, services, and construction works that meet the EU's resource efficiency standards. In EU countries where public procurement accounts for 16% of GDP, green public procurement holds significant potential for driving the market towards more environmentally friendly products (Institute for Environmental Policy, 2018). Currently, green public procurement is voluntary, but the European Commission plans to propose minimum mandatory criteria and targets, as well as mandatory monitoring of green public procurement's implementation.

Slovakia has not yet met the non-binding goal of achieving 50% green contracts in selected product groups. The National Action Plan for Green Public Procurement for 2016–2020 set an aspirational target to reach 50% green contracts within selected product groups of the total public procurement volume. The Environmental Strategy 2030 sets an even higher target of up to 70% of the total value and quantity of contracts in public procurement. However, according to monitoring results, in 2021, green contracts in Slovakia accounted for only about 18% of the value of procured goods and services (Enviroportal, 2021).

[15] Slovakia does not yet have eco-modulation implemented, but mandatory rates for determining the costs of ensuring separate collection and waste recovery of packaging waste and non-packaging products are specified in Regulation No. 373/2015 Coll.
[16] Annex 10c to Decree No. 371/2015 Coll.

Systemic changes in education, transparency, and monitoring will contribute to the increased use of green public procurement (Institute for Environmental Policy, 2018). In countries such as Hungary, Austria, Belgium, and Portugal, there is a focus on educating procurement process participants, motivating them to apply green criteria, and raising awareness about the possibilities of green purchasing. In the Netherlands, emphasis is placed on simplifying the system to make it accessible to the widest possible audience.

Education

Investments in education regarding recycling are an effective measure to increase recycling rates (Sidique , et al., 2009). Schools, as social environments with daily attendance, alongside families, significantly contribute to shaping students' habits and attitudes (Whitebread & Bingham, 2013). Even small and frequent interventions can be highly effective in cultivating habits among students (Loewenstein, et al., 2016). Education must occur at all levels. In addition to school education, informational campaigns are crucial when introducing various measures, leading to higher sorting rates, increased volumes of sorted waste, and higher purity of sorted collections.

Currently, in Slovakia, only PROs are required to conduct promotional and educational activities focused on sorting, waste management, and waste prevention under the Extended Producer Responsibility framework. According to activity reports from the two largest PROs for packaging, expenditures on these activities in 2021 accounted for only 1.3% of all costs. Some countries have implemented mandatory minimum expenditure requirements for PROs on awareness campaigns. In Slovakia, it is recommended to adopt a strategy for environmental education within formal education, which currently does not exist (Bodáczová, et al., 2021).

Distance to Infrastructure and Collection Frequency

The distance to sorted waste collection infrastructure is a key factor in achieving higher sorting rates (Mattsson, et al., 2003). A Dutch study indicated that placing biowaste collection containers closer to apartment buildings increases the likelihood of sorting (VANG, 2020). The distance to mixed municipal waste containers is also important. Door-to-door collection of sorted waste similarly has a significant impact. Besides distance, the frequency of sorted waste collection and adequate capacity are crucial (Roberts & Devine, 2020).

In Slovakia, there is currently an obligation to collect sorted waste at a distance equal to or less than the location of mixed waste collection. Since 2021, there is an obligation to implement sorted collection of biowaste in single-family homes at a distance of 0 meters from the residence, i.e., a door-to-door collection system. For apartment buildings, an appropriate distance is considered to be the same as the location for mixed waste collection.[17] From 2023, the same requirement applies to the sorted collection of other components (paper, plastics, and glass).

[17] Waste Act No. 79/2015 Coll.

Other Behavioural Measures

People's attitudes and responses to environmental measures often differ from expected behaviour (OECD, 2012). An effective tool is explaining the importance of sorting and providing information on how to sort correctly and how sorted waste is used. A British study showed that measures including sorting instructions, emotive labelling near bins, feedback, and smaller bins in suitable locations increased recycling rates by 33 to 40% (Roberts & Devine, 2020). A Dutch study found that providing information had the most significant impact on increasing sorting among people who were already sorting beforehand (VANG, 2020).

Waste tracking eliminates anonymity and provides an overview of waste production, creating a psychological effect on residents. For example, in the Slovak village of Košeca, waste production was reduced solely by implementing automatic waste tracking and high-quality awareness campaigns, without pay-as-you-throw collection (JRK, 2019). Setting group goals and commitments helped reduce littering around waste bins in the Netherlands (IPR Normag, 2010). The Dutch study also found that motivation to sort biowaste was higher due to group goals, feedback, and information on how their community sorts waste. Low social cohesion and oversight in apartment buildings lead to lower sorting rates compared to family homes (VANG, 2020).

3 Waste Management Model

The waste management model focuses on evaluating the impacts of selected measures on municipal waste. In preparing the model, we based our assumptions on the current state of waste production and management, as well as the processing capacities available. The model includes a forecast of municipal waste production, considering the economic and population developments in Slovakia up to 2055. This forecast incorporates historical data from 2010 to 2022, with the results for 2023 derived from projections.

Based on the estimated impacts of the measures, we created scenarios for the future development of municipal waste production and management, considering both planned measures according to current legislation and additional measures to achieve waste management goals. Each scenario also estimates the rates of sorting, recycling, and landfilling of municipal waste and the distance from meeting the targets. All assumptions, input data, and calculations are detailed in the technical annex.

The model represents a combination of various methods and is based on the so-called European Reference Model (Eunomia, 2014). We estimated the waste production forecast using a regression model dependent on demographic and economic characteristics. The impacts of individual measures were estimated using regression models; in cases of insufficient data, we relied on the experiences of implementing the respective measure in Slovakia or abroad. Similarly to the Eunomia reference model (2014), we subsequently determined the overall costs and benefits of waste management based on data from facility operators or international experiences.

In waste management, we identified selected measures whose impacts can be quantified under Slovak conditions or which have shown significant impact based on successful examples from abroad. Measures aimed at increasing sorted waste collection include pay-as-you-throw waste collection, door-to-door sorted collection, kitchen biowaste sorting, textile sorting, and deposit refund systems. Landfill fees, energy recovery, and pre-landfill waste treatment directly influence waste management.

Table 7 presents the **impacts of individual measures on changes in mixed municipal waste production and landfilling.** The estimated impacts of individual measures represent average values, though specific cases may vary depending on several factors. The effect of pay-as-you-throw collection depends on its form, the availability of sorted collection infrastructure, and can also be influenced by the fees for municipal waste. The sorting of kitchen biowaste may depend on the availability and convenience of infrastructure or the provision of information. Implementing multiple measures simultaneously can lead to an increase in the impact of individual measures.

Table 7: Overview of the impacts of selected measures

Measure title	Impact Description
Pay-as-you-throw	Reduction of mixed municipal waste by 22%
Tag based collection	Reduction of mixed municipal waste by 31%
Volume-frequency collection	Reduction of mixed municipal waste by 11%
Door-to-door sorted collection in single-family homes	Reduction of mixed municipal waste by 15%
Sorted textile collection	Reduction of mixed municipal waste by 2%
Sorted collection of kitchen biowaste	
Apartment buildings – with wastebaskets	Reduction of mixed municipal waste by 7%
Apartment buildings – without wastebaskets	Reduction of mixed municipal waste by 5%
Family houses	Reduction of mixed municipal waste by 6%
Landfilling fee	Reduction of landfilling of mixed municipal waste by 0,11% with a 1% increase in landfill fees
Deposit refund system	Return rate of beverage containers 90%
Mandatory waste treatment before landfilling	Reduction of landfilling of municipal waste by 45%

Source: IEP

The model also provides an estimate of the financial costs and benefits of various scenarios. In waste management modelling, we identified the costs associated with handling municipal waste, including expenses for collection infrastructure, transportation, re-sorting, waste processing, and final disposal or recovery. These costs are compared with a baseline scenario without additional measures, using data from the year 2023.

In addition to financial costs, waste management incurs external environmental costs that are not market-valued. Our analysis evaluates these external costs in terms of greenhouse gas emissions and pollutants produced during waste management, as well as the benefits from energy and material recovery.

The model's assumptions are based on the initial state of the system. These assumptions include the distribution of waste production between family houses and apartment buildings, the setup of collection infrastructure for different types of waste, and waste handling practices. The calculation of each assumption is detailed in the technical appendix. All financial costs are expressed in 2023 prices. When comparing scenarios, we present the state in 2025, including costs, recycling and landfill rates, and additional processing capacity requirements. Financial costs are compared across scenarios, while external costs are presented separately in the technical appendix.

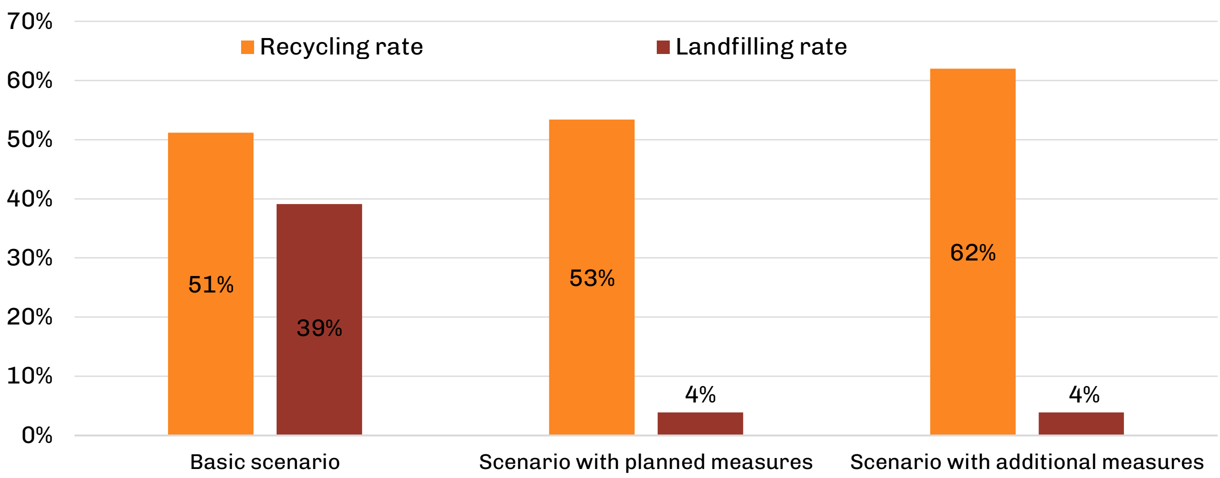
The model serves as a tool for preparing strategic documents in the field of waste management. Its aim is to provide estimates of the future development of municipal waste management following the implementation of various measures, including cost estimates and potential state revenues from landfill fees. Furthermore, the model identifies future processing capacity needs and potential challenges in achieving key recycling, recovery, and disposal targets. The results can be used in the preparation of the Waste Management Program, the Waste Prevention Program, or to inform changes in other legislative documents.

4 Waste in the Future

The development of municipal waste production and management was evaluated within scenarios that consider the adoption of various measures. The scenario with planned measures is based on current legislation, while the scenario with additional measures proposes further actions to increase recycling rates. These scenarios were then compared in terms of cost changes and proximity to recycling and landfill reduction targets for municipal waste.

Planned measures will not be sufficient to meet the municipal waste recycling targets, but the scenario with additional measures will approach the 65% recycling rate target by 2035. The landfill reduction target is expected to be met. Under current legislation, mandatory waste treatment before landfilling and the separate collection of textiles are planned. The municipal waste recycling rate will rise to 53%, and the landfill rate will fall below 10%, meeting the 2035 target. In the additional measures scenario, we proposed implementing more convenient collection of kitchen biowaste and introducing a nationwide pay-as-you-throw system, which would increase the recycling rate to 61%. Future measures will require the establishment of capacities for processing non-recyclable municipal waste.

Graph 25: Comparison of municipal waste management in different scenarios in 2030



Source: IEP

Based on the scenario results, we have identified short-term and long-term challenges and solutions. In the short term, it is crucial to address the current insufficient waste processing capacities and the future plans for building additional capacities that exceed Slovakia's needs. To achieve stability and predictability, a clear strategy for the development of waste management in Slovakia should be established. Improving waste management will require significant enhancements in the availability and quality of data.

4.1 Waste Management Development Scenarios

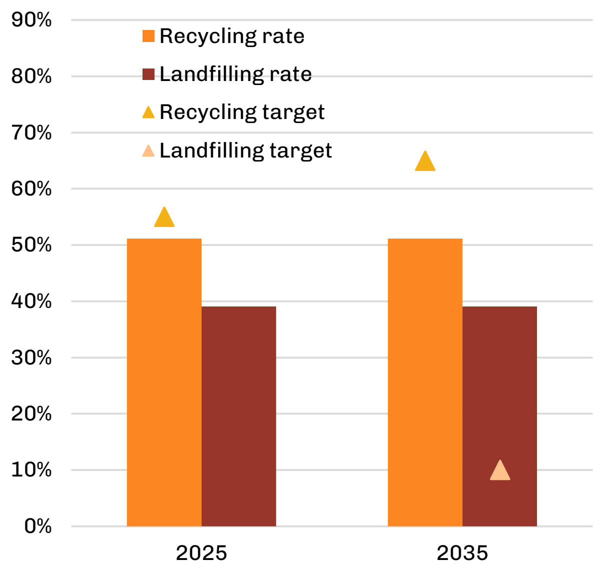
Baseline Scenario without Additional Measures

This scenario serves as a benchmark against scenarios that include additional measures. In the baseline scenario without additional measures, we assumed a growing production of municipal waste per capita based on the forecast detailed in the technical appendix. This scenario reflects the state in 2022, encompassing measures adopted in recent years, including deposit refund system, separate collection of kitchen biowaste, and door-to-door sorted collection. We assumed that without further measures, waste management would remain unchanged.

In the baseline scenario, annual costs for municipal waste management in 2022 amounted to approximately 358 million euros. Of this, costs borne by citizens through local fees were estimated at 245 million euros. For comparison, actual operational costs incurred by municipalities for waste management in 2021 totalled 223 million euros (Statistical Office of the Slovak Republic, 2023). The difference in costs may primarily stem from expenses related to the separate collection of kitchen biowaste, which was fully implemented only in 2022. However, modelled costs do not include operational expenses for civic amenity sites, intermediate bulk containers, and certain types of waste such as minor construction waste or hazardous waste.

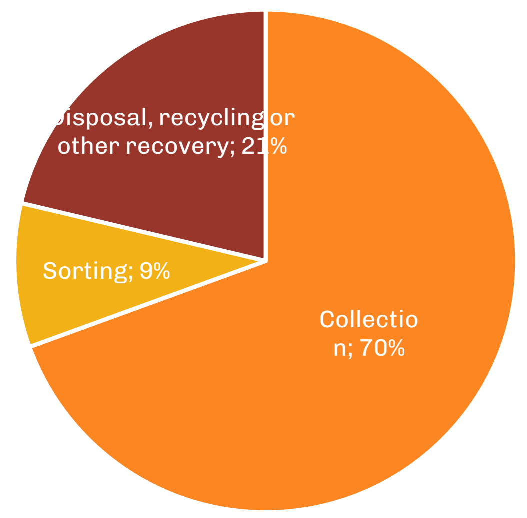
Costs associated with waste collection and transport constitute more than two-thirds of all expenses. Provision of collection infrastructure, including purchase of containers and their cleaning, deposit refund system, and waste transport, accounted for estimated costs of 261 million euros in 2022. Within waste management, landfilling represented the largest cost item at 70 million euros, with less than 20 million euros attributed to landfill disposal fees. Revenue from the sale of separated recyclable materials amounted to 22 million euros. Costs for waste re-sorting and processing represented 9% of total expenses, approximately 32 million euros annually.

Graph 26: Distance to targets



Source: IEP

Graph 27: Financial costs in 2022 (in mil. €)



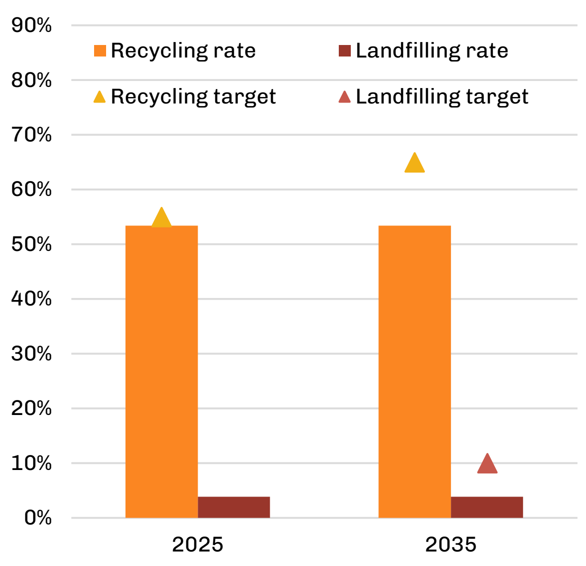
Source: IEP

Scenario with Planned Measures

Under the current legislation, waste management sector plans to implement mandatory waste treatment before landfilling and establish a sorted collection system for textiles. Compared to the baseline scenario, the scenario with planned measures also accounts for additional implementation of door-to-door sorted collection for all family houses and sorted collection of kitchen biowaste in all apartment buildings. Available data indicates that nearly one-third of households in apartment buildings did not have the infrastructure for sorted kitchen biowaste collection in 2022. For door-to-door sorted collection in family houses, we assumed a 90% implementation rate.

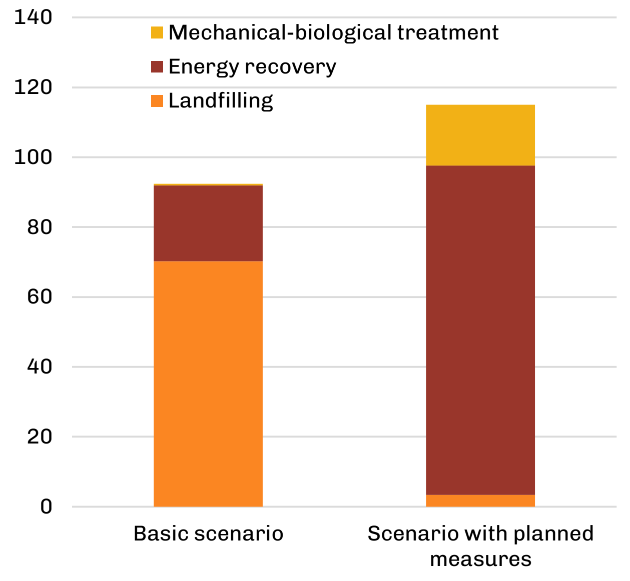
Implementing the planned measures will lead to an increase in annual municipal waste management costs by 16 million euros compared to the baseline scenario. This cost increase will mainly result from the introduction of mandatory waste treatment before landfilling. Conversely, landfilling costs are expected to decrease by up to 65 million euros annually. We assumed that only a portion of the waste would be treated to utilize the capacities of co-incineration facilities for low-calorific waste, with the remaining waste being directly used for energy recovery.

Graph 28: Distance to targets



Source: IEP

Graph 29: Comparison of cost items for waste management (mil. €)



Source: IEP

The adoption of the planned measures would lead to an increase in recycling rates to 53%, and the landfill rate would decrease to below 10%. The significant reduction in the landfill rate is primarily due to the mandatory treatment of waste before landfilling, which will result in the waste being utilized for energy recovery or co-incinerated in cement and heating plants. The landfill rate would subsequently range between 4% and 12%, depending on the utilization of co-incineration capacities through waste treatment and the capacities of energy recovery facilities. Thus, the recycling targets would not be achieved, but the landfill target would be met.

Implementing these measures will require additional capacities for processing non-recyclable waste or transporting it abroad, which is subject to strict conditions. The introduction of mandatory waste treatment before landfilling will necessitate processing capacities for non-recyclable waste amounting to 1.1 million tonnes annually. International transport of mixed municipal waste is rare due to numerous conditions that must be met. Conversely, combustible waste and waste from mechanical processing, which is used to produce RDF, are considered valuable materials and are not subject to the strict conditions applied to mixed municipal waste. However, processing waste abroad may result in higher costs due to greater transportation distances and higher prices for energy recovery in other countries.

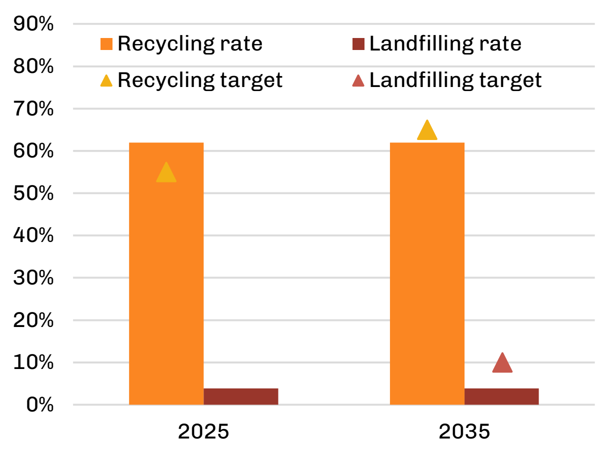
Scenario with Additional Measures

In this scenario, we proposed adopting additional measures, such as more convenient collection of kitchen biowaste and the introduction of comprehensive pay-as-you-throw waste collection. In apartment buildings, kitchen biowaste collection would be ensured not only through containers but also by providing baskets and biodegradable bags to each household. Furthermore, apartment buildings would adopt volume-frequency based pay-as-you-throw collection, with waste containers located in lockable and covered stands. In family houses, a pay-as-you-throw collection system with electronic tracking would be implemented, enabling the measurement of waste production and sorting rates at the individual household level.

These measures would bring Slovakia closer to the 65% recycling target. Implementing the additional measures would increase the recycling rate to 62%. The landfill rate would remain below the target level of 10%, similar to the scenario with planned measures, as the mandatory treatment of waste has the most significant impact on the landfill rate.

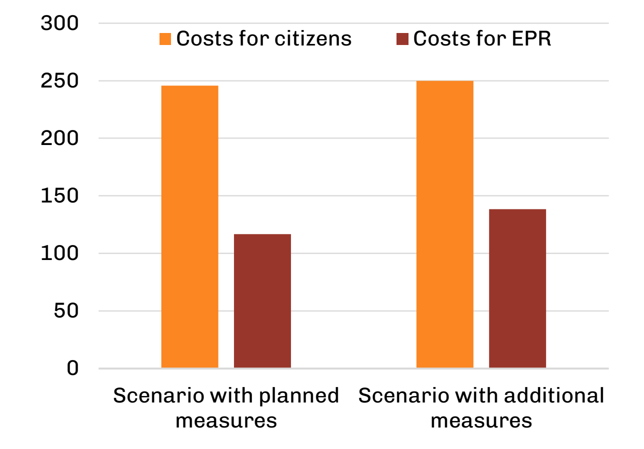
The annual net costs of this scenario would be 25 million euros higher than the baseline scenario, but the costs for citizens would increase by only 4 million euros. The increase in sorting would lead to higher costs for the collection of materials like paper, plastics, and glass, which are covered through the EPR system. The costs for electronic tracking of collection containers and the increased collection of kitchen biowaste would be borne by the citizens.

Graph 30: Distance to targets



Source: IEP

Graph 31: Cost breakdown (mil. €)



Source: IEP

Processing capacities for kitchen biowaste would be lacking at the regional level. The adoption of additional measures anticipates an increase in sorted biowaste, particularly kitchen waste. Existing capacities for processing kitchen biowaste should be sufficient overall; however, regional shortages may occur, especially in the Bratislava and Prešov regions. In Bratislava, a composting facility with a capacity of nearly 30,000 tonnes for processing kitchen biowaste is planned (Enviroportal, 2022).

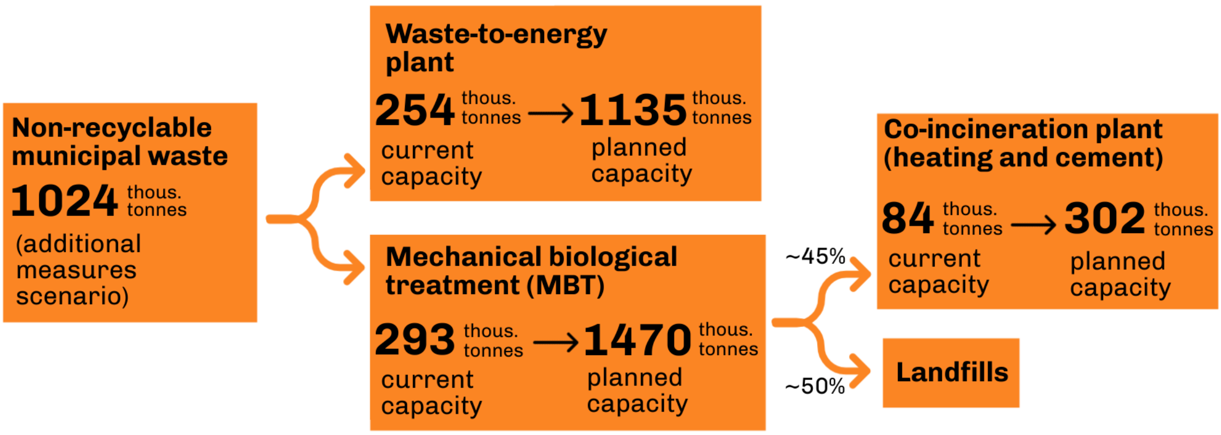
4.2 What to do next

Short-term Challenges and Solutions

The obligation to treat waste before landfilling from 2024 requires addressing the issue of insufficient capacities. The current capacity of mechanical biological treatment (MBT) facilities is less than 300,000 tonnes, which is insufficient to meet the obligation from next year. During 2024, a significant increase in MBT capacities is expected, but their construction might be hindered by lengthy approval processes. Additionally, capacities might be lacking at the regional level. The total planned capacities amount to nearly 1.5 million tonnes, significantly exceeding Slovakia's needs.

Planned initiatives for building waste-to-energy plants exceed Slovakia's needs. Current plans by private companies to construct 8 new facilities[18] and expand 2 existing ones for energy recovery will lead to a total increase in the capacities of these facilities by 881,000 tonnes annually. Additionally, plans by cement and heating plants represent additional capacity for co-incineration of waste in the form of low-calorific RDF from the current 84,000 tonnes to 302,000 tonnes.

Graph 32: Comparison of capacities and production of non-recyclable municipal waste in 2030



Source: IEP

[18] The CCE Šaľa project has received a positive final statement from the EIA process, against which several appeals have been filed. The file is currently referred to the minister of the environment's review committee. Other projects are currently at various stages of development.

Based on the production of non-recyclable waste in the scenario with additional measures, an estimated capacity of 342 thousand tonnes is needed. Assuming the utilization of the projected capacities of cement plants and heating plants for processing RDF, a capacity of nearly 600 thousand tonnes would be required for the production of RDF through mechanical biological treatment and 375 thousand tonnes of capacity for energy recovery.

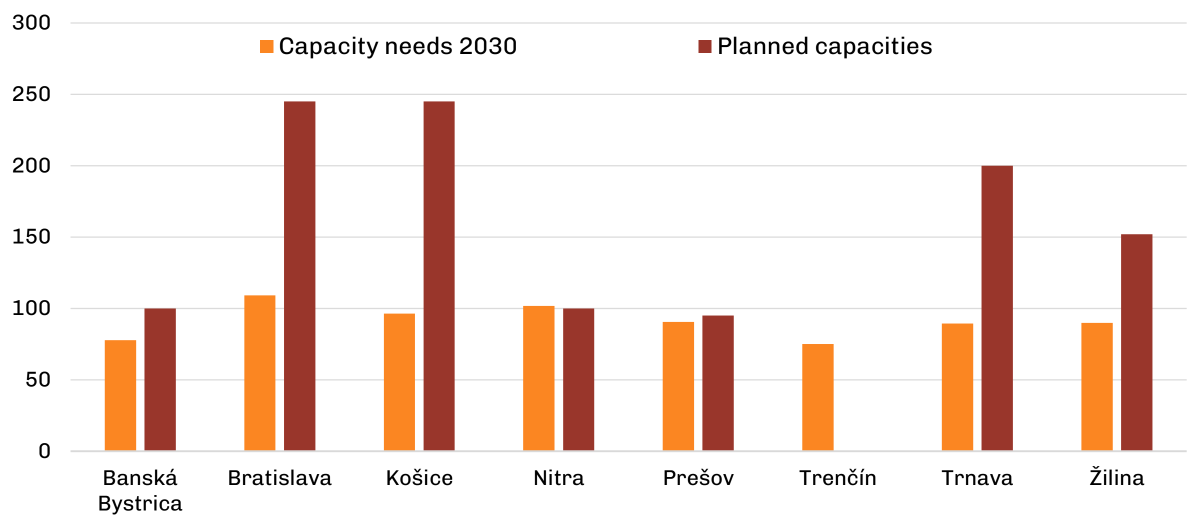
Table 8: Comparison of capacities for processing non-recyclable waste in 2030 (thousand tonnes)*

	Required capacities	Existing capacities	Planned capacities
Municipal waste			
Energy recovery	375	254	1,135
Co-incineration	302	84	302
Mechanical biological treatment	592	293	1,469

** assumption of planned co-incineration capacities being built* *Source: IEP*

Planned capacities in the Bratislava, Trnava, and Košice regions exceed the needs by more than double. Expansion of capacities in existing facilities for energy recovery, including capacities in cement plants for low-calorific fuel, will lead to significant increases, especially in the Bratislava, Trnava, and Košice regions. In other regions, except for Trenčín, planned capacities are approximately in line with projected future production of mixed municipal and bulky waste. Planned WtE plants in the Prešov region, however, are supposed to be located just 20 km from Košice, where an existing WtE plant is already located and plans to expand its capacities. Trenčín region is the only region without plans for facility construction, with some waste potentially processed in planned capacities in the Žilina region. Additionally, one company plans another 3 WtE plants without specified locations yet.

Graph 33: Comparison of planned energy recovery capacities and their needs (thousand tonnes)



** Additionally, one of the companies, plans another 3 WtE plants without specified locations yet* *Source: IEP*

Additional capacities for facilities for energy recovery may also be needed for industrial waste. Among the types of non-hazardous industrial waste suitable for energy recovery are mainly waste after sorting, plastic waste, and mixed packaging. Typically, municipal and industrial waste can be co-processed in WtE plants at a certain ratio to achieve the desired calorific value. At WtE plants KOSIT and OLO, industrial waste represents on average 10 to 25% of the recovered waste. While municipal waste can be recovered independently in WtE plants, there are no known examples of purely industrial waste recovered in conventional WtE plants due to its high calorific value. Insufficient data recording and missing information on final treatment of industrial waste complicate the evaluation of the potential of industrial waste for energy recovery.

Achieving recycling and landfill diversion targets requires the implementation of additional measures, such as comprehensive pay-as-you-throw collection. Additional measures would increase Slovakia's recycling rate to 62%, approaching the 65% target by 2035. The landfilling rate would drop below 10% with the adoption of planned measures, but it requires the construction of necessary capacities.

Long-term Vision

To achieve stability and predictability, it is necessary to create a clear strategy for the development of waste management in Slovakia. Currently, market stakeholders often assume that legally defined deadlines will be postponed, which frequently happens in practice. Moreover, the implementation of measures in strategic documents is not systematically monitored and evaluated. An example is the measures in the Waste Management Program for the years 2021 and 2025, which were supposed to be implemented during 2021, but the document itself was approved by the government only at the end of 2021. It is essential to establish a long-term strategy, with a key component being an Action Plan for the practical implementation of the strategy within a specific timeframe. The study results would provide an analytical basis for the part of the strategy focused on municipal waste, with further measures stemming from specific working groups.

Improving waste management will require a significant improvement in data availability and quality. Insufficient or missing data currently pose a major limitation for any estimates and calculations. It is necessary to establish a functional waste management system that centrally records all necessary data in electronic form. The implementation of measures should be accompanied by regular evaluation of results, for example through surveys and analyses that could be conducted by the Slovak Environmental Agency.

From a long-term perspective, it is crucial to focus on further increasing recycling beyond current targets. To increase sorting rates, measures addressing public behaviour and raising environmental awareness will be necessary. Low market prices for primary materials and natural resources are a barrier to higher recycling rates (OECD, 2018). Another issue is the complex composition of waste, which poses challenges for its processing (Trinomics, 2020). EU countries with the highest recycling rates, such as Germany, Belgium, and Slovenia, do not exceed 70%. Conversely, best practices from regions in Germany and Italy demonstrate the potential to achieve recycling rates of up to 85%. According to the Trinomics study (2020), the maximum potential for municipal waste recycling is similarly estimated at 80 to 90%.

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Appendix

Appendix A: Targets in Waste Management

Table A 1: Overview of targets in municipal waste management

	Current state			Targets			
	2020	2021	2022	2022	2025	2030	2035
Municipal Waste							
Landfilling rate	46%	41%	42%*	-	-	-	10%
Recycling rate	45%	49%	49%*	50%	55%	60%	65%
Biodegradable municipal waste							
Landfilling (thousand tonnes)	445		471	330	330	330	330
Packaging waste							
Recycling rate	71%	74%	69%	55-80%	65%	70%	70%
glass	74%	82%	79%	60%	70%	75%	75%
plastics	56%	60%	54%	45%	50%	55%	55%
paper	82%	84%	77%	60%	75%	85%	85%
metals	71%	76%	97%	55%	70/50%	80/60%	80/60%
wood	61%	57%	39%	25%	25%	30%	30%
Rate of Recovery	74%	80%	76%	60%	60%	60%	60%
glass	74%	82%	79%	60%	60%	60%	60%
plastics	69%	84%	88%	48%	48%	48%	48%
paper	82%	84%	77%	68%	68%	68%	68%
metals	71%	76%	97%	55%	55%	55%	55%
wood	63%	58%	39%	35%	35%	35%	35%
Packaging and Non-Packaging Waste							
Collecting from potential	48%	53%	61%	60%	70%	70%	70%
Single-use plastic beverage containers							
Return rate	-	-	73%	60%	90%	90%	90%
*Share of recyclate ** *	-	-	-	-	25%	30%	30%
Cans							
Return rate	-	-	68%	60%	90%	90%	90%
Construction waste							
Rate of Recovery	81%			70%	70%	70%	70%

** Estimate, final data are not yet available* — *Source: IEP*

*** From 2025 for PET bottles, from 2030 for all beverage bottles*

In the European Parliament, there is currently debate on a proposal[19] for a regulation that aims to amend or add targets to existing legislation. For instance, the proposal includes the requirement for deposit return systems in EU member states that are unable to achieve a 90% rate of separately collected waste, or do not have a feasible strategy to achieve this rate by 2029. Furthermore, measures are proposed to minimize packaging and achieve a permanent reduction in the consumption of lightweight plastic bags to 40 pieces per person per year by

[19] Proposal for a Regulation on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904 and repealing Directive 94/62/EC

2025. Targets are also defined for waste prevention from packaging, minimum recycled content in plastic packaging, and reuse and refill.

Table A 2: Overview of targets in the proposed EU packaging regulation

	2030	2035	2040
Packaging waste			
*Amount of waste generated **	-5%	-10%	-15%
Minimum recycled content share			
PET	30%	30%	50%
Contact-sensitive packaging except PET	10%	10%	
Single-use plastic beverage bottles	30%	30%	65%
Other packaging	35%	35%	65%
The share of reusable or refillable packaging			
Packaging for cold or hot beverages on draught	20%	20%	80%
Packaging for ready-to-eat meals	10%	10%	40%
Mixed beverages packaging	10%	10%	25%
Wine beverage packaging	5%	5%	15%
Packaging for non-alcoholic beverages	10%	10%	25%
Transport and packaging materials	30%	30%	90%
E-Commerce packaging for transport and delivery	10%	10%	50%
Transport packaging such as pallet wrap and straps	10%	10%	30%
Non-cardboard-based multilayer composite packaging	10%	10%	25%

Source: IEP