Institute for Environmental Policy

How to get out of the Wasteland

Waste Management Model of the Slovak Republic

Technical appendix

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The Institute for Environmental Policy is an analytical unit of the Ministry of Environment of the Slovak Republic. The IEP's mission is to provide high quality and reliable environmental analyses and forecasts to the Slovak government and the public.

Ministry of Environment of the Slovak Republic

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List of Abbreviations

RDF	Residual Derived Fuel
EPR	Extended producer responsibility
PRO	Producer Responsibility Organisation
WtE	Waste to energy
MBT	Mechanical biological treatment
URSO	Regulatory Office for Network Industries of the Slovak Republic
RISO	Regional Waste Information System
SEA	Slovak Environment Agency
SIE	Slovak Inspectorate of the Environment
SHI	Slovak Hydrometeorological Institute
PAYT	Pay-as-you-throw
D2D	Door-to-door

1 Waste production forecast

We estimate that municipal waste production will increase from 496 kg/capita in 2021 to 531 kg/capita by 2035, equivalent to 2.9 million tonnes of waste. In the long term, production could reach nearly 3 million tonnes by 2055. We estimated the forecast for municipal waste production using an econometric model based on the development of final household consumption and other socioeconomic and demographic variables that may affect municipal waste.

The production of industrial waste, without mineral waste, will increase due to GDP growth from the current 5.9 million tonnes to 9.7 million tonnes in 2035 and 14 million tonnes in 2055. We estimated the industrial waste forecast based on the share of services in total production and GDP projections. However, technological progress may lead to a decline in waste production in various industrial sectors in the long term. Since we do not know how this will develop in the future, we did not take it into account in the forecast. Mineral waste, whose production is very specific to different EU countries and is usually excluded for better comparability and waste production forecasts, was not included in the estimates.

Without additional measures in waste management, we assume that the handling of municipal and industrial waste will remain the same as in 2020 and 2019. The energy recovery of municipal waste will remain constant in absolute terms due to the limited existing capacity of facilities. We do not anticipate that the capacities of recycling facilities will be restrictive, as waste intended for recycling can be transported outside of Slovakia.

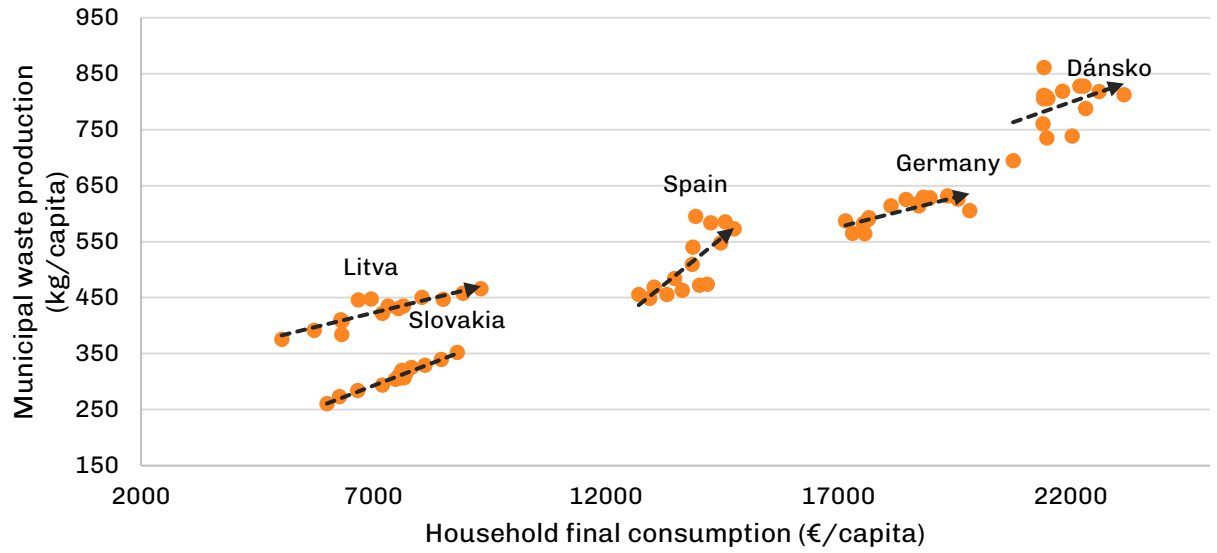
1.1 Municipal Waste

Production

We estimated the development of municipal waste production in Slovakia based on the development of final household consumption and other socioeconomic and demographic variables that may influence waste production. Data from European Union countries during the period 2004-2019 indicate a positive correlation between municipal waste production per capita[1] and final household consumption per capita. The relationship between economic level and waste production is also commonly used in academic literature (Gnonlonfin, et al., 2017); (Iafolla, et al., 2010); (Mazzanti & Zoboli, 2009).

[1] This is municipal waste except for minor construction waste and sewage waste

Graph 1: The dependence of municipal waste production on final household consumption



Source: IEP based on data from Eurostat

Several studies have examined this correlation using the environmental Kuznets curve, which suggests a nonlinear relationship between waste production and income. The Kuznets curve indicates that waste production has an inverted U-shape concerning income. One reason for expecting a nonlinear and gradually declining relationship between economic level and waste production is that, after reaching a certain stage, countries may focus on waste prevention and technological advancements. With higher economic levels and incomes, people's interest and awareness of environmental issues may also increase (Unruh & Moomaw, 1998); (Torras & Boyce, 1998).

Previous studies (Gnonlonfin, et al., 2017), (Mazzanti & Zoboli, 2009), (Khajuria, et al., 2012), (Ercolano, et al., 2018), (Madden, et al., 2019) are inconsistent in their results on whether municipal waste production takes this shape. The Kuznets curve hypothesis is only valid for developed countries (including Slovakia) with a very high turning point (Gnonlonfin, et al., 2017). (Mazzanti & Zoboli, 2009) and (Iafolla, et al., 2010) conducted studies on 25 and 15 EU countries, respectively, and did not confirm the Kuznets curve. The World Bank estimated a significant dependence of both GDP per capita and the squared value of this variable on data from countries worldwide (World Bank, 2018).

In estimating production, we used a model of waste production growth per capita depending on the growth of other variables using an equation

$$\Delta W_{it} = \alpha + \beta_1 \Delta FC_{it} + \beta_2 \Delta GVA_{it} + \beta_3 \Delta GVA^2{}_{it} + \beta_4 \Delta Tourism_{it} + \beta_5 \Delta Educ_{it} + \beta_6 \Delta R\&D_{it} + \beta_7 \Delta HSize_{it} + \beta_8 \Delta Elderly\_ratio_{it} + \varepsilon, \quad (1)$$

where

ΔW_{it} is the year-on-year change in the amount of municipal waste in kilograms per capita,

ΔFC_{it} is the year-on-year change in household final consumption in constant 2015 prices per capita,

ΔGVA_{it} is the year-on-year change in gross value added at constant 2015 prices per capita,

$\Delta Elderly\_ratio_{it}$ is the year-on-year change in the ratio of residents over 65 years old to residents aged 20 to 64,

$\Delta Tourism_{it}$ is the year-on-year change in the average length of stay calculated as the ratio of the number of overnight stays to the number of arrivals,

$\Delta R\&D_{it}$ is the year-on-year change in research expenditure as a percentage of GDP,

$\Delta HSize_{it}$ is the year-on-year change in the average household size by number of members.,

$\Delta Educ_{it}$ is the year-on-year change in the share of the population with tertiary education.

We used final household consumption as an economic indicator that directly influences waste production by residents. Gross value added was used as an indicator of the country's economic maturity, and with this variable and its square, we tested the hypothesis of the Kuznets curve. In addition to economic indicators, we used other demographic and socioeconomic variables that may affect waste production.

It is expected that residents with higher levels of education are more likely to develop altruistic values and environmental awareness (Bruvoll & Nyborg, 2004); (Schultz, et al., 1995); (Callan & Thomas, 1997); (Hage & Söderholm, 2007). However, the impact on waste can be ambiguous (Monavari, et al., 2011). On the one hand, the higher the education level, the more people are aware of environmental problems and the less likely they are to produce waste. On the other hand, waste is transported and placed away from the place of production. As a result, people are not physically subjected to pollution where they live (Gnonlonfin, et al., 2017). Research and innovation expenditures represent a proxy for technological innovations. Their impact on waste production can be negative (e.g., if innovation allows for reducing the weight of product packaging) or positive (e.g., if it leads to the production of new polluting consumer goods or reduces the lifespan of these products) (Gnonlonfin, et al., 2017). In the case of household size, it is expected that the larger the household, the less waste per capita (Mazzanti & Zoboli, 2009). A higher number of tourists may result in higher waste production per capita (Arbulú, et al., 2015). A higher proportion of elderly residents is expected to have a negative impact on waste production. Older people are expected to produce less waste due to lower consumption (Mazzanti & Zoboli, 2009).

Table 1: Estimation of coefficients for explanatory variables

	Coefficient estimate
ΔFC	0.39***
ΔGVA	2.69
ΔGVA²	-1.19
ΔEduc	-0.03
ΔTourism	0.06
ΔR&D	-0.09***
ΔElderly_ratio	0.17
ΔHSize	0.11

*p<0.001***,p<0.01**,p<0.05*,p<0.1 `* *Source: IEP*

From the results, it is evident that final household consumption has a significant positive effect on municipal waste production. However, the growth of gross value

added has no influence, indicating that we did not confirm the hypothesis of the Kuznets curve. The variable R&D is also significant with a negative sign, meaning that a 1% increase in this variable leads to a decrease in municipal waste production by 0.09%. The other variables are not statistically significant. Only significant variables were retained in the model.

Using the calculated coefficients, we subsequently estimated municipal waste production per capita. The forecast for final household consumption until 2023 is derived from official macroeconomic forecasts as of June 2023 (Institute of Financial Policy, 2023). The development in subsequent years is based on the macroeconomic model of the Institute of Financial Policy of the Ministry of Finance of the Slovak Republic. Since there is no forecast for the development of research expenditure as a share of GDP, we assumed that this share would gradually increase from the current 0.84% of GDP to the EU average of 1.65% of GDP by 2055.

The total production of municipal waste was estimated based on the forecast of population growth from Eurostat, to which we additionally added minor construction waste and the growth of metal waste, which were not part of the modelled production (viac v Box 1).

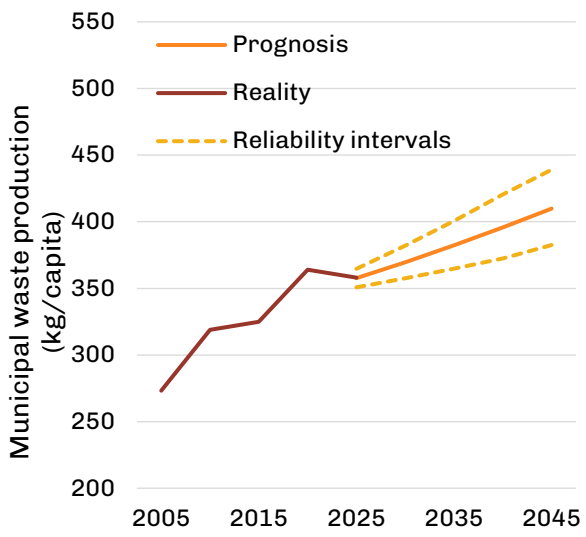
Box 1: Calculation of total municipal waste production

For modelling purposes, the share of metals was adjusted to the level observed during the period of 2010-2014 before a change in reporting, which led to a significant increase in metals since 2015. Metals accounted for an average of 0.65% of total municipal waste production until 2015, whereas in 2018-2019, it reached up to 15%. The significant increase in reporting metals is mainly due to efforts to achieve higher rates of sorting, resulting in lower landfill fees for municipal waste.

To calculate the total production, we then added municipal waste collected outside households based on changes in reporting methodology since 2020. According to data from 2020 and 2021, we estimate that the production of this waste represents approximately 8.5% of all municipal waste.

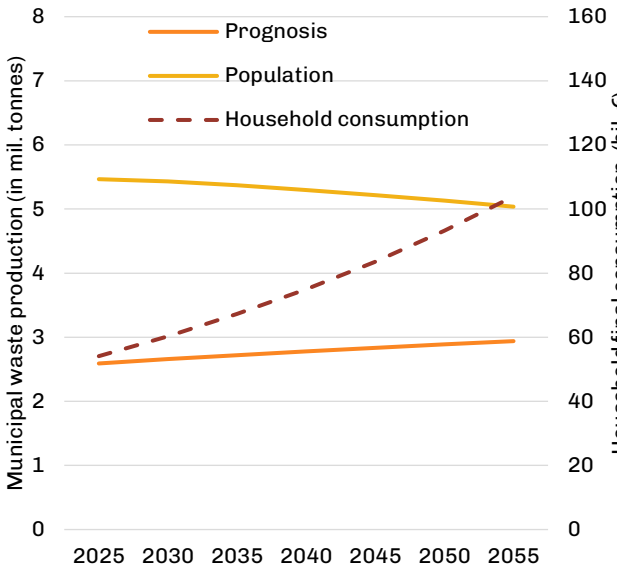
We estimate the total production of municipal waste to be 2.7 million tonnes in 2035 and just under 3 million tonnes in 2055. Per capita municipal waste production is projected to reach 507 kg annually by 2035. The production forecast was determined using an econometric model that incorporates economic and population trends in Slovakia. We also took into account preliminary data for the year 2022, which indicate a slight decrease in total household municipal waste production compared to the previous year. The main reason for this is that, unlike previous years, the amount of sorted garden biowaste did not increase. This waste includes waste from parks and public spaces, which can vary significantly from year to year.

Graph 2: Forecast of household municipal waste*



*excluding metal waste Source: IEP

Graph 3: Forecast of municipal waste production (in mil. tonnes)



Source: IEP

Table 2: Forecast of municipal waste production

	2022	2025	2030	2035	2055
Municipal waste					
Total (thousand tonnes)	2,560	2,591	2,660	2,721	2,939
Per capita (kg)	468	474	490	507	584
Municipal household waste excluding metal growth					
Total (thousand tonnes)	1,924*	1,955	2,008	2,053	2,218
Per capita (kg)	352*	358	370	382	440

*reality Source: IEP

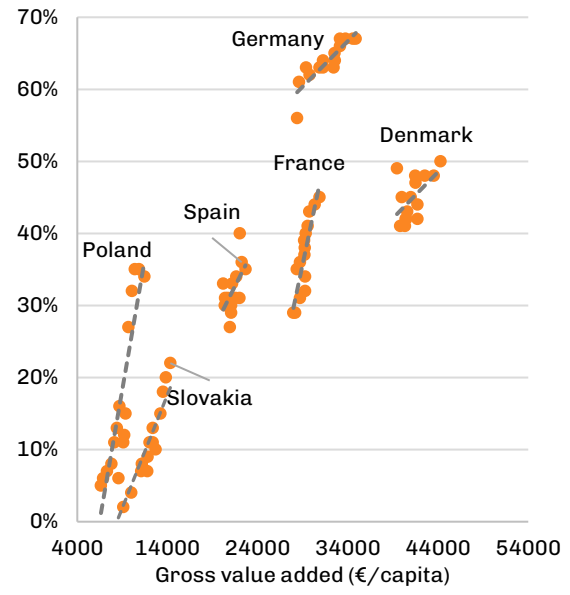
Management

When managing municipal waste, we assume that recycling will remain constant at 42% based on the year 2020 in the scenario without further measures. This assumption is derived from the model of the European Environment Agency (Eunomia, 2014), which projects that the level of various waste management methods will remain constant after the last reported year. Against this baseline scenario, subsequent dynamic projections of the future can be compared when implementing various measures. In the scenario without measures, we consider the energy recovery of municipal waste to remain constant at approximately 200,000 tonnes annually, limited by existing facility capacities. The remaining municipal waste will be landfilled.

It can be expected that the recycling rate in the country will increase even without the introduction of additional measures. This could be due to improvements in education levels, technological progress, or a natural increase in environmental awareness. We attempted to estimate the recycling rate or the amount of recycled waste based on gross value added and other socio-economic variables using data from EU member states for the period from 2004 to 2019.

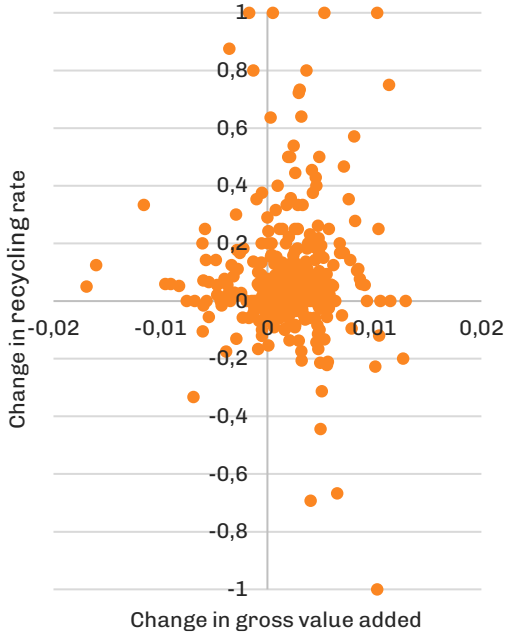
However, despite the apparent correlation between the recycling rate and gross value added per capita, estimated models suggest that changes in gross value added do not have a significant impact on recycling changes. This could be because states implement various measures to promote recycling, and the exclusion of these measures from the model could lead to imprecise and skewed estimates. Data on the implementation of recycling support measures in individual countries since 2004 are not available.

Graph 4: The dependence of the recycling rate on the level of the economy



Source: IEP

Graph 5: The relationship between changes in the level of the economy and recycling



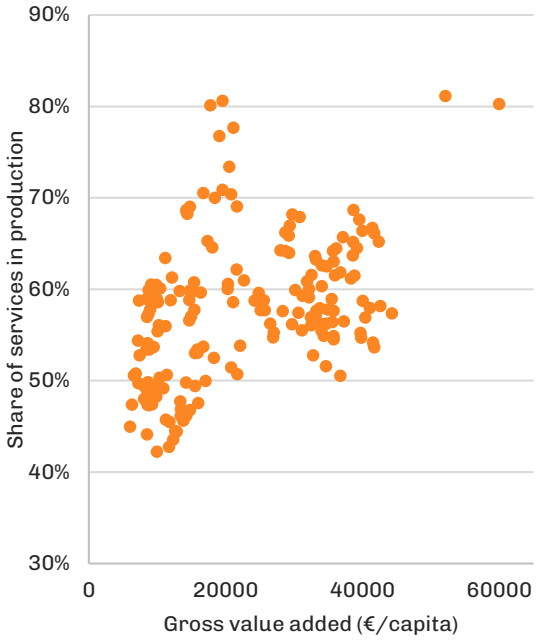
Source: IEP

1.2 Industrial Waste

Production

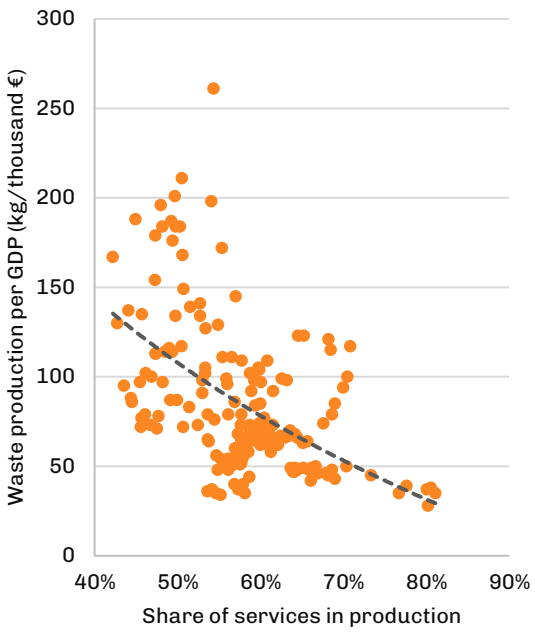
We estimate that the production of industrial waste as a percentage of GDP will gradually decrease. The total production of industrial waste excluding mineral waste will increase from the current 5.6 million tonnes to 7.3 million tonnes by 2035 and 10.7 million tonnes by 2055, due to GDP growth. In our forecast, we did not account for potential technological advancements due to the lack of data. However, technological progress could lead to a reduction in waste production across various industrial sectors in the long term. Therefore, the forecast should be considered an upper estimate, particularly in the long term. The production of industrial waste depends on the size and composition of the economy's production in a given country. It is expected that industrial waste production will grow at a slower pace than GDP, as economies tend to transition from manufacturing to services after reaching a certain stage, resulting in less waste production (Tsurumi & Managi, 2010). Data from EU countries for the period from 2004 to 2018 indicate a positive relationship between the share of services in total production and gross value added per capita. As the share of services in total production increases, there is a nonlinear decrease in waste production as a percentage of GDP. Another reason for the nonlinear relationship between GDP and waste production is technological (Hettige, et al., 2000).

Graph 6: Relationship between the level of economy and the share of services



Source: IEP

Graph 7: Dependency of the share of services and waste production



Source: IEP

In estimating the development of industrial waste production per GDP depending on the share of services in total production, we used available biennial data from Eurostat for the period 2004-2018 for EU member states. Industrial waste production per GDP is expressed in kilograms per thousand euros at constant 2015 prices. The generation of industrial waste per GDP does not include mineral waste. According to Eurostat, these wastes are excluded because they mainly originate from construction and mining activities, which vary significantly across EU countries. Industrial waste excluding mineral waste better reflects trends and improves comparability between countries. For calculating the share of services in total production, we used data on production at current 2015 prices in individual sectors. Constant prices, which account for price inflation and real growth, are not available for production, but the production ratio in one sector relative to others is not dependent on the prices used. We verified this relationship using a regression model expressed by the equation

$$\log(W_{it}) = \alpha + \beta_1 Services_{it} + \varepsilon, \qquad (2)$$

where

$\log(W_{it})$ is the logarithmic transformation of industrial waste production per GDP, and

$Services_{it}$ is the share of production in the service sector.

Table 3: Estimation of the coefficients of the explanatory variables

	Coefficient estimation
Intercept	6.14
Services	-3.64***

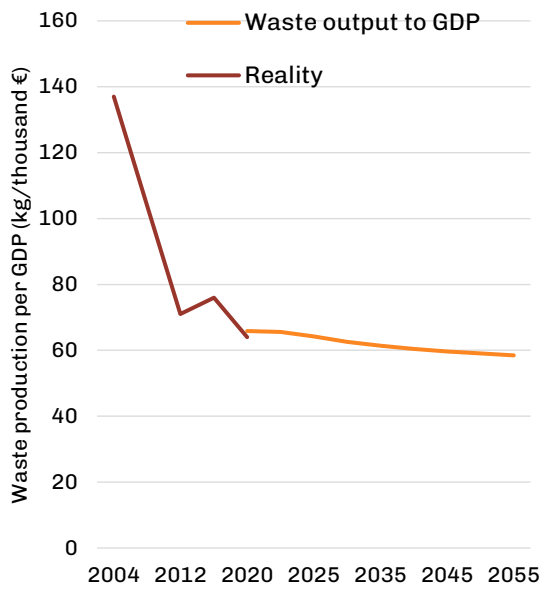
*p<0.001***,p<0.01**,p<0.05*,p<0.1 `*

Source: IEP

In the model specification, we also tested a model with fixed effects for years and fixed effects for countries. The resulting coefficients were nearly identical to those of the model without fixed effects, which we kept as the final model for simplicity. The results of the coefficients indicate that the share of services in production has the expected negative significant effect on waste production per GDP.

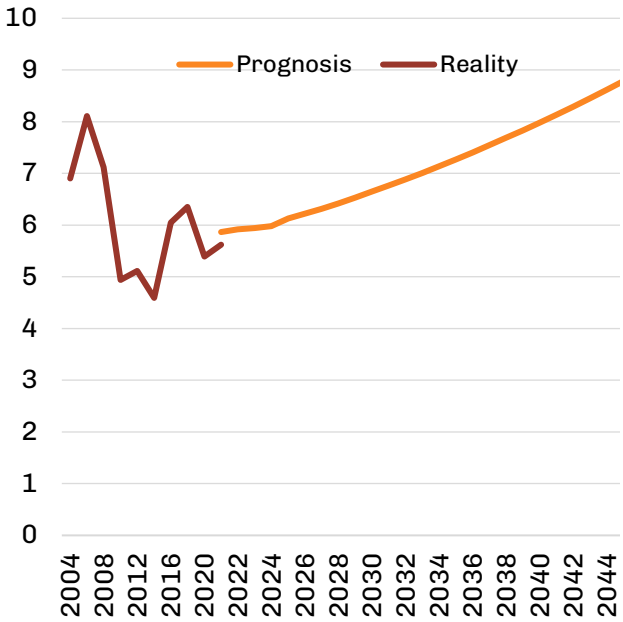
The share of the services sector in total production increased annually by an average of 0.8% in Slovakia and the EU during the period 2004-2018. For the future, we anticipate a similar growth in services in Slovakia, which would mean reaching a 61% share by 2055 compared to the current 46%. The current EU average is 58%. The GDP growth forecast is based on the macroeconomic model of the Institute of Financial Policy (Ministry of Finance of the SR, 2023).

Graph 7: Forecast of industrial waste production to GDP



Source: IEP

Graph 8: Forecast of industrial waste production (mil. tonnes)



**excluding mineral waste*

Source: IEP

2 Capacities

2.1 Landfills

In Slovakia in 2022, waste was deposited in 81 landfill sites, of which 62 were designated for non-hazardous waste, including the majority of municipal and industrial waste[2]. Another 8 landfills were for hazardous waste, and 11 for inert waste. Since 2015, the total number of landfills has decreased by almost a third.

The estimated available capacity for non-hazardous waste landfills at the end of 2022 was 12.9 million tonnes (viac v Box 2). Currently, new landfills cannot be opened, but capacities of existing waste landfills can be expanded. Such expansions occur annually, with permits issued by the Slovak Environmental Inspectorate or the relevant district office.

The capacities for inert waste landfills are currently sufficient, but increased demand may be expected in the future[3]. In the near term, due to the introduction of mechanical-biological treatment before landfilling of municipal waste, there may be increased demand for inert waste landfills. Inert waste, comprising about 25% of treated waste, consists of materials without any biological, physical, or chemical activity, including construction waste such as bricks, concrete, soil, and other materials from buildings and demolitions.

Currently, there is no centralized system for tracking all landfills. This information can be obtained either directly from landfill operators, Slovak Environmental Inspectorate, or district offices. Operators are also required annually to report data on available capacity to the Ministry of Environment, but these reports often lack completeness, exhibit high error rates, and are inconsistent over time. Therefore, precise capacities of landfills in Slovakia are not currently known.

Table 4: Capacities of active landfills

	Number	Estimated spare capacity at the end of 2022
		in mil. of tonnes
Landfill of non-hazardous waste	62	12.9
Landfill of hazardous waste	8	0.5
Inert waste landfill	11	9.5

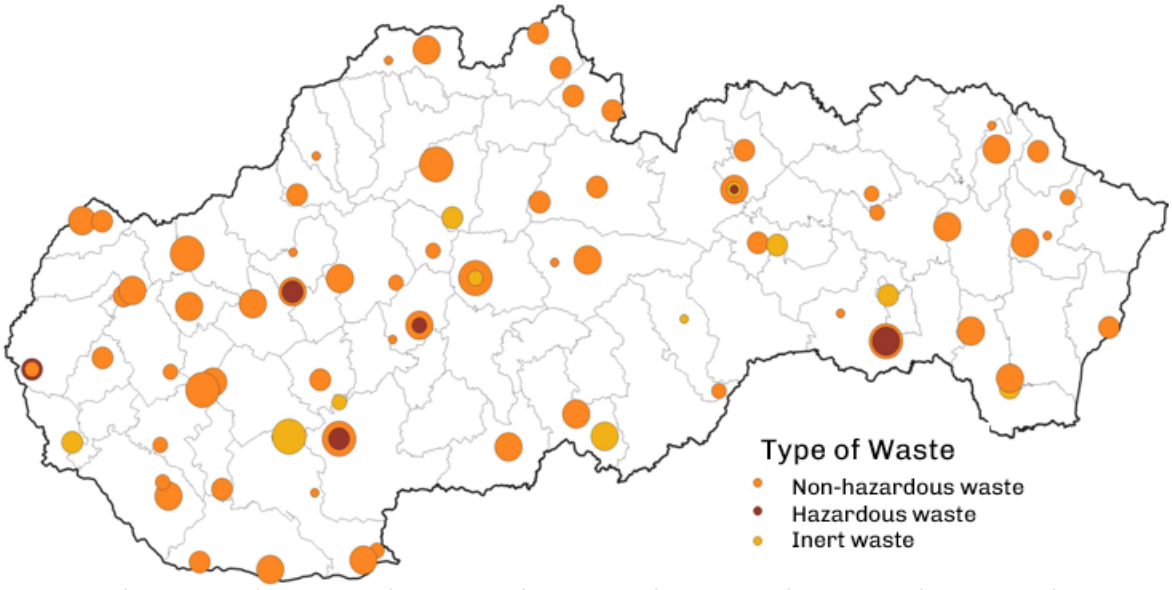
Source: IEP

Waste landfills in Slovakia are not evenly distributed. The highest capacities are found in non-hazardous waste landfills in the Banská Bystrica and Košice regions, each exceeding 2 million tonnes. Conversely, landfills in the Bratislava region have capacities of less than 125 thousand tonnes. In 2020, several municipalities in this region experienced regional

[2] Landfills have permits for specific waste catalogue numbers, and not all of them are permitted to landfill mixed municipal waste.
3 In the case of inert waste landfills, one landfill accounts for more than 90% of the capacity; it is a repository for power plant stabilizer.

shortages in landfill capacities for municipal waste. Increasing the rate of sorting and subsequent recycling is therefore crucial for maintaining functional waste management.

Graph 9: Map of landfills by type and estimated capacity at the end of 2022



Source: IEP

In the case of some older landfills, Slovakia faces lawsuits from the European Commission for their non-closure. Currently, 21 landfills in Slovakia are under proceedings from the European Commission at the stage of the first lawsuit. Waste is no longer deposited at any of these landfills, so their closure does not lead to a loss of landfill capacities. In most cases, restoration has already been completed or is ongoing. Intensive negotiations are underway with operators of the other landfills aimed at achieving their swift restoration.

Box 2: Estimating landfill capacity

Operators report the available capacity at the end of each year in cubic meters as part of their record sheets. However, the amount of waste deposited is reported in tonnes. To estimate future capacity adequacy, it is necessary to determine a conversion ratio. According to information from operators of 12 non-hazardous waste landfills, the ratio ranges from 0.8 to 1.6 tonnes/m^3 depending on the type of waste, compaction intensity, and level of sorting of biowaste and lightweight commodities.

In calculating estimated landfill capacities in tonnes, we relied on record sheets provided by landfill operators from 2015 to 2019. The available capacity at the end of 2019 was approximately 15.6 million m^3, of which 7 million m^3 were for non-hazardous waste landfills. Based on the amount of waste deposited and available capacity from the end of 2015 to 2019, we estimate that on average 1.08 tonnes of waste is deposited per m3 of non-hazardous waste landfill. Similar estimations were made for hazardous and inert waste landfills, estimating 0.75 tonne and 1.3 tonnes/m^3, respectively.

Thus, the available capacity for non-hazardous waste landfills at the end of 2019 was approximately 7.5 million tonnes. Using data on deposited waste quantities at individual

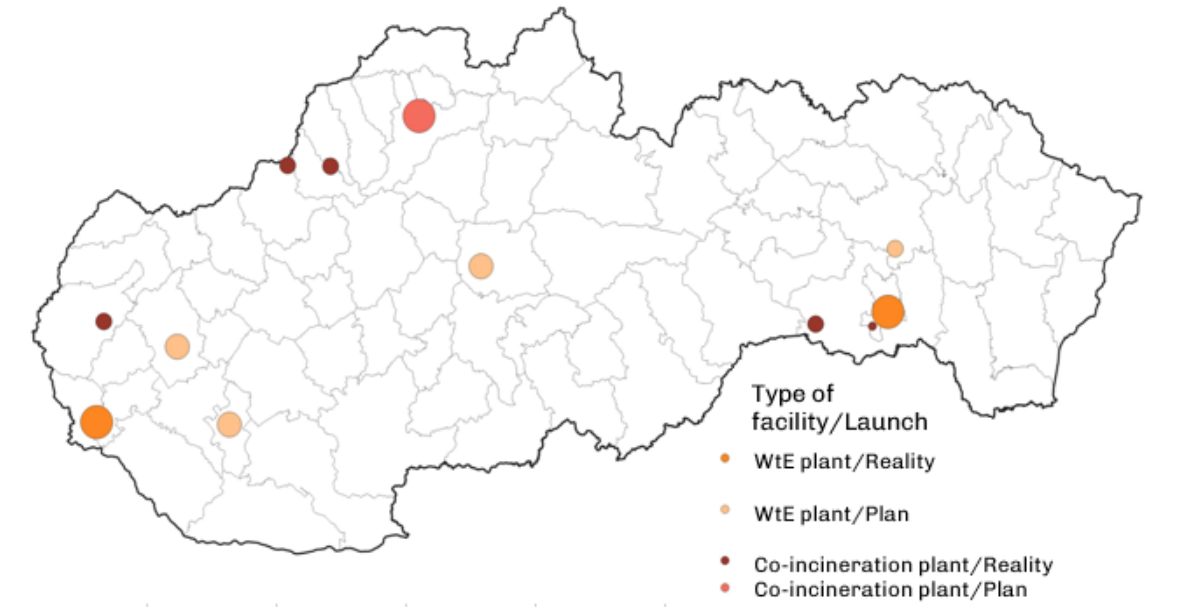
landfills and capacity expansions in 2020, we estimate that the available capacity at the end of 2020 reached 8.2 million tonnes.

Operator data is incomplete, with approximately 6% not reporting the amount of waste deposited or available capacity. Since specific landfill data is not currently linked to waste data, it is not possible to supplement this information retroactively. Additionally, there is no unified system to record whether a landfill was expanded in a given year, potentially increasing its capacity.

2.2 Energy Recovery and Incineration

Energy recovery of waste in Slovakia occurs in waste-to-energy (WtE) plants and facilities for co-incineration of waste. This includes four cement plants and one lime production facility. Additionally, Slovakia hosts several incinerators for hazardous waste from hospitals and industries. Currently, the capacity of WtE plants in Slovakia amounts to 254 thousand tonnes of waste per year. The WtE plant in Bratislava can process 134 thousand tonnes annually, while the remaining 120 thousand tonnes are processed in Košice. In Bratislava, approximately 90% of the processed waste comes from municipal sources, primarily municipal waste from the city. The remainder consists of industrial waste, particularly mixed packaging and residual waste from mechanical sorting lines. In Košice, industrial waste constitutes only 21%, with the rest being municipal waste from Košice, Prešov, and surrounding municipalities.

Graph 10: Map of WtE plants and co-incineration plants in Slovakia by capacity



** only the facility in Rohožník currently also co-incinerates fuel from low calorific municipal waste, in the future a facility in Turňa nad Bodvou should be added* *Source: IEP*

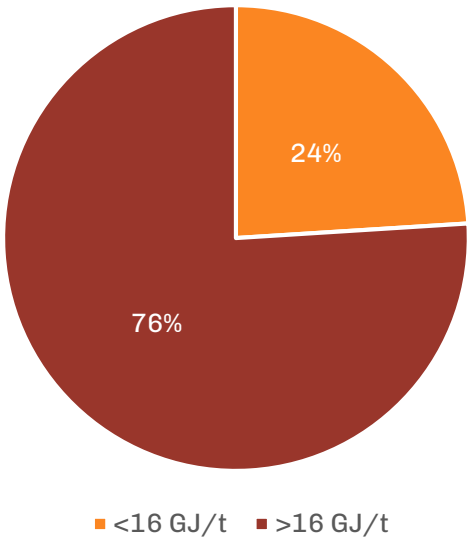
***Ewia is planning 3 more WtE plants, no specific location yet*

Future capacities of WtE plants could increase significantly. One of the intentions is to establish up to 5 circular economy centres, each with an annual energy recovery capacity

of 100 thousand tonnes[4]. Additionally, the city of Bratislava is working on a project to modernize and green WtE plant, including the construction of a third boiler by 2027, which will increase the actual capacity of WtE plant by 26 thousand tonnes of waste annually. A similar modernization of WtE plant, increasing its actual capacity by 60 thousand tonnes, is also underway in Košice, scheduled for completion in the second half of 2025. Furthermore, two additional facilities are in the Environmental Impact Assessment (EIA) process: one in Drieňov with a capacity of 95 thousand tonnes and another in Hontianske Tesáre with a capacity of 100 thousand tonnes of waste annually.

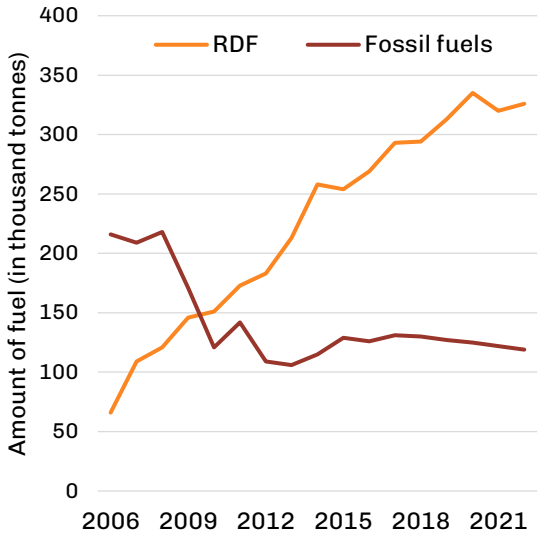
Energy recovery of waste in cement plants currently reaches 350 thousand tonnes, with potential capacity to increase to 500 thousand tonnes according to information from manufacturers. Cement plants use waste in the form of residual derived fuel (RDF) produced through mechanical or mechanical biological treatment (MBT) of waste. Currently, only one cement plant utilizes low calorific value RDF, including fuels derived from mixed municipal waste. CRH plans to use low calorific fuels in its cement plant in Turňa nad Bodvou, thereby increasing its utilization capacity to 150 thousand tonnes. More than 80% of the utilized RDFs are imported from abroad, primarily from Austria, Italy, Slovenia, and Belgium.

Graph 11: RDF consumption by calorific value in 2020



Source: IEP based on data from Association of Slovak Cement Producers

Graph 12: Use of RDF in cement plants



Source: IEP based on data from Association of Slovak Cement Producers

Current capacities for producing RDF are insufficient for fully utilizing the waste processing capacities of cement plants in Slovakia. After mechanical biological treatment of mixed municipal waste, only 45% of the waste by weight is converted into RDF. According to experiences of RDF manufacturers in Slovakia, processing more calorific waste, such as post-sorted waste from mixed packaging, plastics, and tires, can retain up to 88% of the waste by weight. The overall potential for producing RDF thus depends on the used type of waste.

[4] The CCE Šaľa project has been issued a favourable final opinion from the EIA process, against which several appeals have been filed. The file is currently referred to the Appeals Committee of the Minister of Environment. Other projects are currently at various stages of development.

Table 5: Capacities of WtE plants

	Number of facilities	Capacity (thousand tonnes)	
		Currently	Planned
WtE plant	2	254	1,035
Cement plant	4	350	500
of which use of low calorific value RDF		85	150
Heating plant			
of which use low calorific value RDF	1	-	109-152

Source: IEP

The capacities of mechanical waste treatment facilities reach 623 thousand tonnes. According to information from a study by the Association of the Waste Industry of the Slovak Republic, mechanical treatment is currently conducted in 14 facilities across Slovakia. The most commonly processed wastes are those after sorting, mixed packaging waste, and high-calorific plastic packaging, with a potential in Slovakia of approximately 280,000 tonnes per year. As the rate of municipal waste sorting increases, the amount of waste after sorting also gradually increases.

Current capacities of mechanical biological treatment (MBT) facilities are insufficient to meet obligations from the beginning of 2024, covering only one-third of the necessary capacity. According to data from the Circular Economy Section, verified through telephone and email communications with facility operators, the current MBT capacity amounts to 293 thousand tonnes of municipal waste annually. Currently, mixed municipal waste in Slovakia is not subjected to treatment. This is due to low landfilling costs for municipal waste, which favour this option over waste treatment followed by energy recovery in the form of RDF.

A significant increase in MBT capacities is expected during 2024, which would cover three-quarters of the needs for municipal waste management. The total planned capacities for the future exceed Slovakia's requirements. There are currently 21 MBT facilities in Slovakia that have completed the Environmental Impact Assessment (EIA) process but have not yet been built, with a combined capacity expected to reach an additional 850 thousand tonnes annually. Operators anticipate the launch of 11 of these facilities from January 2024, increasing the overall capacity to 538 thousand tonnes annually, with additional facilities expected to come online during the year, further increasing capacity to 658 thousand tonnes annually. Operators of other facilities have not specified their operational start dates.

The construction of facilities may be hindered by the lengthy approval processes. Planned facility launches may also be limited by delays in ongoing processes following the EIA, specifically building and planning permissions (IPPC).

Table 6: MBT capacities in the next few years (tonnes)

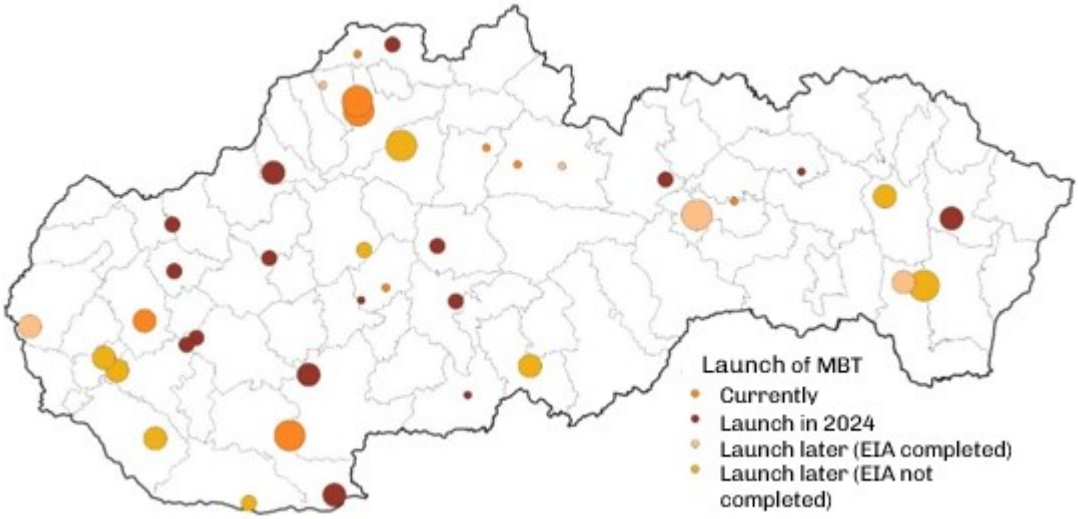
	2023	2024	2025	2030
MBT capacities	293,400	538,400 – 678,400	808,400	1,469,900
of which with approved EIA	293,400	538,400 – 658,400	658,400	1,043,400
Number of facilities	8	19 – 24	27	39
of which with approved EIA	8	19 – 22	22	27

**without counting the mixed municipal waste that is energy recovered in the Bratislava and Košice facilities of the operators*

Source: IEP calculations based on data

After 2024, there may still be lacking capacities at the regional level. Despite the planned capacities of MBT facilities being higher at the national level than expected demand, issues may arise at the regional level, particularly in the Banská Bystrica, Prešov, and Košice regions.

Graph 13: MBT capacities - Regional distribution by capacity and launch date



Source: IEP

Currently, RDF from mixed municipal waste is hardly produced in Slovakia. This is due to insufficient demand for low-calorific RDF from cement plants and low landfilling costs for municipal waste, which favour this option over energy recovery from waste.

Part of the capacities are used for RDF production from foreign waste. In Slovakia, approximately 309,000 tonnes of waste after resorting[5] and mixed packaging waste suitable for mechanical treatment were produced in 2021. Only 32% of this waste was utilized in a WtE plant, while 33% ended up in landfills[6] despite high costs of around 80-90 euros per tonne. The reason could be that several operators of sorting lines also manage landfills. They may also use a lower landfill fee for landfilling this waste at 7 euros per tonne instead of 30 euros per tonne. According to the regulation, this rate applies to sorted waste only when it cannot be processed in another way due to its characteristics.

[5] Waste Code 19 12 12.
[6] A further 31% of the waste did not have a specified final disposal method

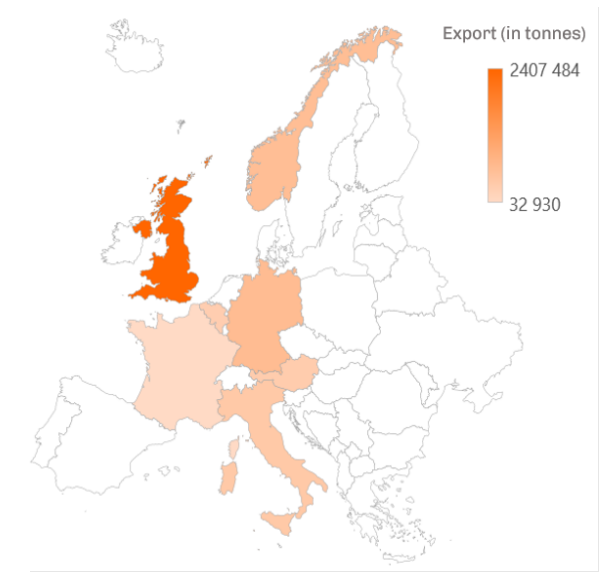
Another option for utilizing RDFs is energy recovery in heating plants. Unlike cement plants, heating plants can use waste with lower calorific values. Compared to facilities for energy recovery, they are not bound to regular and long-term waste disposal, or RDF, as they can burn biomass in boilers. Furthermore, they can be built on a smaller scale. The transition of heating plants from coal to RDF and biomass will require investments in new technology. MH Manažment, managing six Slovak heating plants, currently has a project for a multi-fuel boiler as part of the ecological upgrade of a plant in Žilina, scheduled to start operations in 2027 (Enviroportal, 2023). MH Manažment currently has no plans to build similar facilities, but considers using multi-fuel boilers in the future to replace worn-out equipment.

Under certain conditions, non-recyclable waste can also be processed abroad. According to regulations[7], mixed municipal waste can be transported provided proximity, priority utilization, and self-sufficiency are considered. In 2019, mixed municipal waste from EU countries was exported almost exclusively for energy recovery (Eurostat, 2021). The most mixed municipal waste was exported from the Netherlands to Germany and from Germany to Switzerland. Finland and France also exported mixed municipal waste. Transporting mixed municipal waste is relatively rare, as several conditions must be met, and the receiving country may object. Conversely, combustible waste and waste from mechanical processing[8], which is used to produce RDFs, are exported from several countries, mainly Western Europe, for energy recovery purposes. This type of waste is already becoming a valuable material in the form of fuel for cement plants and is subject to less stringent conditions than mixed municipal waste, although its transport also requires a permitting process[9]. Processing waste abroad, however, may lead to higher costs due to greater transport distances and higher energy recovery prices in other countries.

Graph 14: Mixed municipal waste exports

Source: IEP

Graph 15: RDF export



Source: IEP

[7] Regulation (EC) No 1013/2006 of the European Parliament and of the Council on shipments of waste.
[8] Waste Code 19 12 10 a 19 12 12.
[9] Regulation (EC) No 1013/2006 of the European Parliament and of the Council on shipments of waste.

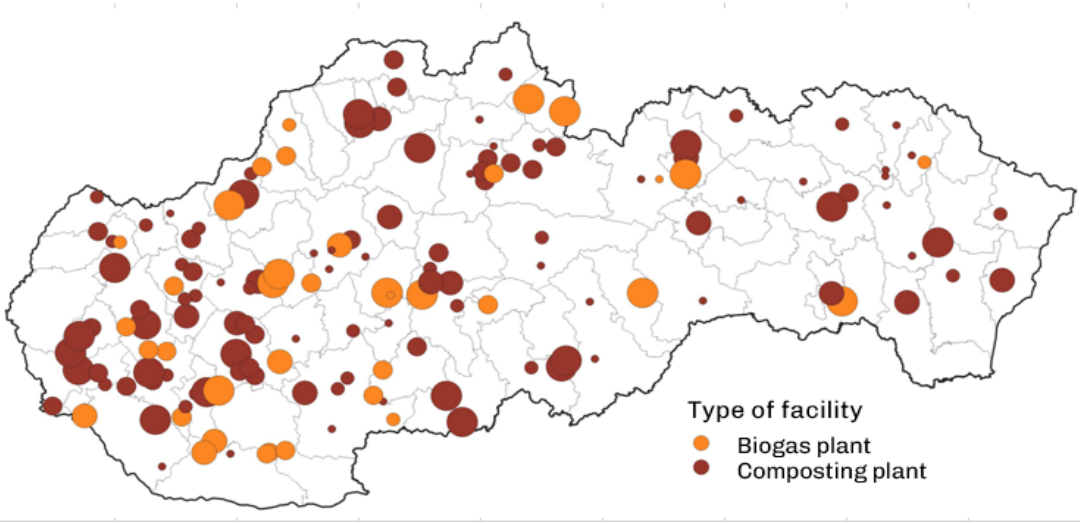
2.3 Composting and Anaerobic Digestion

Sorted kitchen or garden biowaste can be processed in a composting facility or a biogas plant. According to Waste Act[10], sorted municipal waste is prohibited from being disposed of in landfills. In the case of kitchen biowaste, there is an additional requirement[11] for hygienisation before further processing. This means the waste must reach a minimum temperature of 70°C for at least 1 hour to eliminate dangerous bacteria. When estimating the number of facilities and their capacities for biowaste processing, we relied on data from JRK, the Slovak Biogas Association, and State Veterinary and Food Administration of the Slovak Republic for the year 2023. Due to incomplete data, we verified approximately two-thirds of operators by phone.

In Slovakia, there are 367 composting facilities for processing kitchen or garden biowaste, but only 27 have permits from the State Veterinary and Food Administration of the Slovak Republic for handling kitchen biowaste. These permits are only granted to facilities equipped with the necessary technology, such as a hygienisation line, or those that demonstrate they can ensure hygienisation through their own methods, proving compliance with pathogen limits under Regulation No. 142/2011.

According to the Slovak Biogas Association, there are 77 functional biogas plants in Slovakia, of which 37 have permits for waste management. Only 12 of these are permitted to handle biologically degradable kitchen and canteen waste.

Graph 16: Map of composting facilities and biogas plants for kitchen and garden biowaste



Source: IEP

It is not possible to determine the capacity for a specific type of waste precisely. Processing facilities report the total capacity for all permitted types of waste in their reports on waste generation and management. Based on this data, we estimated the capacity of facilities for processing garden and kitchen biowaste, noting that these capacities also serve other types of waste for which the facility is permitted. Besides biowaste from municipal waste, these facilities primarily process waste from restaurants and catering establishments, as well as biowaste from agriculture, horticulture, forestry,

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

[11] The obligation stems from EU Regulation 1069/2009.

and the food industry. Data on the amount of biowaste from restaurants and catering establishments has been included in the municipal waste records since 2020, amounting to 10,000 tons in 2021.

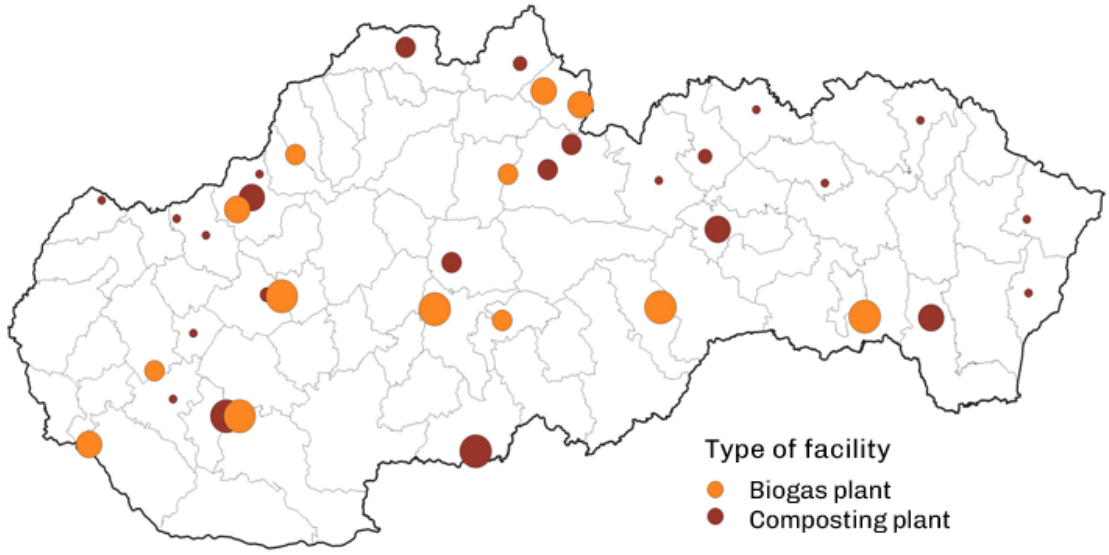
Facilities authorized to handle garden or kitchen biowaste have a total annual capacity of 1,465 thousand tonnes. There is a total of almost 1,451 thousand tonnes of capacity for processing garden biowaste, of which nearly 1,046 thousand tonnes are composting capacities. Despite the authorization to process this waste in biogas plants, it is not processed there because parts of it, such as wood and leaves, are not suitable for processing. In the case of kitchen biowaste, the annual capacity is 254 thousand tonnes. This capacity could be increased by adding hygienisation facilities.

Table 7: Capacities of facilities for the treatment of garden or kitchen biowaste

	Number of facilities	Capacity (thousand tonnes)
Composting facility	367	1,048.1
of which garden and other	365	1,045.6
of which kitchen and other	27	56.8
Biogas plant	37	416.5
of which garden	34	405
of which kitchen	12	197
Total	**404**	**1,464.6**

Source: IEP

Graph 17: Map of composting facilities and biogas plants for kitchen biowaste only



Source: IEP

The exact capacity for processing kitchen biowaste is not known, as facilities report total processing capacities that include other wastes not requiring hygienisation. In reality, the capacity of hygienisation lines and waste shredders cannot be precisely determined. Based on telephone and email communication, we verified two-thirds of the capacity volume.

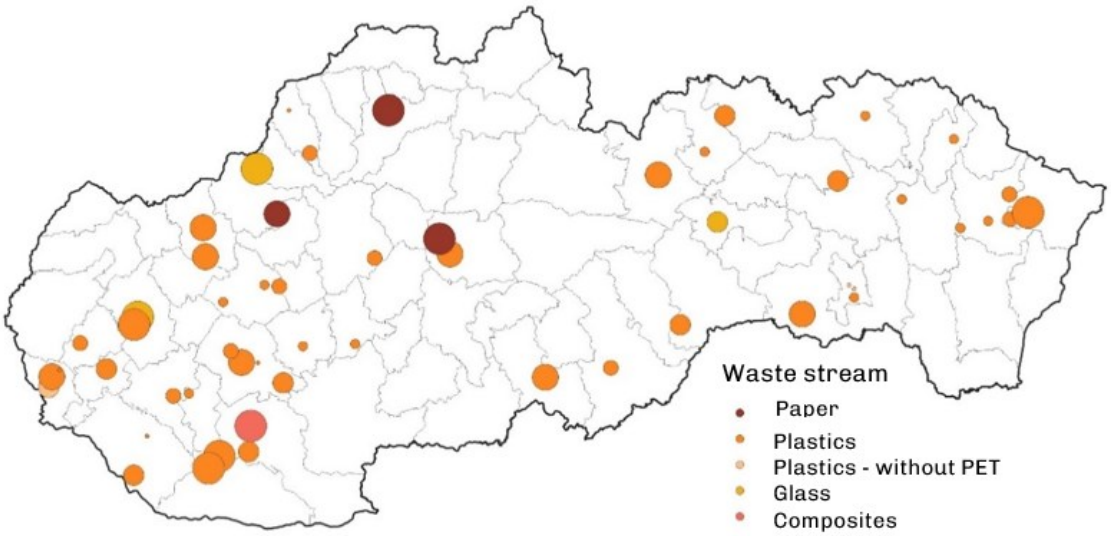
Part of the sorted waste can be composted in home composters, but their registration is lacking. Since 2023, only a municipality demonstrating that 100% of its residents compost is exempt from the obligation to sort garden and kitchen biowaste. According to data from

the Statistical Office of the Slovak Republic for the year 2022, kitchen biowaste is collected using composters in 538,000 households living in family houses, while sorted collection using collection bins is utilized by fewer than 400,000 households.

2.4 Material Recycling

Similarly to biowaste, information about individual facilities is only available in paper form at district offices, and verifying them is time-consuming. Regarding the number of facilities, we relied on the list of recycling facilities from four PROs, reports on waste generation and management for the years 2017-2018, which we verified by phone in 2019, and the list of authorized final waste processing facilities from the Regional waste information system (RISO).

Graph 18: Map of material recycling facilities for selected types of waste



Source: IEP

Most facilities for material recycling serve for processing plastics. Paper recycling is carried out in three facilities in Slovakia, and glass recycling also in three facilities. There are three facilities in Slovakia for recycling municipal waste glass with a total capacity of 182,000 tonnes. Paper waste recycling occurs in three facilities with a capacity of 150,000 tonnes. The highest number of facilities exists for processing plastics, with 53 facilities, and their capacity reaches 234,000 tonnes. Regarding plastics, 19 facilities do not have permission to handle waste from sorted municipal plastic waste, but only for handling plastic packaging.

Table 8: Capacities of material recycling facilities (thousand tonnes)

	Number of facilities	Capacity	Production in 2021
Paper	3	150	303
Plastics	53	234	196
of which plastic from municipal waste	*34*	*176*	*83*
Glass	3	182	94
Composite packaging	1	0.27	0.04

Source: IEP

Existing capacities are insufficient for recycling all types of waste; for plastics, capacities for each type of plastic are not known. Capacities for glass processing are more than

double compared to the production of glass waste in Slovakia in 2022. According to information from the operator of the Vetropack Nemšová facility, with a capacity of 150,000 tonnes per year, capacities are utilized only at 65%, and part of the waste glass needs to be imported from abroad. Conversely, capacities for paper material recycling are inadequate. Regarding plastics, it is not possible to determine whether capacities are sufficient for all types of materials. This is because recycling facilities mostly process specific types of plastics based on the material, such as PET, HDPE, LDPE, PP, PS, PE. However, plastics are registered in permits and notifications according to a catalogue number, which indicates the origin of plastic waste (municipal or industrial waste), not the type of material.

3 The Costs of Collection and Individual Waste Management Methods

3.1 Collection

The collection of waste involves costs associated with procuring infrastructure, transporting waste, and subsequent sorting. Additionally, municipalities may opt for more convenient or targeted collection methods for residents, such as implementing electronic waste tracking, providing wastebaskets for collecting kitchen biowaste and bin bags to every household, or constructing lockable waste stands and semi-underground containers.

For sorted waste collection, additional costs arise from sorting. Transport costs depend primarily on the type of waste, the collection system, and the transport distance. According to Sensoneo, the average distances from the collection point to the transfer station or collection yard, where sorting and waste processing occur, are similar for various types of waste, ranging from 6.5 to 9.2 km. Door-to-door collection from family houses incurs higher costs due to longer container handling times and greater transport distances compared to collection from apartment buildings. The type of waste also affects unit collection costs. Sorted plastic waste, compared to mixed municipal waste or glass, has a larger volume and lower weight, leading to higher unit costs.

Table 9: Input parameters of collection costs

Parameter	Characteristics	Costs	Source
Collection containers at apartment buildings			
Mixed municipal waste	1,100l, plastic container	215 €/ container	Contracts
Sorted collection	1,100l, plastic container	194 €/ container	Contracts
Kitchen biowaste	240l, partially modified containers	37 €/ container	Contracts
Wastebaskets and bin bags		3.2 €/ wastebasket 1.1 €/ 25ks bags	Contracts, JRK
Information leaflet		0.4 €/ unit	Contracts
Collection containers at family houses			
Mixed municipal waste	120/240l	27 €/ container	Contracts
Sorted collection	120/240l	27 €/ container	Contracts
Kitchen biowaste	120/240l	37 € / container	Contracts
Garden biowaste	120/240l	30 € / container	Contracts
composter		205 €/ unit	ITMS
Washing of collection containers			
Mixed municipal waste	1,100l, 1x per year	22 €/ container	Contracts
Kitchen biowaste	240l, 8x per year	6.3 €/ container	Contracts
Electronic waste tracking*	RFID chips, automated system		Sensoneo, GX Solutions, MIM, JRK
Investments			

Mobile barcode scanner		722 €/ municipality	
sensors on the collection vehicle		6,030 €/ vehicle	
RFID chip		1.1 €/ container	
Operation			
Collection container		2.8 €/ container /year	
collection vehicle		895 €/ vehicle/ year	
app		250 €/ municipality / year	
Semi-underground containers	5,000l, circular shape	4,000 €/ container	Contracts
Maintenance and servicing		3,1 €/ container/ year	Redox
Stands at apartment buildings	lockable	7,115 €/ stand	Contracts
Collection			
1,100l container		5.19 €/ collection	Contracts
120l container		0.98 €/ collection	Contracts
240l container		1.92 €/ collection	Contracts
Sorting			Collection companies
Paper		68 €/tonne	
Plastics		256 €/tonne	
Composite packaging		117 €/tonne	
Metal containers		168 €/tonne	
Glass		4 €/tonne	

**prices fluctuate depending on the frequency and type of container inventory as well as the specific data requirementsof local governments* *Source: IEP*

3.1.1 Infrastructure

Collection Container and Composters

For analysis purposes, we considered only plastic collection containers, which are gradually replacing metal ones. The lifespan of these bins is estimated to be 10 years. The costs for different types of collection containers are based on information from waste collection companies. Prices for composters were derived from data on projects by 31 municipalities within the Quality of Environment Operational Programme, available on the ITMS website. The average cost of a garden composter, with a lifespan of 20 years, is approximately 205 euros as of 2023.

For the collection of kitchen biowaste, we accounted for modified containers equipped with ventilation holes or bio-filters to minimize odour and bacterial growth. According to JRK, 1100-liter containers are unsuitable because large bins often lead to higher contamination levels. For apartment buildings, we assumed the use of 240-liter containers, which promote the development of aerobic bacteria. According to a study by Association of the Waste Industry of the Slovak Republic, which surveyed 103 municipalities in 2021, the predominant container sizes are 120 and 240 litres (Association of the Waste Industry of the SR, 2022). For the introduction of a more convenient kitchen biowaste collection, we also included costs for household wastebaskets, biodegradable bin bags, and a one-time investment in informational leaflets for each household, priced at 0.4 euros per leaflet. These estimates are based on costs provided by JRK and contracts from the cities of Trenčín, Trnava, Žilina, Prievidza, and Partizánske.

For the containers used for mixed municipal waste and kitchen biowaste in apartment buildings, we also considered the cost of washing the bins. According to waste collection companies, washing is performed once a year, with a unit cost of 22 euros per bin. For 240-

liter containers used for kitchen biowaste, washing costs are 6.25 euros per wash, with an estimated frequency of eight times a year, excluding winter months.

Electronic Waste Tracking

Municipalities currently implementing pay-as-you-throw waste collection first adopt electronic waste tracking systems. These systems provide the necessary data to set up a fair and accurate collection system. Compared to tag based collection or volume-frequency systems, electronic waste tracking incurs higher costs due to the need for software and devices for automatic bin tracking, system operation, and expert consultation. However, the system's full automation removes human error and allows for tracking data on sorted waste, enabling the setting of rewards for higher sorting rates.

Electronic tracking can utilize containers or bin bags marked with barcodes, QR codes, or RFID chips. The simplest systems involve additional operational costs for purchasing a scanner, an employee to scan the codes, and marking the containers or bin bags. Fully automated systems, which do not require manual scanning, provide access to the database and regular data analysis, potentially incurring higher costs. Municipalities can choose to track not only mixed municipal waste containers but also sorted waste bins to evaluate household-level sorting and subsequently set incentive fees and discount systems.

To estimate costs for electronic waste tracking, we assumed an RFID chip system, which allows for fully automated collection without the need for manual container scanning, as with QR codes. Investment costs include scanning devices mounted on collection vehicles, a portable reader for initial tracking and database maintenance, and the purchase of chips for containers or bin bags. According to company data, we assumed a 10-year lifespan for scanning devices and a 5-year lifespan for RFID chips. Operating costs include system operation, data analysis, and an app for tracking and database management. In a previous study (Institute for Environmental Policy, 2019), the cost estimates for different systems were based on information from companies JRK and MIM, which provide electronic waste tracking in Slovak municipalities. For this analysis, we additionally obtained data from Sensoneo and GX Solutions, which offer RFID chip bin marking with fully or partially automated system operation.

Shared Collection Point for Apartment Buildings

Properly setting up pay-as-you-throw waste collection in apartment buildings requires ensuring bin access only for the building's residents using lockable shared collection points**.** Our cost estimates for building shared collection point were based on 16 contracts from Slovak cities that have already implemented such shared collection point (e.g., Žilina, Prešov, Trebišov, Zlaté Moravce, Bánovce nad Bebravou). Median costs for constructing a shared collection point are 7115 euros, adjusted to 2023 prices. The number of required enclosures was estimated from city data (Zlaté Moravce, Revúca, Levice, Nové Zámky, Žilina), with an estimate of 51 apartments per shared collection point or 138 residents per shared collection point. The number of already modified shared collection points was estimated at 5%, based on information from the collection company Marius Pedersen, which serves nearly 1 million residents.

Semi-underground Containers

Over 40 cities in Slovakia use semi-underground containers for waste collection. Their advantages over traditional bins include occupying less space per unit volume, reducing collection frequency, ensuring cleanliness around the bins, and protection against vandalism and rodents. Most of the container is underground, slowing down decomposition and reducing odours. According to Nitrianske komunálne služby, which manages nearly 280 such containers in Nitra, semi-underground containers can accommodate 20% more waste per unit volume due to self-compaction.

According to the collection companies, the average cost of semi-underground containers is 4000 euros, with a lifespan of 20 years. The average service and maintenance cost per container is 3.1 euros per year, based on 2021 data from Redox-Enex, adjusted for 2023 prices. The average volume of semi-underground containers is 5000 litres, requiring fewer units compared to traditional 1100-liter bins while maintaining the same collection frequency. Cities like Trnava, Zvolen, Senec, Šaľa, and Trenčín reduced the number of traditional bin enclosures by 30-40% after installing semi-underground container enclosures. According to Redox-Enex, Slovakia has an estimated 350 semi-underground container enclosures, totalling over 2000 containers.

A potential disadvantage of semi-underground containers is the increased distance to the infrastructure. However, according to REDOX - ENEX, several Slovak cities have built semi-underground container enclosures without significantly changing the carrying distance. This may not be the case everywhere. Furthermore, it is advisable to bring the infrastructure closer to apartment residents to motivate sorting, ideally creating an enclosure for each entrance or apartment building.

3.1.2 Collection

The average cost of collecting a 1100-liter container is 5.19 euros, based on information provided by waste collection companies. The costs for collecting smaller bins are 0.98 euros per 120-liter bin and 1.92 euros per 240-liter bin. Collection costs for smaller bins are higher per volume unit because these containers are often used for door-to-door collection, which involves more time for handling and longer distances. However, smaller bins collect more waste in practice, reducing costs per weight unit. We estimate the cost of collecting 240-liter kitchen biowaste bins at 1.9 euros, based on data from a collection company.

The cost of collecting one tonne of kitchen biowaste depends on the sorting efficiency. When fully filled, a 240-liter container can hold 80 to 100 kg of kitchen biowaste. The cost of emptying one bin could be just 22 euros per tonnes, but this assumes full utilization of the container at each collection. In practice, costs are higher. In Trenčín, at the beginning of kitchen biowaste collection in 2021, approximately 305 tonnes were collected over three months at a cost of 26,000 euros, equating to 85 euros per tonne. With a collection cost of 0.007 euros per liter, the average container fill efficiency was 0.08 kg per liter, comparable to mixed municipal waste bin efficiency.

3.1.3 Sorting

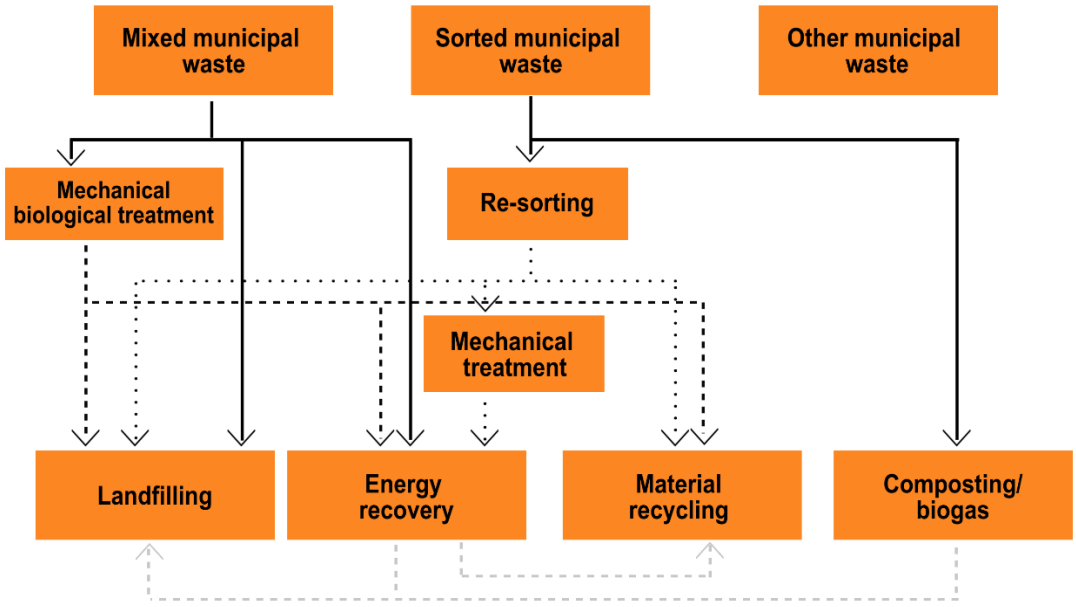
Sorting costs for plastics are 255.85 euros per tonne, 4 euros per tonne for glass, 68.44 euros per tonne for paper, 117.41 euros per tonne for composite packaging, and 168.41

euros per tonne for metals. These values are based on data from waste collection companies. After the sorted fractions are transported to a collection yard or transfer station, the waste must be further sorted by material type. In Slovakia, most sorting lines are manually operated, with only a few being optical. Marius Pedersen, which provides waste management services for nearly 1 million residents, processes 75% of collected plastics on manually operated lines. According to waste collection companies, the proportion of optical lines to manual lines did not change between 2021 and 2023. This is due to the introduction of a deposit system and fluctuating prices in the secondary raw materials market.

3.2 Waste Management

Collected and sorted waste is destined for final disposal or recovery at the appropriate facility. Mixed municipal waste ends up in a landfill, energy recovery facility, or undergoes mechanical biological treatment and is then used as RDF in cement plants. In Slovakia, mixed municipal waste is not additionally sorted, so no part is recycled, except for a small portion of metal waste sorted during mechanical biological treatment or energy recovery. It is prohibited to landfill sorted municipal waste such as paper, plastics, glass, metals, or sorted biodegradable waste. Most of this waste is recovered at recycling facilities, composting plants, or biogas stations. Part of the sorted waste that cannot be recycled for economic or technical reasons is used for energy recovery, landfilled as sorted waste, or used as high-calorific waste to produce RDFs.

Graph 19: Municipal waste management scheme



Source: IEP

The costs of various types of equipment are based on data from operators and providers of these services. The stated costs represent the sum of investment and operational expenses, calculated per tonne of waste based on the equipment's expected lifespan. These costs include all fees as well as revenues from sales. In the case of recycling, we considered the purchase prices at which the material is sold for further recovery.

Table 10: Average costs and revenues of waste recovery and disposal

Type of waste management	€/ tonne	Source
Landfilling of municipal waste		
Gate fee	49	Landfill operators
Landfill fee	19	IEP according to the decree
Energy recovery	95	KOSIT, OLO
Mechanical biological treatment	82	T+T, Ewia
Mechanical treatment	65	Ecorec
Recycling		
Paper and cardboard	-94	Naturpack, Envipak, OLO
Plastics excluding beverage PET	-163	Envipak, OLO
Beverage PET	-457	Naturpack
Glass	-27	Envipak, OLO
Composite packaging	37	Naturpack
Beverage cans	-1,149	Naturpack
Composting	24	JRK, EBA
Hygienisation	19	JRK
Biogas plant	51	Biogas plant operators

Source: IEP

3.2.1 Landfilling

Landfilling costs comprise a landfill fee, which depends on the level of waste sorting in the given municipality, and a gate fee charged by the landfill operator. The gate fee covers the costs of waste disposal, including labour costs and the cost of a purpose-specific financial reserve, which is used for the closure, reclamation, monitoring, and maintenance of the landfill after its closure. According to landfill operators, the gate fee for disposing of mixed municipal waste at a landfill in 2023 stands at 49 euros per tonne. This fee has increased by more than half since 2018, primarily due to higher operating costs, including fuel, wages, and levies.

The landfill landfill fee for municipal waste reached nearly 19 euros per tonne in 2022. The fee amount in individual municipalities depends on the sorting rate from the previous year. According to Envirofond data on revenues and the amount of waste deposited in landfills, the average landfill fee for mixed municipal waste was 18.5 euros per tonne in 2022. Based on the waste sorting rates in various municipalities for 2022, the average fee is expected to be 18.3 euros per tonne in 2023.

Landfills can generate revenue from the sale of electricity produced from captured landfill gas. Data from landfill operators in Slovakia indicate that only 11 landfills actively capture methane from landfill gas for electricity production, accounting for approximately 26% of the total landfilled waste. In 2022, electricity production from landfill gas reached about 8.4 GWh (URSO, 2023). This is a renewable energy source[12], with a fixed price set at 58.66 euros per MWh for facilities commissioned before 2020[13]. In 2022, no facility received a surcharge because the market price of electricity exceeded the fixed price. Electricity production for facilities built after 2020 is not supported.

[12] Act No 309/2009 on the promotion of renewable energy sources and high-efficiency cogeneration
[13] Decree 18/2017 establishing price regulation in the electricity sector and certain conditions for the performance of regulated activities in the electricity sector

3.2.2 Energy recovery

The gate fee for waste-to-energy (WtE) plant was set at 95 euros per tonne in 2023, according to data from OLO and KOSIT, which operate these facilities in Slovakia.

The costs of WtE plants depend on various factors, such as the capacity of the facility, construction location, provision for electricity and heat distribution, and their prices. An optimal WtE plant capacity is at least 80-100 thousand tonnes of waste per year. A suitable location with existing road infrastructure and infrastructure for electricity and heat distribution can reduce investment costs. Continuous year-round demand for heat and electricity is also crucial. In the cost-benefit analysis of constructing a third boiler at the OLO incinerator in Bratislava (Institute for Environmental Policy, 2020), it was shown that the absence of heat consumption would reduce revenues by 23%. The price of electricity and heat also impacts the fee level. According to KOSIT's annual reports for 2021 and 2022, revenues from the sale of electricity and heat average 28 euros per tonne. Since May 2023, WtE plant OLO has been supplying heat to Bratislava households, with a planned heat volume of 23 thousand MWh.

Typical operational costs for incinerators are approximately 20 euros per tonne of waste. Two-thirds of these costs are associated with waste management resulting from the energy recovery process. Solid waste produced during gas cleaning must be disposed of in hazardous waste landfills, costing around 162 euros per tonne, including a landfill fee of 40 euros per tonne. The bottom ash and slag left after energy recovery are disposed of at 57 euros per tonne, with a landfill fee of 7 euros per tonne.

For future facilities, we anticipate combined heat and power generation. The average sale of electricity is estimated at 0.3 MWh per tonne of waste, and heat at 0.27 MWh per tonne. We estimate the unit price of electricity at 126 euros per MWh, or 38 euros per tonne of energy-recovered waste, based on a three-year average on the Power Exchange Central Europe commodity market.

Currently, support through a set electricity price is only available for facilities with highly efficient cogeneration of heat and power up to 1 MW. Typical WtE plant does not fall into this category. WtE plant KOSIT currently receives a subsidy based on a 2014 decision for 54% of electricity produced from renewable sources, i.e., energy from the biological component of waste (URSO, 2014). In 2022, the subsidy was zero due to higher market prices compared to the purchase price (URSO, 2022). There is no current support for electricity production from new WtE plants.

3.2.3 Mechanical Biological Treatment

Mechanical biological waste treatment facilities primarily serve to stabilize the organic component of the waste, with some being equipped with sorting lines. The output after treatment mainly consists of stabilized biological waste, inert waste, and waste suitable for the production of RDF. The facility can also include a sorting line to further sort part of the waste for material recovery. The costs of waste treatment thus depend on the chosen technology, the composition of the waste after treatment, and the costs associated with its disposal or recovery.

The primary aim of introducing mechanical biological treatment (MBT) in Slovakia is to reduce the landfilling of the organic fraction of waste. Since neither the law nor the relevant decree[14] specify any particular requirements for the treatment, we do not anticipate additional sorting of recyclable components. Investment and operational cost data for MBT facilities are based on the KOSIT project and information from T+T, the only company in Slovakia that produced RDF from mixed municipal waste.

The costs for landfilling stabilized biowaste[15], which would constitute 25% of the input waste's weight, amount to 61 euros per tonne. The gate fee is 62 euros per tonne, according to data from six landfills in 2023. We estimate the landfill fee to be 7 euros per tonne[16], as this waste cannot be recovered by other means. An alternative to landfilling is using this waste for reclamation purposes. However, its use as compost is generally not possible, as the material is not sufficiently clean and may contain impurities or harmful substances (Stoiber, et al., 2020).

The remaining part of the waste, which shows no biological activity and is not combustible, constitutes 25% of the input waste's weight and can be landfilled. This type of waste is classified under waste code 19 12 09. We estimate the cost of landfilling this inert waste at 56 euros per tonne, including a landfill fee of 7 euros per tonne for inert waste at a non-hazardous landfill[17]. The gate fee of 49 euros per tonne is based on landfill operators' price lists. The final 5% consists of sorted metals after mechanical processing, which would be sold at 15 euros per tonne (KOSIT).

We assume that the light fraction of waste suitable for RDF production would be used for energy recovery in cement plants. According to T+T, the costs for recovery in cement plants are approximately 35 euros per tonne. Alternatively, this waste could be landfilled, but the cost of landfilling combustible waste would reach 80 euros per tonne, with a landfill fee of 30 euros per tonne and a gate fee of 50 euros per tonne, according to landfill price lists.

Thus, the total costs for pre-landfill municipal waste treatment would amount to 82 euros per tonne, excluding transportation costs. This cost estimate aligns with T+T's experiences to date. Ewia estimates operational costs at 65-75 euros per tonne (Stoiber, et al., 2020). According to T+T, transportation costs for SRF are approximately 20 euros per tonne. The transportation costs are estimated at 20 euros per ton of Refuse-Derived Fuel (RDF) according to the company T+T.

3.2.4 Mechanical Treatment

Part of the sorted waste collection cannot be materially recovered due to economic or technical reasons. This is particularly relevant for plastic waste after sorting within municipal waste. This waste can be mechanically processed to produce high-calorific RDF for use in cement plants. According to operators of MBT facilities for RDF production, the costs average 50 euros per tonne, including delivery to the cement plant (Ecorec, FCC, Brantner, AZ Stav).

[14] Decree 26/2021 Coll. on landfilling and storage of waste mercury
[15] Waste Code 19 12 12
[16] Government Regulation No. 330/2018 Coll., establishing the rates of waste disposal fees and details related to the redistribution of revenues from waste disposal fees.
[17] § 4 (4) of Act No.329/2018 Coll. on waste disposal fees

3.2.5 Composting

The investment costs for a composting facility with a lifespan of 20 years are 10.5 euros per tonne for a composting facility on concrete surfaces with an automatic control and aeration system. These costs cover technology, construction work, and equipment purchase. Operational costs are approximately 13 euros per tonne of waste, resulting in total costs of just under 24 euros per tonne of biological waste. The cost estimates for composting are based on data from JRK and EBA.

The resulting compost is not always of sufficient quality for sale. The most common use is selling it as organic fertilizer or substrate. Municipal composting facilities often distribute compost free of charge due to its low quality, excess quantity, and funding from grants that do not allow for selling the compost. Municipalities use large amounts of compost for landscaping and soil work.

Hygienisation

According to EU regulations[18], **biodegradable kitchen waste, which contains animal by-products, must undergo hygienisation** before further recovery. Several facilities enable biowaste hygienisation, such as the fermenter, or CSC container (JRK). This container offers easy handling, mobility, and an automated hygienisation process. It does not require construction modifications and can be easily added to existing composting facilities. Although hygienisation is required only for kitchen biowaste, this waste must be mixed with structured garden biowaste to achieve the correct material density and hygienised together. The material is mixed in a 1:1 ratio. According to JRK, investment and operational costs are 16.7 euros per tonne of hygienised kitchen waste. These figures align with data from four facilities, where the costs of hygienisation average 19 euros per tonne in 2023.

3.2.6 Biogas Plant

A biogas plant can recover up to 95% of waste, producing electricity, heat, and liquid fertilizer in the form of digestate. Cost information was provided by the Budča facility, which includes hygienisation and processes kitchen biowaste. The average investment cost for a lifespan of 20 years is 13 euros per tonne of processed waste, and operational costs are 110 euros per tonne. Landfilling the remaining 5% of waste constitutes a minimal part of operational costs, only 2-3 euros per tonne of processed waste, considering a landfill fee of 7 euros per tonne and a landfill disposal fee ranging from 36 to 54 euros per tonne.

The income for a biogas plant comes from selling electricity and heat. According to the Budča biogas plant, energy production from kitchen biowaste averages 260 kWh per tonne of waste, while biowaste from restaurants can produce up to 440 kWh per tonne. The potential for energy production decreases over time between waste collection and its processing. Heat production averages 186 kWh per tonne of waste. According to the Regulatory Office for Network Industries of the Slovak Republic regulations, this is a renewable energy source, supported by a fixed electricity price of 90 to 102 euros per MWh, depending on capacity, until 2020. Estimated anaerobic digestion costs are based on

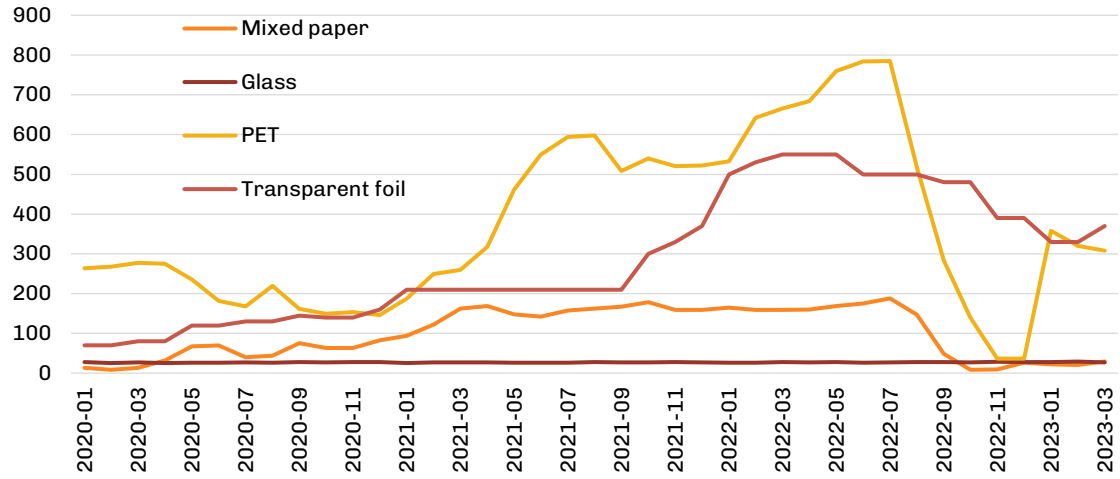
[18] Regulation (EC) No. 1069/2009 laying down health rules concerning animal by-products and derived products not intended for human consumption.

information from three biogas plant operators and amount to 51 euros per tonne of processed waste.

3.2.7 Recycling

In our analysis of recycling, we considered the paid prices of materials, which represent the revenues from selling the material for recovery. Data were provided by Naturpack and Envipak, as well as companies OLO and Marius Pedersen. While some material prices remain stable, others, such as plastics or paper, fluctuate depending on the prices of primary raw materials, the economic situation, the state of industrial production, and other factors.

Graph 20: Development of purchase prices of selected materials in 2020-2023 (€/tonne)



Source: IEP based on data from Marius Pedersen, OLO, Naturpack and Envipak

The buyback prices for mixed paper varied between 2020 and 2023. In 2021, prices stabilized at an average of 136 euros per tonne. After reaching a peak of 172 euros per tonne in July 2022, prices sharply declined to 16 euros per tonne in October 2022 due to decreased economic activity and market stabilization among suppliers. **For our analysis, we used an average buyback price of 94 euros per tonne for the 2022-2023 period.**

The market for PET materials was influenced mainly by oil prices, industrial developments, and the COVID-19 pandemic, which brought changes in consumer and producer behaviour. According to Naturpack, average PET prices for 2022-2023 were around 457 euros per tonne. We determined the average price of PET material as a weighted average of the prices for different types of PET (transparent, blue, green, etc.) based on their proportion in sorted collection data from Envipak. Mid-2022 saw the highest average PET material price at 785 euros per tonne. A similar trend was observed with recycled films, typically less marketable than PET, due to material shortages in Europe caused by production shutdowns and disrupted supply chains during the pandemic (Bragagni, 2021). Since Slovakia introduced a deposit system in 2022, effectively removing PET bottles from sorted collection, the average price for other plastics was estimated at 163 euros per tonne based on Envipak and OLO data from sorted plastic collections.

For this analysis, we used average material prices for 2022-2023. The average price for glass was consistently 27 euros per tonne, aluminium averaged 1,149 euros per tonne, and the buyback price for other metals was 154 euros per tonne during the same period. For composite packaging, recyclers charged between 35 and 113 euros per tonne.

Table 11: Long-term average purchase prices of materials (€/tonne)

Paper and cardboard	94
Plastics excluding beverage PET	163
Beverage PET	457
Glass	27
Composite packaging	-37
Beverage cans	1,149
Mix of metals	154

Source: IEP based on data from Naturpack, Envipak, OLO for the period 01/2022 – 03/2023

3.3 External Costs, Resource Savings

In waste management, significant environmental impacts arise that are not accounted for through market prices, requiring the determination of their shadow prices. The processing of waste generates negative externalities such as greenhouse gas emissions and pollutants, contributing to climate change and environmental pollution. Additionally, energy recovery of waste and landfilling can create discomfort for nearby residents, such as odours, visual pollution, and noise. In the case of landfills, leachate can contaminate soil and groundwater. However, these processes can also create positive side effects, such as cost savings on resources and prevented emissions from conventional energy and material production. In this analysis, we evaluated external costs from the perspective of greenhouse gas emissions and pollutant production.

Table 12: Assumptions on external costs and savings on resources

Parameter	Characteristics	Costs	Source
Greenhouse gas emissions	CO_2, CH_4, N_2O	190 €/ tonne CO_{2ekv}*	IEP based on EK a EEX
Pollutants			World bank
NO_x		10,557 €/ tonne	
SO_2		10,392 €/ tonne	
TZL		42,887 €/ tonne	
Conventional electricity production	Energy mix	113 €/ MWh	CPS energy model
Greenhouse gas emissions	0.16 tonne CO_{2ekv}/MWh	30.4 €/MWh*	OKTE 2022
Pollutants		2 €/MWh	NEIS
Conventional electricity production		98 €/MWh	CPS energy model
Greenhouse gas emissions	0.27 tonne CO_{2ekv}/MWh	51.3 €/MWh*	ETS, MH TH
Pollutants		2.5 €/MWh	NEIS

**price of greenhouse gas emissions increases over time, the table shows the average value over the period 2023-2045*

Source: IEP

Certain external costs are partially included in various fees, such as landfill charges, air pollution fees, or emission allowances under the European Emissions Trading System. However, these fees do not fully reflect the total external costs associated with different waste management methods. For Waste-to-energy plants, we estimate the costs of

pollutants to be 6.7 euros per tonne of waste, whereas current fees account for only 0.04 euros per tonne of waste. Besides cement plants, none of the facilities for final waste disposal bear costs for greenhouse gas emissions since they are not part of the emissions trading system. The external costs of landfills are partially included in the landfill disposal fees. In 2022, the average landfill fee for municipal waste was approximately 19 euros per tonne, while the external costs of greenhouse gas emissions were around 42 euros per tonne.

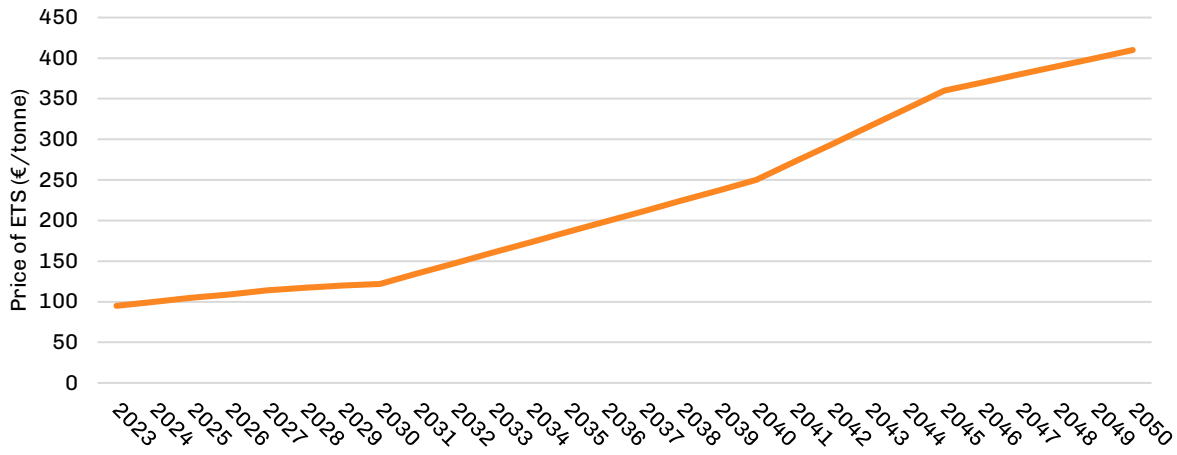
3.3.1 Assumptions

Unit Costs of Emissions and Pollutants

The impacts of emissions and pollutants on the environment are assessed using shadow prices, which reflect the opportunity costs. The external costs of greenhouse gas emissions are estimated based on the prices of emission allowances in the EU ETS. The development of allowance prices is derived from EUA futures prices according to the European Energy Exchange (EEX) until 2030 (EEX, 2023). After 2030, we assume a more ambitious scenario from the EC (the so-called WAM scenario), which aligns with achieving climate neutrality by 2050 and projects an increase in the price of EU ETS allowances to 250 euros per tonne by 2040 and 410 euros per tonne by 2050. This estimate is based on recommendations from internal EC documents.

To normalize the global warming potential of various greenhouse gases, each type of emission is converted to CO_2 equivalents. We assume the global warming potential for each type of emission as reported by Slovak Hydrometeorological Institute in 2020.

Graph 21: The development of emission allowance prices in the EU ETS (€/tonne)



Source: IEP based on data from EEX and EC internal documents

Pollution costs for NO_x, SO_2, and particulates are derived from World Bank estimates (World Bank, 2019). As of 2023 price levels, these costs are 10,560 euros per tonne for NO_x, 10,392 euros per tonne for SO_2, and 42,887 euros per tonne for particulates.

Energy Sources

The financial and external cost savings from generating electricity and heat compared to conventional production were calculated based on price trends from the CPS energy model for Slovakia under the existing measures scenario. The savings amount to 113 euros per MWh for electricity and 98 euros per MWh for heat.

Approximately 70% of conventional electricity production comes from low-emission nuclear energy (OKTE, 2022). The average emission production is only 0.16 tonnes of CO_{2eq} per 1 MWh of energy (OKTE, 2022). The emission factor for heat production was recalculated based on data from the annual report of MH Teplárenský Holding, which represents the six largest heating plants in Slovakia, at 0.27 CO_{2eq} per 1 MWh of heat (MH Teplárenský Holding, 2022). Data on pollutants were taken from the NEIS emissions information system. The external costs of pollutants from conventional electricity generation are valued at 2 euros per MWh, and for heat, 2.5 euros per MWh.

3.3.2 Landfilling

The main source of emissions in landfilling is landfill gas, which consists of approximately 50% methane and 50% carbon dioxide (Environmental Protection Agency, 2010). The amount of emitted emissions depends on the quantity and composition of the waste, moisture, temperature, and oxygen access in the landfill. Unlike energy recovery, where emissions are released immediately during energy recovery, landfill emissions are released gradually with a delay ranging from 6 months (Pipatti & Svardal, 2006) to up to 100 years. Thus, the amount of emissions cannot be calculated solely based on the amount of waste landfilled in a given year.

In estimating methane and carbon dioxide production, we used the estimates from an IEP study, which applied the first-order decay model LandGem (Institute for Environmental Policy, 2020). This estimate includes methane capture in landfill gas at 11 landfills in Slovakia. On average, 0.88 tonnes of CO_{2eq} are produced from 1 tonne of landfilled municipal waste over an extended period. Statistical Office of the Slovak Republic estimates 0.87 tonnes of CO_{2eq}.

3.3.3 Energy Recovery

In energy recovery, CO_2 emissions are generated, along with smaller amounts of CH_4 and N_2O. Since WtE facilities are not required to monitor or report emission quantities, emissions are estimated using a model from the Slovak Hydrometeorological Institute. Based on emission factors for different waste types and waste composition analyses by INCIEN, it is estimated that 0.82 tonnes of CO_2 equivalent greenhouse gas emissions are produced per tonne of waste. The estimated emissions from the WtE facility in Bratislava are as high as 1.04 tonnes of CO_{2eq}, reflecting higher emissions due to more calorific waste with a lower proportion of biological content compared to the national average.

A portion of the waste used for energy recovery is of biological origin, and emissions from the biological component are considered carbon-neutral. However, some studies count all emissions regardless of their origin (Rabl, et al., 2008). Excluding these emissions does not allow for the preferential treatment of options that could eliminate these emissions, such as composting biowaste. The estimated share of biological content in the WtE plant in

Bratislava is 35%, while in the Košice facility, it is 53%. According to INCIEN's analysis of the composition of mixed municipal waste, the biological content averages 62% across Slovakia. The differences are attributed to the fact that up to 90% of the population in Košice and Bratislava live in apartment buildings, where garden waste is not present in mixed municipal waste. For existing WtE plants, emissions were considered based on available waste composition data. For future facilities, the waste composition was assumed to reflect the Slovak average.

During energy recovery, pollutants such as NO_x, SO_2, CO, particulate matter, total organic carbon, dioxins, and heavy metals are released. Data on the amounts of these pollutants emitted from the WtE plants OLO and KOSIT are available from annual emission reports. The total cost of emitting these pollutants is approximately 7 euros per ton of waste used for energy recovery.

3.3.4 Mechanical Biological Treatment

Landfilling primarily results in the production of methane emissions, with their quantity depending on various factors. For municipal waste, we assume that only inert waste and the biocomponent after mechanical biological treatment will be landfilled. Inert waste, which constitutes 25% after mechanical biological treatment, has no biological activity and therefore produces almost no emissions. Emissions from the landfilled biocomponent, including carbon dioxide emissions, average 0.5 tonnes per tonne of waste. This emission calculation is based on the EPA model (Environmental Protection Agency, 2005).

The remaining portion of municipal waste after mechanical biological treatment forms RDF used in cement plants, where it produces emissions from energy recovery. According to data from Ecorec, which conducted an analysis of RDF from mixed municipal waste supplied by T+T, the carbon content in the fuel averages 51%. Emissions from energy recovery are then calculated by multiplying the amount of carbon by a coefficient of 3.67 (SHI, 2023). The estimated emissions thus reach 1.9 tonnes per tonne of RDF. However, part of these emissions pertains to the energy recovery of biomass. According to data from the Slovak Hydrometeorological Institute, emissions from the fossil part of the RDF average only 56%. Emissions from the energy recovery of the fossil part are estimated at 0.83 tonnes per tonne of RDF.

We assume that cement plants would utilize RDFs even without the mechanical biological treatment of waste from Slovakia, as the waste would be imported from abroad. Therefore, the incremental amount of emissions or pollutants from energy recovery in cement plants would be zero.

3.3.5 Composting

In Slovakia, pile composting is predominantly used, which generates methane and N_2O emissions. The National Inventory Report uses emission factors of 10 g CH_4 per kg of dry matter in biological waste and 0.6 g N_2O per kg of dry matter in biological waste (SHI, 2023). When recalculated for the total production of biological waste, the emission production reaches 0.30 tonnes CO_{2eq} per tonne of composted waste.

In addition to the composting process itself, emissions also arise from its application. According to a study by Eunomia, the use of compost is associated with biogenic emissions of 0.4 tonnes CO_{2eq} per tonne of kitchen waste and 0.5 tonnes CO_{2eq} per tonne of garden waste. Moreover, N_2O emissions occur, which also happen when synthetic fertilizers are used. According to Eunomia, the avoided emissions from the production of synthetic fertilizers are 0.08 tonnes CO_{2eq} per tonne of garden waste and 0.13 tonnes CO_{2eq} per tonne of kitchen waste, with avoided costs of pollutants amounting to 1.82 euros per tonne of garden waste and 2.31 euros per tonne of kitchen waste.

Using compost also results in N_2O emissions; however, compared to synthetic fertilizers, these are expected to be lower due to the more stable nature of the nitrogen contained in compost. The advantage of organic nitrogen in compost is its gradual release and lower leaching potential compared to artificial fertilizers, reducing the need for irrigation and the likelihood of soil erosion.

3.3.6 Biogas Plant

In a biogas plant under anaerobic conditions, biogas is produced, which is burned to generate electricity or heat. During this process, biogenic CO_2 emissions amount to 0.45 tonnes CO_{2eq} for kitchen waste and 0.27 tonnes CO_{2eq} for garden waste. Additionally, digestate is produced, used for agricultural purposes, potentially replacing synthetic fertilizers. Its use leads to additional emissions of 0.05 tonnes CO_{2eq}/tonne of digestate from kitchen waste. Similarly to composting, it prevents emissions and pollutants from the production of synthetic fertilizers. Estimated avoided emissions amount to 0.05 CO_{2eq} per tonne of digestate from kitchen waste, with avoided costs of pollutants totalling 2.05 euros per tonne of digestate.

Processing biowaste in a biogas plant results in the production of pollutants. Cost calculations were based on NEIS data from 2019, indicating average costs of 22.5 euros per MWh of electricity produced. According to information from the biogas plant in Budča, approximately 400 kWh of electricity is generated from one tonne of waste, consistent with Eunomia's figure of 376 kWh.

3.3.7 Recycling

The external benefits associated with the material recovery of different materials stem from a study by (Eunomia, 2014). The study quantifies impacts on air quality in terms of avoided pollutants such as NOx, particulate matter, and SO2. The impact on climate change is evaluated based on avoided greenhouse gas emissions resulting from saved energy and the production of primary materials. The highest savings are achieved through the recycling of plastics and metals. For non-ferrous metals, such as aluminium, average savings can reach up to 9.2 tonnes CO2eq per tonne of material, as the production of primary materials represents an energy- and resource-intensive process, while sorted aluminium is 100% recyclable.

Table 13: Saved emissions and pollutants

	Greenhouse gas emissions (tonne CO_{2eq}/tonne of waste)	Pollutants (€/tonne of waste)
Paper and cardboard	-0.06	-27
Beverage PET	-1.18	-28
Plastics excluding PET	-1.08	-28
Glass	-0.23	-8
Ferrous metals	-1.63	
Non-ferrous metals (aluminium)	-9.17	

Source: IEP based on data from Eunomia

3.4 Model Limitations and Possible Improvements

Not Covered Waste Types

Within the framework of the model, the costs of collection and processing selected types of municipal waste are quantified, influenced by the implementation of various measures. The total proportion of municipal waste with quantified costs averages 91% of the weight of municipal waste, excluding metal waste. Regarding industrial waste, only the development of production and handling is listed without quantifying costs.

Data

A significant limitation is the quality of reported waste production data. Regarding data on sorted waste collection, there are discrepancies in school collection, paper buyback schemes, and domestic composting of biowaste. Despite legal obligations, buyback centres and mobile units often fail to report all collected quantities, leading to discrepancies in records. Reporting of collected quantities within buyback schemes should be monitored, possibly with penalties for non-compliance. Data on domestic composting are also not included in records. Domestic composting contributes to achieving the goal of reducing mixed municipal waste and increasing sorting and recycling rates. Including these data would lead to even better sorting and recycling results. However, including domestic composting data may be problematic; a methodology for recording such waste could be a solution.

Another limitation is insufficient data on processing facility capacities and their utilization. Currently, there is no unified electronic record of the number and capacities of facilities, regularly updated. Estimates of facility numbers and capacities for waste processing are based on data provided by the Ministry of Environment of the Slovak Republic and from the private and third sectors.

Regularly updated data also lack analyses of the composition of mixed municipal waste. In 2020, the Ministry of Environment of the Slovak Republic established a unified methodology for analysing mixed municipal waste and planned to conduct such analyses regularly. However, to date, these analyses have not been conducted, resulting in a lack of regular data updates essential for evaluating measures aimed at increasing waste sorting.

Qualifications of other Measures

Section 4.3 outlines additional measures to improve the state of waste management. However, the impacts of these measures have not been quantified and are therefore not included in the current model. The study also did not address waste prevention measures due to a lack of literature on the effects of such measures. In the future, it is possible to incorporate the impacts of these measures and quantify their effects on costs and the methods of handling municipal waste.

Transportation Costs

When estimating the costs of waste transportation, we relied on current data from collection companies and municipal contracts. However, the costs are presented only in euros per tonne of waste or euros per container collection. Changes in waste management could alter the unit costs of collection. According to Marius Pedersen, the average distance to a landfill is approximately 25 km. The closure of landfills could increase this distance. Similarly, with the introduction of mandatory waste treatment, we expect that mechanical biological treatment facilities would be established near only some landfills, as only 50% of the treated waste is landfilled, with the remaining part co-incinerated in cement plants.

Since we cannot predict changes in distances, we cannot estimate the increase in unit transportation costs. Similarly, the model does not include external transportation costs in the form of produced emissions and pollutants.

4 Analysis of Selected Measures in Waste Management

Within the waste management sector, we have identified specific measures whose impacts can be quantified under Slovak conditions or have shown significant effects based on successful examples from abroad. Measures aimed at increasing sorted waste collection include pay-as-you-throw collection, door-to-door sorted collection, collection of kitchen biowaste, textile recycling, and deposit systems. Landfill fees, or fees for energy recovery from waste, as well as pre-landfill waste treatment, directly influence waste management practices.

The table below presents the impacts of various measures on the change in mixed municipal waste production or landfill reduction. The estimated impacts of individual measures represent average values, which may vary in specific cases depending on various factors. The effectiveness of pay-as-you-throw collection depends on its form, the availability of infrastructure for sorted collection, and the level of municipal waste fees. The collection of kitchen biowaste may depend on the availability and convenience of infrastructure or the provision of information. Implementing multiple measures simultaneously can enhance the impact of each individual measure.

Table 14: Overview of impacts of selected measures

Type of the measure	Impact
Pay-as-you-throw	Mixed municipal waste decreases by 22%
Tag based collection	Mixed municipal waste decreases by *31%*
Volume-frequency collection	Mixed municipal waste decreases by *11%*
Sorted door-to-door collection in family houses	Mixed municipal waste decreases by 15%
Sorted collection of kitchen biowaste	
Apartment buildings – with wastebaskets	Mixed municipal waste decreases by 7%
Apartment buildings – without wastebaskets	Mixed municipal waste decreases by 5%
Family houses	Mixed municipal waste decreases by 6%
Combination of measures	
Tag based collection, sorted door-to-door collection and sorted collection kitchen biowaste in family houses	Mixed municipal waste decreases by 49%
Volume-frequency collection and sorted collection of kitchen waste, including household wastebaskets	Mixed municipal waste decreases by 26%
Landfill fee	Decrease in landfilled municipal waste by 0.11% with a 1% increase in the landfill price
Deposit refund system	Return rate on beverage packaging 90%
Sorted textile collection	Mixed municipal waste decreases by 2%
Mandatory treatment of waste before landfilling	Decrease of municipal waste landfilling by 45%

Source: IEP

In addition to the aforementioned measures, there are other actions or factors that we cannot or are unable to quantify, but which significantly impact municipal waste production and sorting rates. Among market and regulatory tools, examples include tax changes to stimulate demand for secondary materials, mandatory green public procurement, and improving the extended producer responsibility system. Measures aimed at influencing human behaviour include providing environmental education, which leads to increased awareness. People's behaviour is also influenced by the availability and suitability of infrastructure, the way measures and their significance are communicated, and the behaviour of others in their surroundings. Several studies have also confirmed the impact of demographic and socioeconomic characteristics of the population on waste production and sorting rates. Therefore, for proper policy design, it is important to analyse the characteristics of the population in the given area, test the measure on a random sample through a pilot project, and then evaluate and implement the measure accordingly.

Table 15: Overview of non-quantified measures

Type of the measure	Impact
Taxes	Increased use of secondary materials, demand for recycling and reuse
Expansion of the EPR system	
Other types of waste, littering	Increased recycling
Ecomodulation	Improved product design, increased recycling
Green public procurement	Increased use of secondary materials, demand for recycling
Behavioural measures	
Education *Infrastructure availability* *Feedback, targets* *Checking, fines*	Increased sorting, waste prevention

Source: IEP

Based on the results of studies and best practices from both abroad and Slovakia, the following recommendations can be summarized for the implementation of various measures:

- Ensure adequate infrastructure, which includes properly set distances, collection frequency, and cleanliness of containers;
- Provide information on waste management methods and the importance of sorting, as well as on waste prevention;
- Offer feedback and possibly set group targets;
- Assess the characteristics of the population in the area and test the measure with a pilot project;
- Ensure compliance monitoring and impose penalties if necessary.

4.1 Measures Focused on Collecting

4.1.1 Pay-as-you-throw Collection of Municipal Waste

Pay-as-you-throw collection is a fee system for waste that applies the "pay-as-you-throw" principle, motivating citizens towards environmentally responsible behaviour (Eunomia, 2003). The costs of collecting and disposing of mixed municipal waste and bulky waste, as

well as the costs for the recovery of sorted biowaste, are borne by municipalities, which collect waste fees from citizens for this purpose. The waste fee can be flat-rate or differentiated based on the amount of waste. According to literature, the latter option (hereinafter "pay-as-you-throw collection") is an effective tool for increasing the rates of sorting and recycling while simultaneously reducing the amount of waste sent to landfills or incinerators. While countries with recycling rates above 45% have implemented pay-as-you-throw collection to some extent, countries with recycling rates below 20% do not use any form of pay-as-you-throw collection (EEA, 2016).

Interest in pay-as-you-throw waste collection among municipalities is growing. While it was implemented in 167 municipalities in 2018, by 2022, this number had risen to 284. Consequently, 16% of the population now pays a fee based on the amount of waste they produce. However, most municipalities continue to charge residents an annual flat fee that is the same for everyone, regardless of the amount of waste produced. Thus, households generating more waste are partially subsidized by those generating less.

In practice, the fee is calculated based on the number of times the waste bin is emptied. The most commonly used method is volume-frequency collection, where the fee is determined by the frequency of bin emptying and the size of the bin. The second most common method is pay-as-you-throw collection using tags. Residents attach a tag to the bin to indicate they want it emptied. Similar systems use specific barcodes, QR codes, or RFID chips to identify bins. When residents want their bins emptied, they place them at a designated spot, the transporter scans the code, and the bin is emptied. Some municipalities use a combination of flat fees and some form of pay-as-you-throw collection. Typically, this means a pay-as-you-throw system for residents in houses and a flat fee for those in apartments.

An alternative approach sets fees based on the weight of the waste. Since 2020, the municipality of Dojč has been using weight-based fees with electronic bin tracking. Each bin's weight is recorded by collection trucks equipped with a reader and weighing system. The household waste fee is then determined based on the actual weight of waste produced in the previous year. While the weight-based system is more costly due to the need for weighing equipment and its calibration, it does not account for the volume of waste in the bin. This can result in unchanged collection frequencies and therefore unchanged collection costs.

Pay-as-you-throw collection in Slovakia reduces the production of mixed waste per capita by an average of 22%. This finding comes from an IEP study that examined the impact of implementing pay-as-you-throw collection on the production of mixed municipal waste and the sorted collection, using data on municipal waste and fee types from 2010-2018 (Institute for Environmental Policy, 2019). The results from the econometric model indicate that the introduction of tag based collection reduces the amount of mixed waste by nearly 31%, and volume-frequency collection by 11%. The impacts on sorted waste collection were low or not significant. However, this could be due to insufficient past records of sorted waste collection, missing data on home composting, or data from paper buyback centres. It was assumed that the reduction in mixed municipal waste would reflect an increase in the individual components of sorted waste collection, depending on their share of mixed municipal waste.

Table 16: Effect of pay-as-you-throw collection (% change compared to flat fee)

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

Source: IEP

Implementing pay-as-you-throw waste collection can be accompanied by challenges such as illegal disposal on unauthorized landfills or exporting waste to neighbouring municipalities without pay-as-you-throw collection. Therefore, alongside pay-as-you-throw collection, it is necessary to introduce preventive measures, such as installing real or dummy cameras with notices of potential fines. Another option is to implement a discount system for higher sorting rates or a two-component fee structure with a minimum fixed fee and a variable fee based on the amount of waste.

Introducing pay-as-you-throw collection in apartment buildings is more complicated compared to family houses, where each household typically has its own bin for mixed municipal waste, or sorting bins or bin bags for sorted collection. In contrast, apartment buildings share common infrastructure among multiple residents. Cities like Bratislava, Žiar nad Hronom, Dubnica nad Váhom, and Spišská Stará Ves use volume-frequency pay-as-you-throw collection in apartment buildings. While this system adjusts the collection frequency between different apartment buildings, it may not be fair to residents within the same building, as not everyone produces and sorts the same amount of waste. Issues also arise with unlocked shared collection points, which can be accessed by residents from other apartment buildings.

According to international best practices, locking containers and using chips or cards with specific identifiers for each resident or household appear to be suitable solutions. In the Italian city of Parma, residents can use "ecostations" if they miss waste collection day, accessed via health insurance cards (ZeroWasteEurope, 2018). The size or amount of waste disposed into a container can be measured by the container's opening size, allowing only a limited volume bin bag to pass through. In South Korea, containers weigh the discarded waste, and waste costs are subsequently charged based on the number of container openings or the weight of the waste, recorded using unique cards for each household.

Another option is the use of special bin bags marked with logos, QR codes, or RFID chips, which are purchased in advance at supermarkets, post offices, or municipal offices. The price of the bin bag includes the cost of collection and disposal or recycling of the waste. On collection day, residents place the bin bags at designated locations in front of apartment buildings, from where marked bin bags are collected. This system is used, for example, in Italian cities like Milan and Seveso, Belgian cities Gent and Destelbergen (Collectors, 2020), or Geneva in Switzerland (Household waste, 2021).

The introduction of pay-as-you-throw waste collection must be preceded by appropriate infrastructure setup and an informational campaign. The effective operation of pay-as-you-throw collection requires available and adequate infrastructure for sorted collection, ensuring collection from door-to-door. It is essential to create a sufficiently convenient and

motivating system for residents and provide them with necessary information before implementing the system.

In practice, municipalities encounter several barriers when implementing pay-as-you-throw collection. The current law on local taxes and fees creates legislative barriers to the effective implementation of pay-as-you-throw collection (Institute for Environmental Policy, 2019) . Calculating the fee based on collection frequency, as well as the method of fee collection itself, does not allow for the consideration of the actual number of collections. Possible solutions include payment of the fee in advance with subsequent settlement or setting the fee with the option to account for the actual number of collections from the previous year. A positive change proposed in the draft amendment to the law on local taxes and fees allows municipalities to reduce the fee for a resident who demonstrates sorting a specified proportion of municipal waste components. According to information from GX Solutions, which provides an automated electronic record system, municipalities face resistance from collection companies when it comes to providing access. These companies must agree to invest in installed reading devices and, most importantly, anticipate optimization or potential changes based on real transparent data. Other barriers include planning and readiness of local governments to finance such a system.

The draft amendment to the law[19] proposes the mandatory introduction of pay-as-you-throw collection in family houses starting in 2025 and in apartment buildings starting in 2030. Evaluation of the interdepartmental consultation process is still ongoing.

4.1.2 Sorted Door-to-door Collection

Sorted waste collection can be conducted in various ways: door-to-door collection, from shared collection points, or from civic amenity sites. In door-to-door collection, each household or family house has its own container for sorted waste. Civic amenity sites are primarily used for collecting bulky waste or minor construction debris, but they can also accept any type of sorted waste.

In Slovakia, sorted waste collection in apartment buildings is done through common collection points. Since 2023, door-to-door sorted waste collection has been mandatory for family houses. According to information provided by PRO Envipak, which covered approximately 1,100 municipalities in 2023, 100% of these municipalities have implemented door-to-door sorted waste collection. Similarly, PRO Nowas and Sewa, covering a total of 210 municipalities, reported full implementation of this system. For PRO Naturpack, door-to-door sorted waste collection is implemented in nearly all municipalities, though not universally. This is due to various obstacles, such as missing data needed for evaluation, and technical and spatial limitations, especially in larger municipalities. Eighteen EU member states collect paper and plastics via door-to-door collection, and 14 countries, including Slovakia, collect biowaste this way (Seyring, et al., 2016). Glass is mostly collected through shared collection points.

Implementing a door-to-door collection system increases the sorting rate and improves the quality of recyclable materials ((Seyring, et al., 2016; Seyring, et al., 2016), (OECD,

[19] LP/2022/725 Act amending Act No 39/2013 Coll. on integrated pollution prevention and control

2006)). Introducing door-to-door collection boosts the sorting of plastics, glass, and metals by 20% compared to collection at common points (Jenkins , et al., 2003). Common collection points are usually located farther from homes, thus providing less motivation for residents to sort their waste. Additionally, shared infrastructure leads to higher contamination of sorted waste. An analysis of a pilot project in single-family homes in Bratislava showed that the contamination rate of sorted plastic was only 11% with bin bag collection, whereas it was as high as 38% with common collection points. Contamination of paper in blue bin bags dropped to 4% compared to 16% at common collection points (Zber a odvoz, 2021). According to an analysis by PRO Naturpack, contamination is higher with common collection containers compared to door-to-door collection in other Slovak municipalities as well, with differences in average contamination levels ranging from 35% to 72% unfavourable for shared collection in apartment buildings (Naturpack, 2022).

Table 17: Pollution rate of sorted waste by type of collection

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

Source: IEP based on data from Naturpack and Envipak

The impact of implementing door-to-door sorted waste collection in Slovakia was estimated using a fixed effects regression model and the matching method, similar to the effect of pay-as-you-throw waste collection in the previous IEP study (Institute for Environmental Policy, 2019). Unlike data on the implementation of quantity-based collection, data on door-to-door collection are not available for the entire country. Therefore, our estimate relied on data from 57 municipalities in the Ponitrie Association of Municipalities, where door-to-door collection was introduced in September 2014[20]. Additionally, we used a list of 1,180 municipalities provided by PRO Naturpack, indicating whether a municipality had door-to-door sorted collection in 2020. Since the exact introduction dates for door-to-door collection in these municipalities were unknown, we only included 366 municipalities that did not employ door-to-door collection. We further verified the implementation of door-to-door sorted collection in 32 municipalities from the Naturpack list, which also had quantity-based collection, through email and phone communication.

Using the fixed effects model for municipalities and years, we compared waste production before and after the introduction of door-to-door collection, accounting for other socioeconomic and demographic variables that could influence waste production. We estimated the following equation:

$$Q_{it} = \alpha_{0i} + \alpha_{1t} + \beta_1 DtD_{it} * PAYT_{it} + \beta_2 DEN_{it} + \beta_3 Under4_{it} + \beta_4 Over65_{it} + \beta_5 Income_{it} + \varepsilon_{it} \quad (3)$$

Q_{it} denotes the amount of mixed or sorted waste in municipality *i* in year *t* (in kilograms per capita),

[20] Each family house received 3 120l containers for paper, plastic and garden bio-waste. The glass containers are shared, distributed throughout the villages.

DtD_{it} equals 1 if the municipality has implemented door-to-door collection in the given year and 0 if not,

$PAYT_{it}$ equals 1 if the municipality has implemented quantity-based collection in the given year and 0 if it has a flat fee,

$DEN_{it}, Under4_{it}, Over65_{it}$ are demographic variables representing population density, the share of residents over 65 years old, and the share of residents under 4 years old,

$Income_{it}$ is an economic variable representing the median monthly income for full-time or part-time employment,

α_{0i} and α_{1t} are fixed effects for municipalities and years.

The use of individual socioeconomic and demographic variables in estimating waste production is explained in the previous analysis (Institute for Environmental Policy, 2019). We also added an interaction term with the measure of implementing pay-as-you-throw collection, which has a significant effect on waste production. Thus, besides the effect of door-to-door collection alone, we estimated the effect of implementing both measures: door-to-door sorted collection and pay-as-you-throw collection. In our estimation, we included only municipalities with less than 10% of apartment buildings in the total number of houses. Several cities, such as Bratislava and Košice, use door-to-door collection but only in family houses. Data from such municipalities could skew the results. Overall, we compared 302 municipalities, with 43 using only door-to-door sorted collection, 12 using only pay-as-you-throw collection, and 17 using both types of collection.

An alternative method to standard regression analysis for estimating the impact of a measure is the matching method, which aims to find matching units from the control group for each unit in the treated group based on their characteristics and then compare the output values. Using the matching method, we verified the results of the fixed-effects model for municipalities that implemented both types of collection. The control group consisted of municipalities that did not use either pay-as-you-throw collection or door-to-door sorted collection.

In the analysis, we employed the propensity score matching method, which represents the conditional probability of implementing a measure given certain observed explanatory variables (Rosenbaum & Rubin , 1983). We estimated the probability of implementing both the door-to-door collection system and the pay-as-you-throw collection using the same explanatory variables as in equation (4) as follows

$$\ln\frac{p}{1-p} = \beta_0 + \beta_1 DENPAYT_{it} + \beta_2 Under4_{it} + \beta_3 Over65_{it} + \beta_4 Income_{it} + \varepsilon \qquad (4)$$

Table 18: The effect of door-to-door and pay-as-you-throw on waste production

	Mixed municipal waste
Effect of pay-as-you-throw collection	-20.0%
Effect of door-to-door sorted collection	-15.0%
Effect of Both Collections Combined	
Fixed Effects Model	-24.6%
Matching method	-25.1%

Source: IEP

The results indicate that door-to-door sorted waste collection, as opposed to collection at shared collection points, significantly reduces mixed municipal waste production by 15%. This reduction in mixed municipal waste is due to the sorting of paper, plastics, composite packaging, and metal packaging, for which the collection infrastructure has been altered. Since glass is almost exclusively collected through shared collection points, its sorting is not expected to have changed. The effect of pay-as-you-throw on mixed municipal waste production is nearly identical to the previous analysis results, which compared all municipalities in Slovakia, thus proving the robustness of the findings (Institute for Environmental Policy, 2019).

However, the actual impact for a specific municipality may vary, potentially being lower or much higher. A municipality with higher fees, a straightforward system with suitable collection frequency, greater environmental awareness, an active mayor in environmental matters, or better information campaigns and data tracking can achieve better results. For example, in the municipality of Šútovce, the introduction of bin bag sorted collection with QR code monitoring in 2020 led to a 38% reduction in mixed municipal waste production and a 180% increase in sorted collection. This success was aided by a discount system that reduced fees for higher sorting rates and by providing composters to every household.

Door-to-door sorted collection had a significant effect in Italy, where mixed municipal waste production fell by almost two-thirds. However, the conditions in Italy are considerably different. The introduction of door-to-door collection there is accompanied by information campaigns, with each household receiving small 30-40 litre bins for paper, plastics, glass, and biowaste, collected at high frequencies. For biowaste, collection occurs two to three times a week, while mixed municipal waste is collected once or twice a week. On average, households in Italy set out mixed municipal waste only once or twice a month. However, the average cost of municipal waste management in Italy is significantly higher compared to Slovakia, which can also influence and alter residents' motivations for increased sorting.

Box 3: The impact of door-to-door collection in the Italian region of Puglia

Door-to-door collection is widespread in Italy, with up to 66% of households using this system (Laurieri, et al., 2020). Municipalities or cities with door-to-door collection achieve a sorting rate of over 80%, compared to the national average of around 56% (ISTAT).

An example is the Italian region of Apulia, where at least 72 out of a total of 258 municipalities use this collection system. Each household is provided with 30-40 litre bins or bin bags not only for mixed waste but also for sorted waste, including kitchen biowaste. On collection day, residents place their bins or bin bags at a designated spot in front of their homes, and after collection, they bring them back indoors. The largest city in the region, Bari, employs this system with a population of just under 330,000.

The impact of introducing door-to-door collection was estimated based on monthly data on municipal waste production and sorting of individual components in municipalities in the region from 2008 to 2020 (Puglia, 2020). We used data from only 72 municipalities out of the total 258, as we did not have data for the others on whether they had

implemented door-to-door collection. For the estimation, a simple regression model was used.

Municipalities that implemented door-to-door collection averaged a 63% reduction in mixed municipal waste production after the system was introduced. The average production of mixed municipal waste thus decreased from 410 kg to 136 kg per capita. For comparison, in Slovakia, this value is 220 kg per capita.

The amount of sorted plastics increased by 46%, paper by 72%, and glass by 114%. The amount of kitchen biowaste sorted increased by 330%, while garden organic waste slightly decreased by 22%. This could be due to some biowaste, such as fruit and vegetable peels, being moved into kitchen biowaste. Overall municipal waste production decreased by 14%. After the introduction of door-to-door collection, the sorting rate averaged 56%, compared to the previous rate of only 15%.

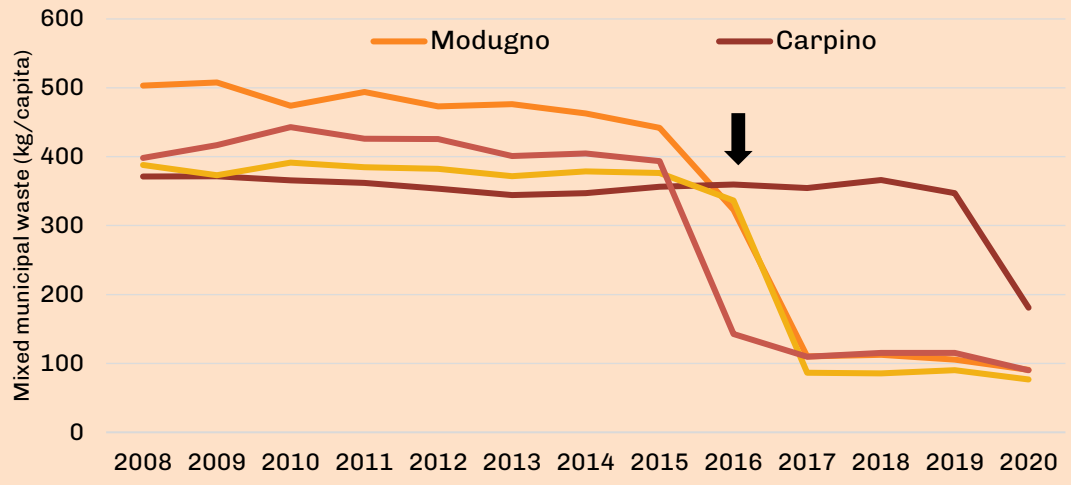
Table 19: The effect of door-to-door collection on waste production

	Mixed municipal waste	Plastics	Glass	Paper	Kitchen biowaste
Effect	-63%	46%	114%	72%	330%
Production after implementation of the system (kg per capita)	136	14	27	18	107

Source: IEP

Thanks to the increased sorting rate, municipalities managed to reduce the landfill fee, which depends on sorting in the previous year. One year after the introduction of door-to-door collection, municipalities managed to reduce the fee by almost half.

Graph 22: Implementation of door-to-door collection in selected areas of Italy



Source: IEP

Implementation of door-to-door waste collection had a significant impact in Italy on reducing mixed municipal waste and increasing recycling rates. However, these results cannot be directly applied to Slovakia due to unobserved socio-economic and demographic indicators that could influence the effectiveness of the system on waste production. In Italy, extensive information campaigns were part of the system implementation, which greatly assisted its adoption. Door-to-door collection is also very convenient, with each household having containers for each type of waste and a high

frequency of waste collection. Moreover, waste management costs in Italy are significantly higher; in 2015, average costs for a family of three reached nearly 200 euros per capita in purchasing power parity terms (Cittadinanzattiva, 2020), whereas in Slovakia, it was only 18 euros per capita in 2018 (Institute for Environmental Policy, 2019). These factors can significantly influence and alter residents' motivations toward higher levels of waste sorting.

4.1.3 Sorted Collection of Kitchen Biowaste

Since mid-2021, municipalities in Slovakia have been required to ensure sorted collection of kitchen biowaste. Prior to 2021, this type of waste sorting was practically non-existent across Slovakia, operating only in a few dozen municipalities. As a result, kitchen biowaste accounts for an average of up to 24% of mixed municipal waste, amounting to 51 kg per capita in 2019. According to waste management legislation, all municipalities have been mandated since 2021 to implement sorted collection of kitchen biowaste, with exceptions only for those municipalities where 100% of households can demonstrate composting[21]. Until 2023, exemptions were also granted to municipalities that have secured energy recovery from waste or parts of municipalities where technical issues prevent collection in historical city centres or sparsely populated areas.

In apartment buildings, sorted collection through communal bins predominates, while in family houses, kitchen biowaste is mainly collected through home composters. According to statistics from the Statistical Office of the Slovak Republic, municipalities and cities opted for sorted collection of kitchen biowaste for 90% of households in apartment buildings. Conversely, more than half of family houses utilize home composters. By employing home composting, municipalities save costs on waste collection and valorization of biowaste. Data also indicate that approximately 11% of households in apartments or family houses did not have infrastructure for sorted collection of kitchen biowaste in 2022, with 317 municipalities lacking any such infrastructure.

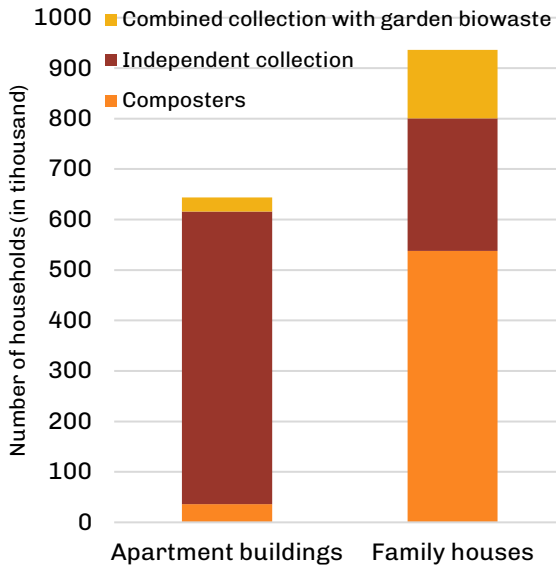
In 2022, approximately 37 thousand tonnes of kitchen biowaste were sorted from households, averaging 14 kg per capita. We estimate a sorting rate of 23% from the total potential in mixed municipal waste. These estimates are based on municipalities where sorted collection of kitchen biowaste through communal bins was introduced. We assumed that the reported kitchen biowaste originates only from households with access to communal bins, not from those using home composters, as home composting is not monitored.

We estimate that the introduction of kitchen biowaste collection achieves an 18% sorting rate from the potential in mixed municipal waste. With a more convenient collection method involving baskets for each household, the effect is slightly higher, reaching up to 24% sorting from the potential. These figures stem from data on kitchen biowaste sorting in 2022 (see Box 4 for more details). The basic collection approach involves providing containers for biowaste sorting, as implemented in cities such as Poprad, Banská Bystrica, or Martin. A more comfortable system setup includes distributing baskets or buckets and biodegradable bin bags to each household. In cities like Žilina, Trnava, Trenčín, Nové Zámky, or Žiar nad Hronom, every apartment household received a small basket for kitchen

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

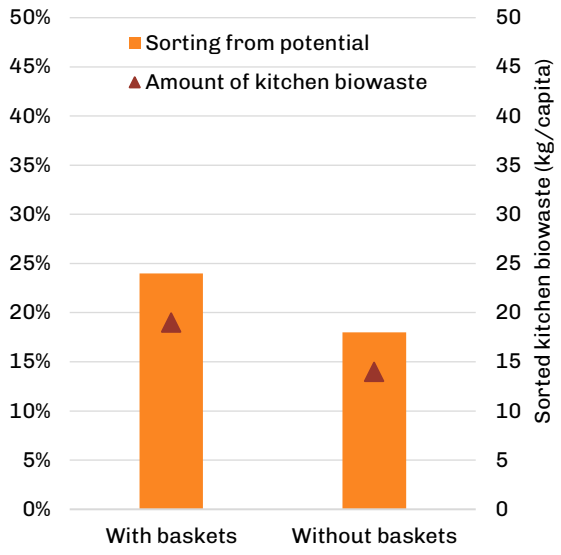
biowaste collection along with biodegradable bin bags and an information leaflet on proper sorting. Residents then dispose of filled bin bags into communal bins near apartment buildings. These cities achieved a sorting rate of approximately 24% in 2022. These results align with international practices and findings from a Slovak study conducted in 2022 (ZOH, 2022).

Graph 23: Methods of kitchen biowaste collection in Slovakia



Source: IEP

Graph 24: Sorting of kitchen biowaste (kg/capita)



Source: IEP

We estimate that implementing sorted collection of kitchen biowaste through home composters or door-to-door collection in family houses will lead to a 40% sorting rate from its potential, based on experiences from the town of Topoľčany. For comparison, municipalities where family houses constitute more than 99% of the built-up area and register non-zero amounts of garden biowaste achieved a sorting rate of approximately 62% for garden biowaste in 2019. A similar level of sorting can thus be expected for kitchen biowaste in family houses. When using home composting, the sorted amount of kitchen biowaste does not enter the municipal waste records, resulting only in a reduction of mixed municipal waste.

Table 20: Effect of sorted collection of kitchen biowaste

	Sorted from the potential in mixed municipal waste	Decrease of mixed municipal waste
Apartment buildings		
Without wastebaskets	-18%	-5%
With wastebaskets	-24%	-7%
Family houses		
Door-to-door/ composters	-40%	-6%

Source: IEP

Box 4: Estimated impact of introducing sorted collection of kitchen biowaste

Slovakia

The impact of introducing kitchen biowaste collection was estimated based on experiences from abroad and Slovak cities and municipalities from 2022. Data from the Statistical Office of the Slovak republic provided insights into the amounts of sorted kitchen biowaste at the

municipal level, as well as collection methods in apartments and houses. Additionally, we researched information for 78 municipalities to determine if they utilize waste basket and bin bag collecting systems for households. The total potential of kitchen biowaste in mixed municipal waste was derived from composition analyses for the years 2020 to 2023. For apartment buildings, we considered a potential of 31%, and for houses, 16% of kitchen biowaste in mixed municipal waste. The rate of sorting from potential was subsequently calculated as the proportion of the collected amount of kitchen biowaste to its potential in mixed municipal waste.

Foreign Practices

In the Italian city of Parma (Ricci, 2020), a system for collecting kitchen waste in large containers resulted in sorting about 50 kg of kitchen biowaste per capita. Following the introduction of door-to-door and quantity-based collection, sorting doubled to just under 100 kg per capita, including approximately 20% from restaurants and canteens. Moreover, contamination of containers decreased from 8.3% to 3.3%.

In the Treviso region of Italy, door-to-door biowaste collection combined with quantity-based collection increased sorted kitchen biowaste to 82 kg per capita annually (Contarina Spa, 2016). According to analyses, biowaste constitutes less than 1% of mixed municipal waste.

In Malmö, Sweden (Heinrich K., 2018), kitchen biowaste collection using waste baskets and paper bin bags in every household resulted in an average of 51 kg per capita annually, representing 47% of its potential. The collection was accompanied by a campaign including advertisements in cinemas, newspapers, billboards, and buses.

According to a Dutch study (VANG Household Waste, 2020), providing a biowaste basket to each apartment household led to regular sorting by an average of 20% of households. Additional measures such as adjusting infrastructure distances, providing information on the importance of sorting, setting group goals, and offering feedback further improved results.

4.1.4 Combination of Measures

Implementing multiple measures simultaneously can lead to an increased impact of each individual measure. This primarily includes introducing door-to-door collection and sorted collection of kitchen biowaste in combination with quantity-based collection. Quantity-based collection can enhance the effectiveness of door-to-door sorted collection compared to shared containers. Citizens can also be incentivized to increase sorting of kitchen biowaste when infrastructure is provided and waste charges are based on quantity.

The introduction of door-to-door sorted collection combined with quantity-based collection reduces the production of mixed municipal waste by an average of 25%. This is derived from results of a fixed-effects regression model and matching methods outlined in section 4.1.2. Both practice and foreign literature indicate that door-to-door collection is conducive to better functioning of quantity-based collection (European Commission, 2018). When households have sorting containers not only for mixed but also sorted waste, it becomes feasible to track the sorting rate of each household. Such a system allows for setting various discounts for those who sort more or produce less waste, while also enabling monitoring to prevent illegal disposal in black dumps. Due to data limitations, it was not possible to analyze the impact of combining these two measures separately for tag based and volume-frequency collection. We assume a proportionally similar increase in the

effectiveness of quantity-based collection; thus, for tag based collection combined with door-to-door sorted collection, we estimate an effect of 39%.

Introducing quantity-based collection alongside sorted kitchen biowaste collection in apartment buildings can motivate citizens to achieve even higher sorting rates of kitchen biowaste up to 60% of its potential. According to the results of previous analyses, implementing tag based or labelled container collection leads to an average 31% reduction in mixed municipal waste production (Institute for Environmental Policy, 2019). This effect can be attributed to increased sorting of components such as paper, plastics, glass, and garden biowaste. We assume this effect does not include sorting of kitchen biowaste, as few municipalities historically provided infrastructure for this waste type. Considering the composition of mixed municipal waste, implementing quantity-based collection can therefore estimate sorting of 60% of the potential for paper, plastics, glass, and garden biowaste. Following the introduction of kitchen biowaste collection in a municipality with quantity-based collection, sorting up to 60% can be expected compared to 40% in a municipality without quantity-based collection. The mentioned municipality of Trnavá Hora achieved sorting rates of 69% through a combination of tag based collection and sorted kitchen biowaste collection via shared containers.

Table 21: Estimation of the impact of the combination of measures on mixed municipal waste

	PAYT, D2D	PAYT, FOOD	PAYT, D2D, FOOD
Family houses	**-39%**	**-41%**	**-49%**
of which paper, plastics, glass	-23%	-15%	-23%
of which garden biowaste	-16%	-16%	-16%
of which kitchen biowaste	-	-10%	-10%
Apartment buildings	**-11%**	**-26%**	**-**
of which paper, plastics, glass	-11%	-11%	-
of which kitchen biowaste	-	-15 %	-

**PAYT – pay-as-you-throw*
D2D – door-to-door sorted collection in family houses
FOOD – sorted collection of kitchen biowaste
Source: IEP

4.1.5 Deposit Refund System for Plastic Beverage Containers and Cans

Since 2022, Slovakia has implemented a deposit system for single-use plastic and metal beverage containers. The deposit amount is set at 15 euro cents (Deposit Administrator, 2023). According to the IEP study, such a deposit rate is expected to achieve a return rate of over 90%, based on data from other countries with established deposit systems (Inštitút environmentálnej politiky, 2018). The system provides direct financial incentives for container return, thereby promoting higher recycling rates, reducing landfilling, and minimizing littering in nature. However, compared to curbside recycling, this system is relatively costly and also increases the cost of the current curbside recycling. This is because current curbside recycling does not benefit from eco-modulation and subsidies for well-recyclable materials like PET and aluminum are redirected to subsidize curbside collection of other materials (Institute for Environmental Policy, 2020).

In Slovakia, the deposit system operates under a centralized model, similar to those widely used in Scandinavian countries, organized by associations of producers. The central system's role is to coordinate activities, finance the system, and act as a clearing center for involved parties. The entire system is funded by manufacturers through an administrative fee per bottle/can. Costs incurred by retailers for manual or automated collection are covered through a handling fee (Deposit return system Administrator, 2023). In 2022, the system's costs amounted to just under 46 million euros, approximately 4 euro cents per beverage container (Deposit return system Administrator, 2022).

In its initial year, the return rate for deposited containers reached 72%, with an expected gradual increase to 90% or more (Deposit Administrator, 2023). At the current deposit rate of 15 euro cents (Deposit return system Administrator, 2023), a return rate of over 90% is anticipated based on data from other countries with established deposit systems (Inštitút environmentálnej politiky, 2018). Prior to the introduction of the deposit system, the estimated sorting rate for PET beverage bottles was 62%. The increase in return rates has led to a decrease in the proportion of deposited containers in mixed municipal waste. According to waste composition analyses by JRK for the years 2020-2021 and 2022-2023, post-introduction of the deposit system, the share of PET in mixed municipal waste decreased from 1.32% to 0.07%.

Table 22: Deposit refund system results for single-use beverage containers in 2022

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

Source: Deposit return system Administrator

4.1.6 Sorted Collection of Textiles

Starting in 2025, EU member states are required to implement sorting collection systems for textiles. Currently, only two countries have established such systems. France and Estonia are the only nations with mandatory sorted textile collection (Joint Research Institute, 2021). The collected textiles are primarily intended for reuse or recycling. The European Commission also proposes the introduction of mandatory Extended Producer Responsibility (EPR) in the textile sector, which would help member countries achieve the goal of implementing sorting collection (European Commission, 2023). EPR for textiles has been in place in France for a long time (more details in Box 5), was introduced in the Netherlands in 2023 (Government of the Netherlands, 2023), and is planned for introduction in Sweden (EEA, 2022). France aims to collect 50% of the textile volume placed on the market, while the Netherlands has set a goal of 75% recycling or reuse by 2030.

In Slovakia, sorting collection of textile waste is currently not mandatory but is done on a voluntary basis, resulting in the collection of only 13% of textiles. According to a representative sample, 77% of Slovak municipalities are involved in the sorting collection of textile waste (MoE SR, 2022). The collected textile waste, after sorting out reusable textiles, is transported to neighbouring countries for further sorting. According to data from the Statistical Office of the Slovak Republic, 9410 tonnes of textile waste were sorted in 2022. Analysis by JRK indicates that textile waste constitutes nearly 5% of mixed municipal waste. The total production of textile

waste from households is estimated at 58,000 tonnes, or 10.5 kg per capita. The average production in the EU is similar, at approximately 11 kg per capita (European Commission, 2022).

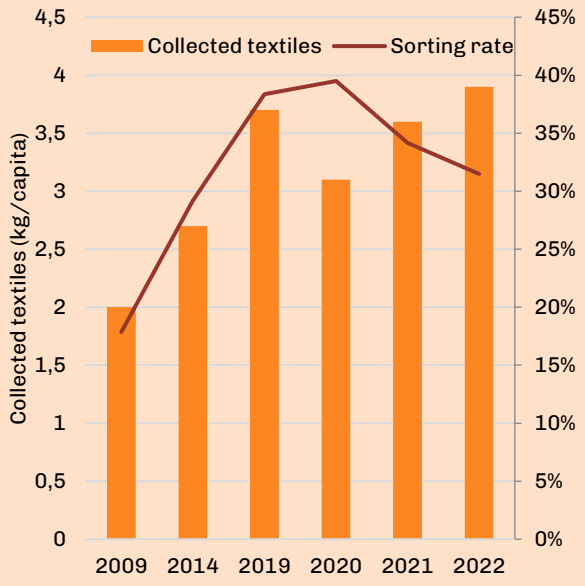
With the introduction of EPR for textiles in Slovakia, we estimate a gradual increase in the collection rate to 20-40%. This estimate is based on the experience of the system in France, which has been operational since 2007. Initially, France collected 20% of textiles, with the rate rising to nearly 40% by 2020. In Slovakia, this would equate to approximately 2.7 to 5.4 kg per capita annually. Currently, France has one collection container for every 1441 inhabitants, and an equivalent system in Slovakia would require about 3780 containers. Ekocharita already operates over 1500 collection containers across Slovakia. Since data on the costs of collection, sorting, and recovery of textiles are not available, we estimated the total cost of the EPR system for textiles based on the costs in France. Adjusting for purchasing power parity, we estimate the costs to be 57 euros per tonne.

Due to the lack of detailed cost data for sorting textile collection, such as the purchase of containers, collection, sorting, and processing, the overall estimated cost was categorized under collection and infrastructure.

Box 5: EPR for textiles in France

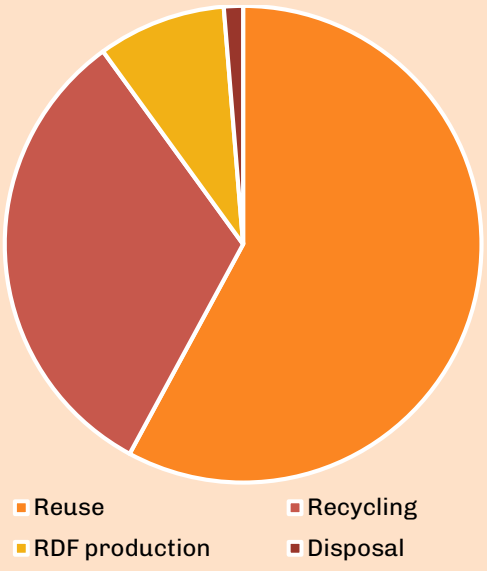
In France, an Extended Producer Responsibility (EPR) system for textile products, including clothing, footwear, and linen, has been in place since 2007. Similar to other EPR systems, manufacturers contribute based on the annual costs of Producer Responsibility Organizations (PROs), which handle not only the collection and processing of waste but also communication, research, development, and education in waste management. The largest PRO manages waste for 95% of the French textile industry. The fees for declared textiles are calculated per unit of product. The average contribution by a textile industry producer per piece is 0.3897 euros for clothing, 0.4326 euros for footwear, and 0.4395 euros for linen, depending on the size and type of the product. On average, producers pay the PRO 71 euros per tonne of textiles.

Graph 25: Trends in collected textile waste in France (tonnes)



Source: IEP

Graph 26: Share of processed sorted textiles



Source: IEP based on data from PRO ReFashion

The goal is to collect at least 50% of the annual volume of textiles sold, which amounts to around 300,000 tonnes or approximately 4.6 kg per person per year. In the past three years, the collection rate has been between 30% and 40%. The target for processing the collected textiles is set at 95%. In 2022, the Producer Responsibility Organization (PRO) collected 260,403 tonnes of textile waste, averaging 3.9 kg per person per year. From the collected volume, 187,609 tonnes were sorted, while over 6,500 obligated entities produced a total of 826,935 tonnes of textiles and footwear (ReFashion, 2022). In 2022, the largest PRO collected a total of 36.6 million euros from the entities, and the costs for 67 sorting facilities and 47,000 collection containers amounted to 22.6 million euros.

4.2 Management Measures

4.2.1 Landfilling Fee

Landfill fees in Slovakia remain among the lowest in the EU, insufficiently motivating people to sort their waste. In 2018, Slovakia had one of the lowest landfill fees for municipal waste, at only 7 euros per tonne, and was among the worst countries in terms of landfill rates. Starting in 2019, the fees began to increase gradually, depending on the sorting rate of the municipality in the previous year. Between 2019 and 2021, the average landfill fee increased from just under 10 euros 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.

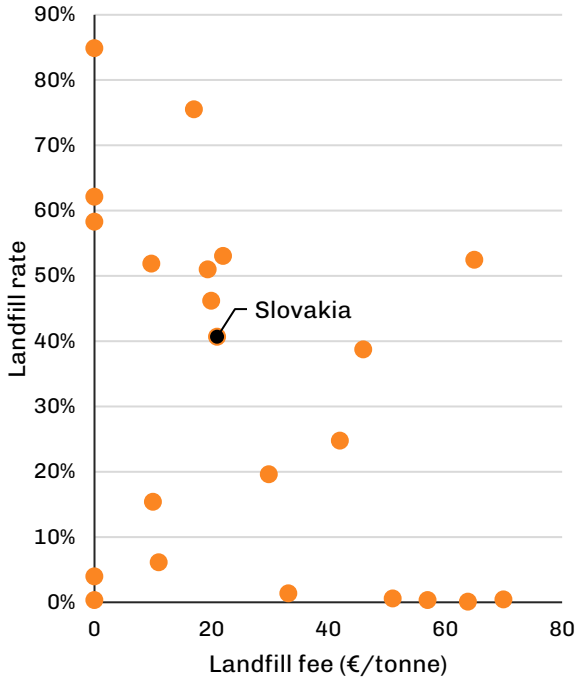
Several studies indicate a significant correlation between higher landfill fees and the rate of municipal waste landfilling (Bartelings & Linderhof, 2000). The effectiveness of landfill fees depends on the extent to which the fee change is reflected in the waste producer's behaviour. An increase in landfill fees in the service sector leads to reduced waste production and landfilling and increased recycling (Bartelings & Linderhof, 2000). However, no significant impact was found for municipal waste. The study attributes this to the use of flat fees for municipal waste, where there is no direct correlation between the cost of collection and disposal and waste production.

Increasing or introducing landfill fees has often been accompanied by additional measures to support recycling and sorting or by banning the landfilling of certain types of waste, making it challenging to isolate the effect of the fee change alone. A meta-analysis by (Acil Allen Consulting, 2014) estimates the arc elasticity of landfilling based on 26 studies at -0.11. This means that a 1% increase in landfill fees reduces the amount of waste landfilled by -0.11%. The reduction in landfilling can correspond to an overall reduction in waste production or an increase in sorting rates. Studies estimating cross-elasticity (Fullerton & Kinnaman, 1996), (Isely & Lowen, 2007), i.e., the effect of landfill fees on waste sorting, differ and do not agree on whether the effect is significant. We assumed that 50% of the waste diverted from landfilling would be sorting and the remaining 50% would not be produced due to waste prevention.

In addition to landfill fees, a landfill ban can also be introduced. In nine EU countries, there is a ban on landfilling combustible waste with an average organic carbon content of more than 5%, related to the waste's calorific value (Cewep, 2022). Five countries have a ban on

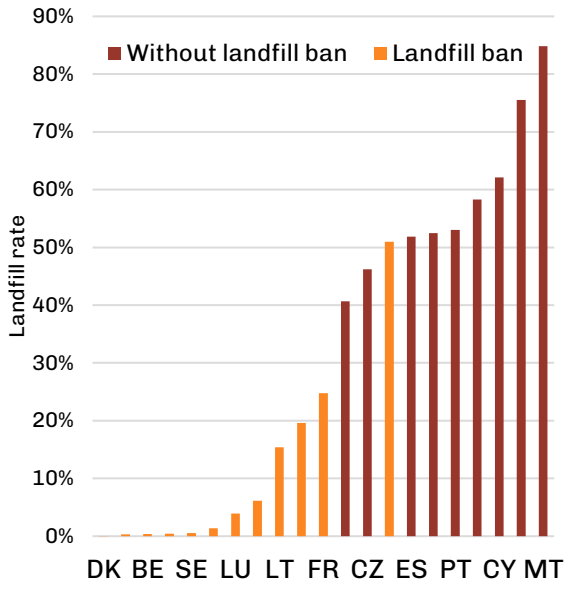
landfilling unsorted and untreated waste. The average municipal waste landfilling rate in these countries in 2021 was around 10%. The exception is Poland, which introduced a ban on landfilling high-calorific waste in 2016 without sufficient time to build capacities for its recovery. In other EU countries without landfill bans and with low landfill fees, the average landfilling rate in 2021 was 58%. In Slovakia, a ban on landfilling untreated municipal waste is expected to come into effect in 2024, but this ban has already been postponed several times[22].

Graph 27: Landfilling fees in 2021



Source: IEP based on data from Eurostat, CEWEP

Graph 28: Landfill Bans on High-Calorific Waste



Source: IEP based on data from CEWEP

4.2.2 Energy Recovery Fee

Within the EU, nine countries have implemented a fee for energy recovery, i.e., waste incineration. The fees range from 5 to 75 euros per tonne, and in some countries, the fee amount depends on the type of waste and the disposal method (EEA, 2023). In Belgium, a lower fee applies to incineration with energy recovery, while a higher fee applies to incineration without energy recovery. In France, there is a tax exemption for incineration with energy recovery and high energy efficiency. Spain applies a lower fee to outputs from mechanical biological treatment. Latvia and Italy have this fee only for waste incineration. Sweden had an energy recovery fee for two years, but it was abolished in 2023 due to changes in the European electricity market (IEA Bioenergy, 2023).

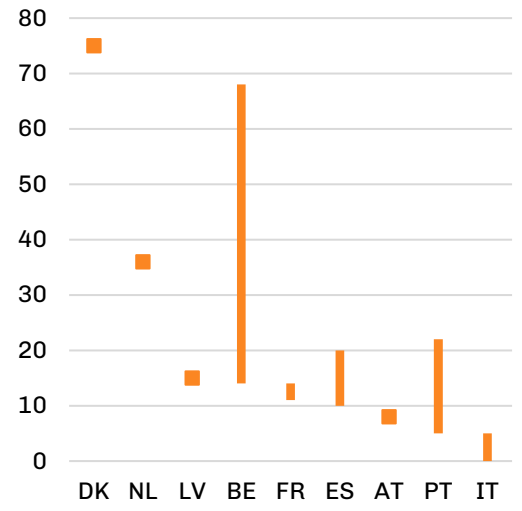
The goal of the fee is to promote recycling; however, no study has currently confirmed a direct impact on the recycling rate (OECD, 2019). In Belgium and the Netherlands, the energy recovery fee aims to encourage recycling and reduce dependence on waste-to-energy processes. According to the Dutch government, the fee amount, which is adjusted

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

annually, is sufficiently motivating. Despite a sharp increase in the fee 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 grow. Literature confirms that tax rates must be set based on market conditions, considering the marginal costs of alternative waste management options (Weerdt, 2022).

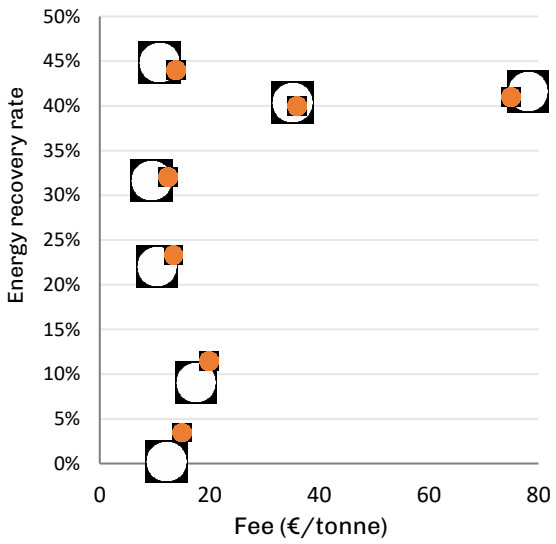
Additionally, the purpose of the fee is to include the impacts of pollutants and emissions from energy recovery and incineration (Freire-González, et al., 2022). In Denmark, the energy recovery tax depends on the calorific value of the waste and the amount of heat produced. The aim is to limit the energy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

Graph 29: Fees for municipal waste energy recovery (euros/tonne)



Source: IEP based on data from EEA

Graph 30: Rate of energy recovery and fee for energy recovery



Source: IEP

The European Commission (EC) plans to integrate waste-to-energy into the EU ETS. In line with the European Green Deal, the EC aims to incorporate waste-to-energy facilities into the ETS system. Starting from 2024, member states will be required to monitor and report emissions produced by the combustion of fuels in municipal waste incineration facilities (Directive 2003/87/EC). By 2026, the EC will assess the feasibility of including municipal waste incinerators in the EU ETS from 2028, with the possibility for member states to delay this inclusion until 2030.

4.2.3 Mandatory Treatment of Waste before Landfilling

The goal of treating waste before landfilling is to stabilize the organic fraction in municipal waste, thereby reducing greenhouse gas emissions and the overall amount of waste sent

to landfills. According to the amended Waste Act, starting in 2024[23], only waste that has undergone treatment can be landfilled. This measure is based on the EU Waste Directive[24], which mandates that countries reduce the proportion of biological waste in landfills. Mechanical biological treatment (MBT) is primarily considered such a treatment. In Slovakia, MBT will need to meet specific technical parameters related to oxygen consumption (AT_4) and methane production (GS_{21}).

The dry fraction sorted during mechanical treatment can be used as RDF due to its calorific value. Up to 45% of mixed municipal waste can be used to produce RDF (Stoiber, et al., 2020). Since the law and relevant decree[25] do not specify further details of the treatment, additional sorting of recyclable components is not anticipated.

It is expected that 45% of waste will be used as RDF in cement plants for energy recovery because the costs of selling RDF to cement plants are lower compared to landfilling. Additionally, from 2027 onward, it will no longer be permissible to landfill the calorific fraction of treated waste. Stabilized biowaste, which would constitute 25%, would either be landfilled or used for reclamation purposes. Using it for compost production is unsuitable due to the potential presence of harmful substances. The remaining 25% of waste, which shows no biological activity and is non-combustible, can be landfilled.

Most operators of future MBT facilities confirmed the ability to process bulky waste, which will also be subject to the ban. The utilization of treated bulky waste is based on a Belgian analysis, which found that 82% of bulky waste consists of combustible materials and 18% is inert waste (Bel, 2019).

The mandatory treatment of waste before landfilling has been repeatedly postponed. The ban on landfilling untreated waste has been delayed several times, in 2021 and 2023, due to insufficient capacities and the unpreparedness of facility operators.

4.3 Non-quantified Measures

In addition to the quantified measures, there are other measures or factors that we cannot or are unable to quantify but which may have a significant impact on the change in municipal waste production and the rate of sorting. In the realm of market and regulatory tools, this includes changes in taxes to stimulate demand for secondary materials or mandatory green public procurement. Another measure is the improvement of the extended producer responsibility (EPR) system by adding additional types of waste, differentiating fees for various materials based on their environmental impact, and supporting more eco-friendly product design.

To improve waste collection and management, it is also necessary to increase public environmental awareness through education, providing information, offering convenient infrastructure, and other behavioural stimuli such as feedback, removing anonymity, and

[23] 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.
[24] Directive 2018/850
[25] Decree 26/2021 Coll. on landfilling and storage of waste mercury

enforcing compliance with obligations. Measures aimed at waste prevention and reuse play an irreplaceable role in adhering to the waste management hierarchy.

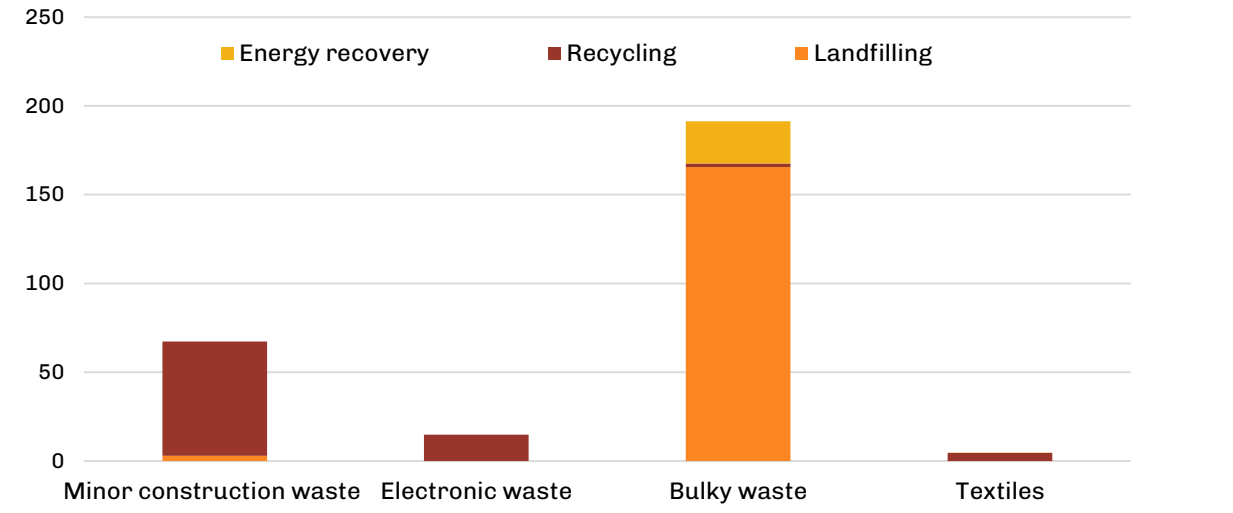
4.3.1. Mandatory Waste Treatment before Landfilling

According to the waste management hierarchy, the top priorities for waste management are waste prevention, followed by preparation for reuse. Promoting waste prevention, along with reuse and preparation for reuse through the implementation of measures from the Waste Prevention Program of the Slovak Republic 2019-2025 (MoE SR, 2018), is an essential and key part of Slovakia's long-term efforts to reduce the amount of waste generated within its territory.

Quantifying measures aimed at waste prevention or reuse is often challenging. According to EEA guidelines, it is difficult to establish a direct link between specific measures and waste production, especially for measures that target human behaviour and whose effects may be delayed (EEA , 2021). The guidelines recommend collecting relevant data, conducting surveys, developing indicators, and evaluating the impact of these measures. In the European reference model from the EEA, which we used as a basis, the section on waste prevention measures was also not used due to a lack of data on the quantitative effects of these measures (EEA, 2018).

Prevention and reuse have significant potential for improving the state of 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. The introduction of mandatory waste treatment before landfilling and the subsequent ban on landfilling the combustible fraction will lead to the energy recovery of this waste. A better alternative is prevention and reuse. Bulky waste is considered a priority for reuse (MoE SR, 2018). Other wastes suitable for reuse include small construction waste, waste from electrical and electronic equipment, and textiles and clothing.

Graph 31: Selected types of municipal waste suitable for reuse



Source: IEP

According to a British study, up to 32% of bulky waste can be reused without any modifications (WRAP, 2012). With minor repairs, up to 51% of bulky waste can be utilized. To

facilitate the reuse of bulky waste, reuse centres can be established where residents can bring functional and well-preserved items for further use. Such centres are common abroad, for example in Vienna, Prague, and Brno. In Bratislava, a reuse centre was established in 2022 in collaboration with the collection company OLO. In less than half a year of operation, the centre was visited by 50,000 people, saving 100 tonnes of potential waste (Odpady portal, 2023).

One of the best-organized and structured reuse systems operates in the Flemish region of Belgium (OVAM, 2015). There are a total of 31 reuse centres, where on average 10 kg of products per capita are collected annually, with 50% being reused and 50% recycled. Second-hand products can be purchased in 127 shops, whose number has significantly increased thanks to a well-thought-out communication strategy and growing popularity. Approximately 22% of sales in these shops come from furniture, which accounts for up to 19,000 tonnes.

Online marketplace also present a significant potential for further product application. On the two largest Slovak online marketplace, there were more than 600,000 products listed in 2021, which would fall into the category of municipal waste. We estimate that this corresponds to nearly 4,200 tonnes, with the largest share of weight comprising electronic devices and furniture. In Germany, for example, the largest platform for selling used items, eBay, facilitates the annual reuse of nearly 120,000 tonnes of electronic devices, 18,000 tonnes of furniture, and 15,000 tonnes of clothing (EEA, 2018).

Reuse will be officially reported for the first time from 2023, including data from marketplace. According to the European Commission decision[26] setting the methodology for reporting reuse, data on reuse will be reported for the first time by mid-2023 and will cover the year 2021. The reporting of reuse data will include information from shops, online platforms, donations, or other channels. According to available information from the Slovak Environment Agency, zero values were reported for all four product categories[27] for 2021 due to the lack of a methodology for data collection at the national level.

Slovakia is implementing several measures to prevent and reuse waste. The Waste Prevention Program of the Slovak Republic 2019 – 2025 (MoE SR, 2018) includes support for building reuse centres and reuse centres located at collection yards. It also considers the possibility of introducing financial incentives, e.g., from the Environmental Fund, for entities involved in preparing items for reuse (e.g., furniture, textiles). Regarding reuse, the program includes several measures aimed at supporting the increase of reusable packaging. Examples include the mandatory use of reusable and compostable dishes at public events or analyzing the possibilities of reusing construction material from demolition and reconstruction works, currently being developed in collaboration with the OECD.

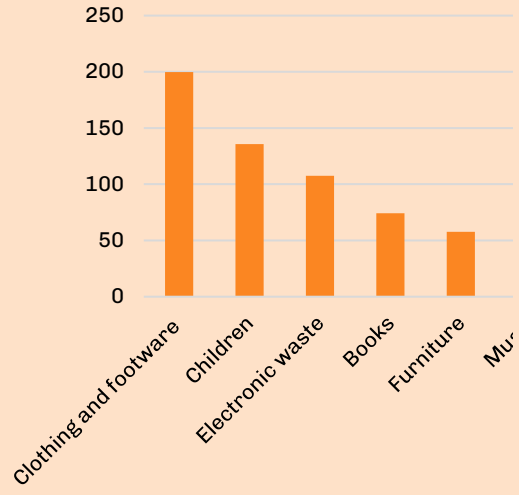
[26] Decision No. C(2020) 8976 establishing a common methodology and format for reporting on re-use in accordance with Directive 2008/98/EC of the European Parliament and of the Council.
[27] These product categories are textiles, electrical and electronic equipment, furniture and building materials and products under Commission Decision 2021/19.

Box 6: Potential of online marketplaces

Selling products for further use is becoming increasingly popular on online marketplaces. According to information on the two largest Slovak online marketplaces, bazoš.sk and bazár.sk, more than 600,000 items currently for sale would fall into the category of municipal waste. This mainly includes used clothing and footwear, which make up to one-third of the total. Following these are children's items, various electronic devices (including computers and mobile phones), books, furniture, and music-related items. Within the furniture category, the main items are tables, beds, sofas, armchairs, wardrobes, and children's furniture.

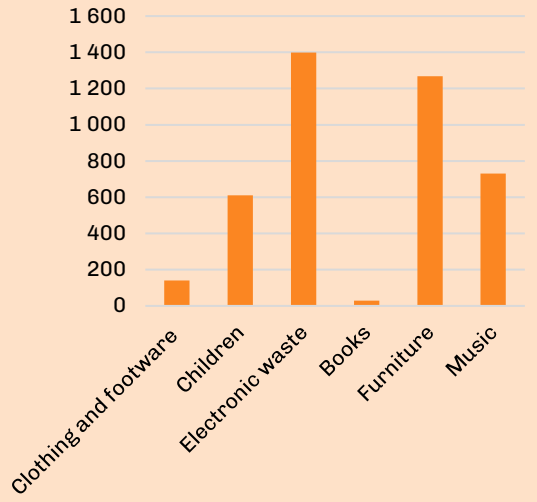
Based on British data on the average weight of products in different categories (FRN, 2021), we estimated that the total weight of these items reaches nearly 4,200 tonnes. The largest weight categories are electronic devices and furniture, approximately 2,700 tonnes. This is followed by children's items and music, with musical instruments forming the largest portion of the latter. Clothing represents about 140 tonnes, and books about 30 tonnes.

Graph 32: Products on online marketplaces (thousands of items)



Source: IEP based on *bazoš.sk and bazár.sk*

Graph 33: Estimated weight of online marketplace products (in tonnes)



Source: IEP based on *bazoš.sk and bazár.sk*

4.3.2. Taxes

Market instruments, such as taxes or subsidies, are commonly used to stimulate the transition to a circular economy (OECD, 2020). To improve the market for recycled plastics, which is currently dependent on the market for primary plastics and oil prices, the (OECD, 2018) recommends increasing taxes on primary materials or reducing excise taxes on recycled plastics. To support reuse, Sweden reduced VAT on repairs of bicycles, clothes, shoes, and electrical devices from 25% to 12% in 2017 (EEA, 2019). In 2021, the UK introduced a tax on plastic packaging placed on the market that contains less than 30% recycled plastics (UK Government, 2021). The EU also set minimum recycled material content for PET beverage containers at 25% from 2025 and 30% from 2030.

Additionally, the European Union introduced a levy on non-recycled plastic packaging for all member states starting in 2021. In 2021 and 2022, Slovakia paid approximately 34 million euros annually. Currently, this levy is covered by the state budget, and there is no

mechanism for producers responsible for placing plastic packaging on the market to contribute to financing this levy. In response, several countries are implementing additional plastic taxes. Spain's excise tax on single-use plastic packaging took effect in 2023 with a rate of 0.45 euros per kg (Ferriz, 2023). Italy plans to introduce a tax on primary plastic used in the production or import of single-use plastic items at the same rate as Spain in January 2024 (Krahl, 2022). Similarly, the Netherlands introduced a fee for single-use plastic cups and containers on July 1, 2023 (Scheuchzer, 2023). The fee directly applies to customers for takeout or delivery in such packaging. Consumers pay an extra 5 to 50 euro cents per container. Additionally, businesses must offer reusable packaging or the option for customers to fill their own containers or cups.

4.3.3. Extension of the EPR System

Additional types of waste

In most cases, extended producer responsibility (EPR) is focused on packaging, electronic and electrical equipment, batteries, tires, and end-of-life vehicles. Some countries are expanding the scope of their systems to include other products, such as furniture. In 2021, Belgium introduced extended producer responsibility for mattresses (OVAM, 2021), following a pilot project aimed at exploring eco-design possibilities and markets for recyclates from discarded mattresses.

Litter

Under the Directive on reducing the impact of certain plastic products on the environment, the European Commission is introducing extended producer responsibility for the costs of cleaning up 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. Producers are responsible for compensating municipalities for the costs of collecting, transporting, and processing this waste.

In Slovakia, a decision on how to implement this directive has not yet been made. A suitable solution would be to integrate this obligation into the existing EPR system for packaging, primarily to save on administrative and transaction costs. In the first phase, producers would pay fees to the authorized organizations (PRO) at a rate determined by the Waste Act, based on international practices (more in Box 7). The funds would then be distributed to municipalities based on population size. Subsequently, SAŽP would conduct a litter analysis to evaluate the actual quantity and costs of litter. In the second phase, fees would be adjusted based on the results of this study.

Box 7: Overview of litter management solutions in EU countries

T**he Czech Republic will create a new EPR system for tobacco companies**. Companies can choose to participate in the EPR system individually or through newly created collective systems (CS). These CS are required to ensure coverage of litter removal costs for at least 90% of municipalities in the Czech Republic, covering at least 90% of the population. The CS will also be required to allocate a separate portion of funds for awareness activities. The exact amount for awareness activities has not yet been determined, but it is expected that a minimum amount will be set for manufacturers to spend on these efforts. The new collective systems will be responsible for contracting and paying municipalities. A state authority will issue permits for CS within three months of the application submission, and CS will likely be required to contract the selected 90% of municipalities covering at least 90% of the population

within approximately 12 months from the date of obtaining the permit. The law will not specify the payment frequency, so it is assumed that payments will be on an annual or multi-year basis. The number of CS is not predetermined, and it is expected that several such systems will emerge.

Belgium plans to determine payments for the removal of small waste based on a study conducted by OVAM, the public waste agency for Flanders. The study involves analyzing collected waste and categorizing it into selected categories. One of the categories includes cigarette filters, which accounted for 41% of all waste by number but only 2.5% by weight and 1.1% by volume. Using these figures, they arrived at a result of 15% through an arithmetic average, which they consider to represent the cost of cigarette waste. The rationale for using a simple average is that the number represents mainly the cost of cleaning, sweeping, and collection, weight represents transportation and processing (incineration) costs, and volume represents a cost factor for logistics and the price of collection sites (waste bins). They consider all these costs to be approximately equal; therefore, 15% of the total waste costs will be allocated to companies marketing tobacco products. In Flanders, Belgium, this will amount to approximately 24 million euros, or roughly 0.42 eurocents per cigarette sold.

Sweden is implementing an EPR system based on fixed and variable payments. Each producer of tobacco products with filters and single-use plastics will be required to pay a fixed administrative fee per product category, which will go to the state, and a variable fee, which will depend on the weight and likely the amount of collected waste, and will be directed to municipalities and cities. The variable fee will be paid to municipalities based on the costs of waste cleaning, transportation, disposal, and overheads, all divided by weight and the number of different waste categories. The amount of the variable fee has not yet been determined, but it is expected to be decided by July. The EPR system is undergoing significant changes, and the distribution of funds to municipalities and cities will now fall under the Ministry of Finance.

Table 23: Overview of littering solutions in EU countries

Country	Solution	Rate for tobacco companies	Rate for producers of plastic products
Czech republic	Reimbursement of Littering costs to municipalities through EPR	Not yet determined	
Poland	New fee, likely through EPR	Maximum of 0.325 euro cents per cigarette	Maximum of 1.1 euro cents per cigarette
Austria	New fee, likely through EPR	Per number of cigarettes / per pack	Not yet determined
Belgium	Reimbursement of littering costs to municipalities through EPR	15% of total costs (approximately 0.42 euro cents per cigarette)	Not yet determined
Sweden	Fee + Reimbursement of costs to municipalities through the Ministry of Finance	Fixed (285€/year) + variable	Fixed (48€/year) per category + variable

Source: IEP based on OVAM, Ministerstwo Klimatu i Środowiska, MZP ČR, BMK, Reloop Europ

Ecomodulation, ecodesign

Individual fee rates for producers under Extended Producer Responsibility (EPR) should be differentiated based on environmental criteria, such as recycled content, biodegradability, availability and processing capacity complexity, or recyclability information directly on the packaging (Watkins, et al., 2017). Such fee differentiation is referred to as ecomodulation.

Several countries in the European Union already apply ecomodulation today. For example, in Belgium and Spain, minimum rates are set lower for PET and HDPE packaging compared to other plastics due to their better recyclability (Institute for Environmental Policy, 2020). In France, they use a system of bonuses and penalties awarded to producers based on several criteria. Bonuses include providing information on correct sorting on packaging or through campaigns, reducing packaging production, and packaging recyclability. Penalties are mainly based on packaging characteristics that limit recyclability.[28]

Fee modulation also stimulates the creation of more environmentally friendly product designs (OECD, 2020). The product design itself determines up to 80% of its environmental impact (European Commission, 2020). Providing information on the environmental properties of products through product labelling is another key tool for increasing resource efficiency across the entire product value chain.

Currently, it is not possible to quantify the impact of ecomodulation on increasing recyclability and recycling of waste. This is also based on an OECD study, according to which only a few countries have recently started adjusting fees under EPR based on these criteria (OECD, 2021). Knowledge about the performance of these systems is thus limited. Initial results from the French system, however, indicate a decrease in the proportion of products subject to penalties.

In 2023, Slovakia will start collecting data through EPR on the material composition of packaging and non-packaging products, including the proportion of recyclates, which will help better adjust ecomodulation in Slovakia[29].

4.3.4. Green Public Procurement

Green public procurement involves purchasing goods and services that meet resource efficiency standards set by the EU. In EU countries, where public procurement accounts for 16% of GDP annually, green public procurement has a high potential for developing a market for more ecological products (Petríková, et al., 2018). In Slovakia, it represents 6.6% of GDP. Currently, green public procurement is voluntary, but the European Commission plans to propose minimum mandatory criteria and goals, and introduce mandatory monitoring of the implementation of green public procurement (EC).

The National Action Plan for Green Public Procurement for the years 2016-2020 set an ambitious non-binding target to achieve 50% green contracts in selected product groups

[28] Slovakia does not yet have ecomodulation in place, but Decree 373/2015 Coll. provides for mandatory rates for determining the costs of ensuring the sorted collection and recovery of packaging waste and waste from non-packaging products.
[29] Annex 10c to Decree No 371/2015 Coll.

from the total volume of public procurement. According to the Slovak Environmental Agency (SAŽP), however, green contracts accounted for less than 11% of the value of procured goods and services in 2019 (Enviroportal, 2021). Systemic changes in education, transparency, and monitoring will contribute to the expansion of green public procurement (Petríková, et al., 2018). In Hungary, Austria, Belgium, and Portugal, attention is paid to educating individual actors in the procurement process, motivating them to apply green criteria, and raising awareness about green purchasing opportunities. In the Netherlands, emphasis is placed on simplifying the system for users to make it accessible to the general public. In Korea, there is ongoing online monitoring of institutions' voluntary compliance with set goals, while in the USA and Canada, goals are reliably evaluated on an annual basis.

4.3.5. Education

Awareness of waste management and student habits can be improved through environmental education programs. Schools, as social environments with daily attendance alongside families, significantly contribute to shaping students' habits and attitudes (Whitebread & Bingham, 2013). In the learning process, even small and sufficiently frequent interventions can be very effective in fostering habits among students (Loewenstein, et al., 2016). A successful educational intervention in Vietnam resulted in up to 96% of the involved students showing interest in waste management activities. Before the educational workshop, only 29% of students had knowledge about eco-bags, and 55% were aware of their difficulty in decomposition. As a result of the intervention, these figures increased significantly to 87% and 71%, (Hoang & Kato, 2016).

According to research, expenditures on recycling education are an effective measure to increase recycling rates (Sidique, et al., 2009). Currently, in Slovakia, only producer responsibility organizations focusing on sorting, handling, and waste prevention under extended producer responsibility (EPR) have the obligation to carry out promotional and educational activities. According to reports from the two largest packaging waste management organizations, promotional and educational activities accounted for only 1.3% of all costs in 2021. In some countries, mandatory minimum expenditures on awareness-raising by packaging waste management organizations are established.

It is recommended to adopt an environmental education strategy within formal education, which currently does not exist in Slovakia (Bodáczová, et al., 2021). Effectively integrating environmental education into formal education would help prevent future problems and build an active approach to the environment.

Education must take place at all levels. In addition to school education itself, informational campaigns and providing information when implementing various measures are crucial, leading to increased citizen involvement in sorting, higher quantities of collected sorted waste, and cleaner sorting collections.

4.3.6. Distance to Infrastructure and Collection Frequency

Several studies indicate that proximity to sorting collection infrastructure is one of the key factors for higher recycling rates (Mattsson, et al., 2003). A Dutch study also confirmed that proximity to bins for collecting biowaste in apartment buildings increases the likelihood

of sorting (VANG Household Waste, 2020). Another significant factor was the distance from bins for mixed municipal waste, with bins for biowaste being less used if they were farther away compared to bins for mixed municipal waste. A study from London showed that providing plastic bin bags to households in apartment buildings led to increased sorting (Roberts & Devine, 2020). Introducing door-to-door sorting collection systems compared to centralized collection points also represents infrastructure proximity, which significantly impacts increased sorting rates.

Several countries currently legislate the average distance from residences to collection bins (Institute for Environmental Policy, 2020), while in Slovakia, only a minimum annual export volume per municipality and waste component is established within the collection standard. The study suggests introducing an obligation to collect sorted waste within a maximum distance of 150 meters from residences. According to the Friends of the Earth - SPZ handbook (2010), an optimal delivery distance for collecting biowaste in apartment buildings is considered to be between 30 to 50 meters. Since 2021, there has been an obligation to introduce sorted collection of biowaste in apartment buildings at a distance of 0 meters from residences, i.e., a door-to-door collection system. For apartment buildings, the appropriate distance is considered to be the location of mixed waste collection. The same obligation applies from 2023 for sorted collection of other components such as paper, plastics, and glass. In addition to distance, the frequency of collection and related adequate capacity are crucial. Overfilled and contaminated collection bins can lead to reduced motivation for sorting and disposal of waste into bins for mixed municipal waste ((WRAP, 2018), (Roberts & Devine, 2020)).

4.3.7. Other Behavioural Measures

Several studies indicate that people's attitudes and reactions to environmental measures often differ from expected behaviours (OECD, 2012). Motivation for environmental behaviour can depend on internal values as well as external factors, such as communication of measures, behaviours of others in the vicinity, or even financial incentives (Agovino, et al., 2019). Additionally, people typically follow the status quo, even when it does not represent a rational choice.

Several studies and social experiments have focused on evaluating the impacts of various waste management interventions. These include the aforementioned study on infrastructure availability or collection frequency (VANG Household Waste, 2020). Another effective tool is explaining the importance of sorting and providing information on how to sort correctly and utilize sorted waste. In a British study (Roberts & Devine, 2020), measures such as providing information on sorting methods, emotive labelling near bins, feedback, and smaller bins in appropriate locations led to an increase in recycling rates by 33 to 40%. A Dutch study (VANG Household Waste, 2020) showed that providing information had the greatest impact on increasing sorting among individuals who already sorted waste. In the Swedish city of Malmö (Heinrich K., 2018), the introduction of kitchen waste collection was accompanied by a campaign informing residents that sorted biowaste is processed in a biogas plant and subsequently used as fuel for city buses and waste collection vehicles. The average amount of kitchen biowaste sorted here amounts to 51 kg per resident per year, which is 47% of its potential.

Waste evidence removes 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 introducing automatic waste registration and effective public information, without quantity collection (JRK, 2019). OECD also recommends providing households with feedback on the amount of waste produced to increase waste sorting (OECD, 2017). Setting group goals and a collective commitment helped reduce littering around trash bins in the Netherlands (IPR Normag, 2010). According to a Dutch study, motivation for sorting biowaste was higher due to setting group goals, feedback, and providing information on how their surroundings sort waste. Low social cohesion and lack of control in apartment buildings lead to lower sorting rates compared to family houses (VANG Household Waste, 2020).

4.3.8. Maximum Recycling Potential

The maximum potential for recycling municipal waste reaches 80 to 90%. Best practices from regions in Germany and Italy show the possibility of achieving up to 85% recycling rates. The maximum recycling potential of municipal waste is estimated similarly at 80 to 90% (Trinomics, 2020).

Box 8: Best practice in Europe

Treviso, Italy

The province of Treviso in northern Italy is among the best regions in terms of municipal waste management (ZeroWasteEurope, 2018). The introduction of quantity-based collection, kitchen waste collection, and door-to-door collection has led to an increase in recycling rates to over 85%. The annual production of mixed municipal waste is only 55 kg per capita.

Additionally, municipalities in this province have the lowest waste management costs in all of Italy. While the average waste fee in Italy was 298 euros per household in 2015, it was only 185 euros in the province.

The goal of the company responsible for waste collection and management in the region is to achieve a recycling rate of up to 96.7% by 2022 and reduce the production of mixed municipal waste to 10 kg per capita. The company also aims to prevent waste generation, seeking to reduce municipal waste production from the current 373 kg to 280 kg per capita, while the EU average reached up to 502 kg in 2019.

Aschaffenburg, Germany

In the German district of Aschaffenburg, a quantity-based collection system with identification and weighing of containers at the door was introduced in 1997. This initiative led to an increase in recycling rates up to 86% and reduced the production of mixed waste to 50 kg per capita annually (Morlok, et al., 2017). Door-to-door collection of paper and plastics has been implemented as part of the system.

The introduction of quantity-based collection using weighing also led to a reduction in costs from 172 to 245 euros per year for a four-person family in the years 1991-1995 to 111 euros in 2013 (European Commission, 2018).

5. Modelling Waste Management Scenarios

5.3. Setting up the system in the baseline state

Table 24: Assumptions about model setup

Parameter	Description	Source
Percentage of inhabitants in apartment buildings	50%	SODB 2021, Eurostat
Garden biowaste collected within the infrastructure	37%	IEP calculation
Infrastructure		Municipalities
Apartment buildings	1,100l, shared collection of plastic, composite and metal packaging	
Kitchen biowaste	240 l	
Family houses	120/240l, bin bags	
Garden and kitchen biowaste	120/240l, composter	
Percentage of family houses with composter	42%	IEP calculation based on the Slovak Statistical Office

Source: IEP

5.3.1. Distribution of Waste Production in Apartment Buildings and Family Houses

Total waste amount was divided between waste produced in family houses and apartment buildings, as several measures are proposed according to the type of construction. In terms of municipal waste data, production is recorded only at the level of the entire municipality, so it is not possible to determine exactly what the production is in family houses and apartment buildings. In the division, we therefore relied on the ratio of the number of flats and family houses in individual municipalities and cities in Slovakia according to the 2021 SODB data. According to the 2021 census, the number of flats accounted for less than 50% of the total number of flats and houses in Slovakia. For future years, we assumed the same ratio, with the total number of family and apartment houses depending on the projected number of inhabitants.

We assumed that residents of family houses and apartment buildings within one municipality produce the same amount of each waste component per capita, except for garden biowaste, which is almost exclusively found in family houses. Since mixed municipal waste in family houses also contains unsorted garden organic waste, we assumed a higher production of mixed municipal waste per capita in family houses.

5.3.2. Composition of Waste in Family Houses and Apartment Buildings

Since some measures target only a specific type of development, such as door-to-door sorted collection in family houses, for the purposes of calculating the sorting of individual components, we have divided the composition of mixed municipal waste by type of development. The data is based on analyses by JRK for the years 2020 to 2023.

Table 25: Composition of mixed municipal waste based on building type

	Apartment buildings	Family houses
Paper	8.89%	8.61%
Plastics, composite packaging and metal containers	15.79%	13.71%
Glass	5.75%	4.61%
Garden biowaste	0%	15.56%
Kitchen biowaste	30.03%	16.12%

Source: IEP

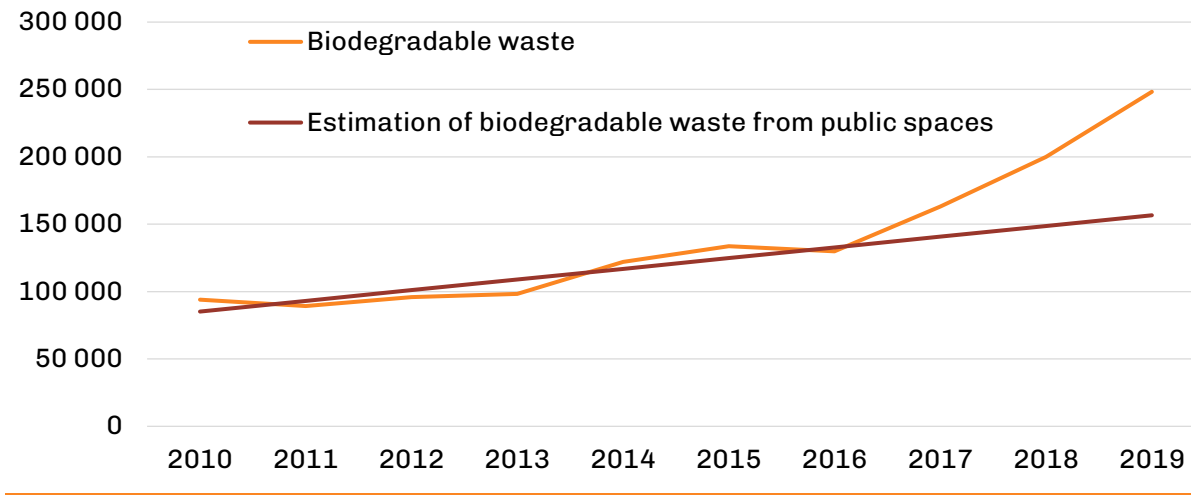
5.3.3. Waste Collected outside the Infrastructure

Waste collection is ensured through infrastructure of collection containers or, alternatively, through recycling centres. In Nitra (NKS, 2020) and Bratislava (OLO, 2020), approximately 10% of the total collected waste (excluding mixed municipal waste) was gathered at recycling centres. Bulky waste, small construction debris, and electronic waste constituted the largest portion. For paper, additional waste is collected through redemption centres or school collections, which do not incur costs within the infrastructure and sorting. As the portion of waste originating from redemption centres or recycling centres is unknown, for simplicity, we considered only waste collected exclusively through collection containers.

A portion of waste in municipal records is collected outside households. Since 2020, Slovakia has included waste from restaurants, catering facilities, and packaging waste not only from sorted municipal waste but also from other sources with similar characteristics and composition as household waste. This segment represents approximately 9% of the total municipal waste production.

Only a portion of biodegradable waste is collected within the infrastructure from apartment buildings. The remainder comes from park maintenance, public spaces, and recycling centres. For example, in Bratislava in 2018, only 28% of the total registered biodegradable waste was collected through infrastructure (OLO, 2020). Estimating the amount of biodegradable waste that belongs to collection from apartment buildings, we based our calculations on trends from 2010-2016, prior to the mandatory collection of biodegradable waste. We assume that biodegradable waste within the infrastructure represents only 37% of the total biodegradable waste production for the year 2019.

Graph 34: Share of organic waste from public spaces in total organic waste: Handling of industrial waste in EU countries in 2018



Source: IEP

5.3.4. Collection Infrastructure

Within waste collection, it is possible to adjust the number of available containers or the frequency of collection to achieve the best possible infrastructure availability at the lowest costs. The measures proposed in this analysis affect the reduction or increase in the infrastructure needs for different types of waste components. Since the goal of the analysis is not cost optimization of collection, **we assumed that the number of containers would remain unchanged, but the collection frequency would vary depending on increased sorting of individual waste components.** Although the cost of purchasing standard collection containers is lower compared to collection costs, the number of containers is limited by the availability of free spaces around apartment buildings. Additionally, low collection frequencies could lead to discomfort in the form of odours or potential rodent presence.

We estimated the current number of waste containers for various types of waste in apartment buildings based on data from several locations in Slovakia (e.g., Bratislava, Vranov nad Topľou, Nitra, Banská Bystrica) and information from PROs. In apartment buildings, 1100-liter containers are typically used for mixed municipal waste and sorted waste components. For mixed municipal waste, we assume 32 residents per container, for plastics and paper 100 residents per container, and for glass 150 residents per container. We assume combined collection of plastics, metals, and beverage cartons (PMK) as practiced in most municipalities in Slovakia. The number of containers for mixed municipal waste in family houses was estimated based on the number of such homes, with each home having a 120 or 240-liter container. The number of containers for sorted waste in family houses without door-to-door collection was calculated in the same way as for apartment buildings. For door-to-door sorted waste collection, 120 or 240-liter containers or bin bags are used. Since we do not know how many municipalities use bin bags versus containers for door-to-door sorted waste collection, for simplicity, we assumed the use of containers for each family houses.

For the sorted collection of kitchen biowaste in apartment buildings, we assumed 240-liter modified containers, which ensure lower contamination compared to larger containers and support the growth of aerobic bacteria. According to regulations[30], capacity must be provided for each resident with a minimum volume of 250 litres. This capacity is calculated as the product of container volume and collection frequency. In a more comfortable system setup, in addition to waste containers, we considered providing baskets and biodegradable bin bags with an informational leaflet for proper sorting of kitchen biowaste in every household. In family houses, the sorted collection of kitchen biowaste must be ensured through door-to-door collection, which can be either standalone or combined with garden biowaste. The disadvantage of combined collection is that such waste is not suitable for processing in biogas plants due to the woody debris from garden biowaste. Moreover, according to JRK, combined collection leads to lower sorting rates. For simplicity, we considered only sorted collection of kitchen biowaste.

An alternative option to the sorted collection of kitchen and garden biowaste is the implementation of home composting, which allows municipalities to save operational costs

[30] Decree 348/2020 implementing certain provisions of the Waste Act

for waste collection. According to the law since 2021, municipalities that demonstrate 100% composting by their residents are exempted from providing sorted collection of kitchen biowaste. Home composting is primarily used in family houses. According to the Statistical Office of the Slovak Republic, 42% of households in family houses use composters for waste collection. Community composting is also feasible in apartment buildings, requiring collective care and measures against unauthorized handling. However, since community composting facilities for apartment buildings constitute a very small part in Slovakia, they were not included in the model.

5.3.5. Collection Frequency

We estimated the collection frequency using the number and size of containers and the coefficient of waste volume per litre of container. The volume of mixed municipal waste per litre of container is based on data from OLO, NKS, and INCIEN. For sorted waste collection, the coefficient was determined based on data from PRO Envipak, Ecycling, and information provided in the regulation[31].

Table 26: Estimation of waste amount per litre of container (kg/litre of container)

Paper	0.042
Plastics, composite packaging and metal containers	0.015
Glass	0.137
Mixed municipal waste	
120/240l, bin bags	0.14
1,100l	0.08

Source: IEP based on data from *OLO, INCIEN, NKS, Envipak, Ecycling*

The average frequency of waste collection for mixed municipal waste from apartment buildings ranges around 75 times per year, corresponding to collection frequencies between once and twice weekly. We estimate the average collection frequency for paper and plastics to be approximately once per week, and for glass once per month. Similarly, for family houses, we calculated the average frequency of mixed municipal waste collection at 36 times per year using the same method. According to data from the Statistical Office from 2019, municipalities with less than 1% share of apartment buildings also had an average collection frequency of 35 times per year.

When estimating the frequency of segregated collection of kitchen biowaste, we relied on the regulation which sets the frequency at 2 times per month up to 2 times per week, depending on the season, type, and size of the container. We calculated with partially adjusted containers having an annual collection frequency ranging from 80 to 90 times. Similarly, we estimated the frequency of garden biowaste collection at approximately 39 times per year, with no collection taking place from December to February.

5.3.6. Management of Waste from Sorted Collection

From the point of sorting waste to its final recycling, losses can occur for various reasons. Part of the collected material consists of impurities due to incorrect sorting. Further losses occur after waste sorting, as only the economically and technologically recyclable portion

[31] Decree No. 371/2015 Coll., implementing certain provisions of the Waste Act

of waste is sent for recycling. The remaining portion ends up in landfills or undergoes mechanical processing to produce RDF for use in cement kilns. When estimating waste management after sorting, we relied on data from waste management companies and the Statistical Office of the Slovak Republic for the year 2021.

Table 27: Management of waste from sorted collection

	Recycling	Energy recovery	Landfilling
Paper	89%	0%	11%
Plastics	36%	40%	25%
not beverage PET	23%	47%	30%
Glass[32]	94%	0%	6%
Composite packaging	60%	9%	31%

Source: IEP based on data from PRO

After the introduction of a deposit system for single-use beverage containers, PET beverage containers will be exempted from the selective collection system under the Extended Producer Responsibility (EPR). Since PET is the most recycled material among plastics, the deposit system will significantly impact the handling of plastic waste from selective collection. According to Envipak's analysis, PET beverage containers constitute 51% of plastics after collection and sorting, i.e., after removing impurities. With plastics averaging 25% contamination and an estimated 95% recycling rate for collected PET, only 11% of non-beverage PET plastics are recycled.

5.3.7. Pre-landfill Treatment and Energy Recovery

The introduction of mandatory waste treatment before landfilling may lead to the need for mechanical biological treatment facilities, as well as direct energy recovery of waste. Most EU countries that have previously banned landfilling of untreated or incinerable waste have built facilities for direct energy recovery from waste. The reason is limited capacity for using RDF, as well as comparable costs between energy recovery and mechanical biological treatment.

The potential for mechanical biological treatment of mixed municipal waste in Slovakia is limited by the existing capacities of cement plants, which could potentially accept produced RDF. According to cement industry data, only 33% of cement kiln capacities are utilized for processing low-calorific SRF. An alternative is exporting produced SRF abroad, which, however, may significantly increase the cost of mechanical-biological treatment, and the off-take could still be problematic. Additionally, the costs of both mechanical-biological treatment and energy recovery are approximately at the same level, with transportation costs potentially being the main difference.

5.3.8. Composting and Anaerobic Digestion

We assume that kitchen biowaste will be locally utilized, with a third of collected kitchen biowaste going to biogas plants. Due to processing limitations of kitchen biowaste at biogas plants, we anticipate regional utilization within a maximum distance of 60 km. Our assumptions are based on the experience of the city of Trnava, which transports sorted kitchen biowaste for processing at the biogas plant in Bošany, approximately 65 km away.

[32] V prípade opakovane použiteľných obalov, najmä skla platí, že s odpadom sa nemusí nakladať v rovnakom roku.

We estimated the potential utilization of biogas plant capacities based on the number of municipalities and their mixed municipal waste production located within a 65 km radius from the three largest biogas plants for kitchen biowaste processing. We assume that 34% of kitchen biowaste will be processed at biogas plants.

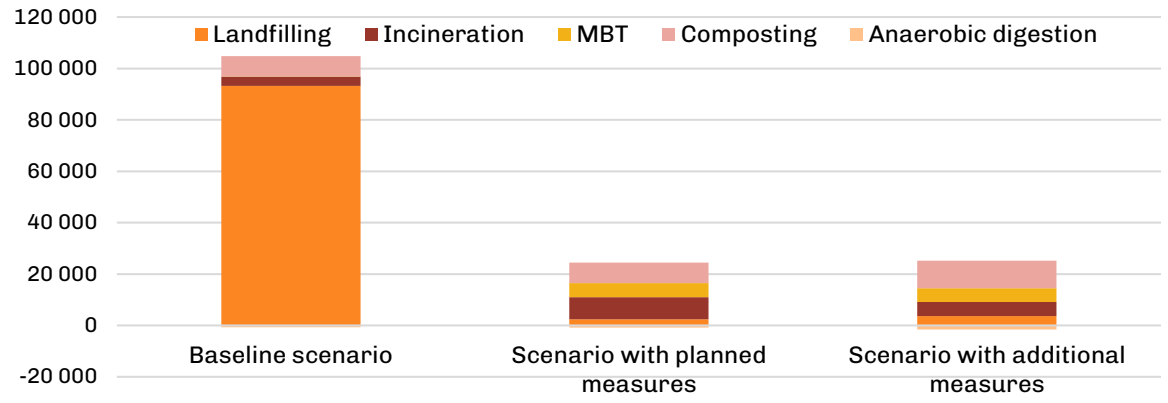
5.4. External Costs in Municipal Waste Scenarios

In the baseline scenario, the net external costs amount to just under 94 million euros per year. Most of these costs arise from greenhouse gas emissions produced at waste landfills. On the other hand, recycling represents resource savings of approximately 11 million euros.

In comparison to the baseline scenario, external costs decrease by 63 million euros due to the introduction of mandatory waste treatment, thereby reducing methane emissions at waste landfills. The total net external costs will amount to 12 million euros per year.

The scenario with additional measures would incur external costs of 10.4 million euros. Compared to the scenario with planned measures, the cost level does not change significantly; savings are achieved through better sorting and thus reduced handling of non-recyclable waste through energy recovery or landfilling.

Graph 35: Comparing external costs between scenarios



Source: IEP

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