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# MUNICIPAL WASTE IN SLOVAKIA AS A POTENTIAL FOR THE CIRCULAR ECONOMY[3]

Abstract – If we talk about municipal waste in connection with circular economy, each European produces about 500 kg/year of waste. Less than half of it is 46% recycled, 27% is incinerated and 24% is landfilled. However, if we talk about the Slovak Republic, in 2019, 1 person produced an average of 421 kg/year of waste, and this indicator has a significantly rising character. In the context of the circular economy, an interesting indicator is precisely the rate of waste recycling, which is at the level of 38.5% in Slovakia. A similar analysis of municipal waste generation in selected EU countries was carried out in 2019, with the aim of identifying the potential for residual municipal waste generation, taking into account historical data, EU targets and existing residual waste treatment capacities. The results of this assessment for the Slovak Republic are discussed in article, which indicate a lack of processing capacity for non-recyclable waste.

**Keywords:** municipal waste, Slovakia, circular economy.

## 1. INTRODUCTION

There is pressure from all sides to reduce the amount of municipal waste production, to increase the rate of sorting and recycling, or to reduce the share of landfills (Taušová, Mihaliková, Čulková, Stehlíková, Tauš, Kudelas, Štrba, Domaracká, 2020). These trends are noticeable in all Member States, and of course they are gradually being reflected in Slovak legislation (Castillo-Giménez, Montañés, Picazo-Tadeo, 2019). However, the legislation also pushes us into price increases under the influence of waste treatment obligations, or the management of biodegradable waste or kitchen waste. This is clearly not liked by local governments and residents, who will feel the rising costs of waste management in the near future (Ukkonen, Sahimaa, 2021). The upward trend in energy prices, the current geopolitical tensions in the world and the ever-increasing prices of emission allowances oscillating above EUR 80/ton of $CO_2$ emitted from fossil fuels are a natural outcome of the penetration of waste management and energy into one functional

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unit (Hubatka, Theisen, 2021). It is the energy recovery of waste in Waste-to-energy plants that solves several of the mentioned goals or price problems. Despite the fact that waste management is currently increasingly regulated, monitored and evaluated by the EU, landfilling still prevails in Slovakia, with up to half of municipal waste ending in landfills (Taušová, Mihaliková, Čulková, Stehlíková, Tauš, Kudelas, Štrba, 2019). Equally unflattering is the indicator of waste production *per capita*, which is increasing from year to year in EU countries, but also in Slovakia. However, this could be seen as an opportunity in the context of the circular economy and the present. It is the knowledge of the production of "own" waste in own country in detail determines its efficient use, which from the point of view of the circular economy (Circular Economy), as one of the youngest interdisciplinary industries, has become increasingly important in recent years (Lacy, Long, Spindler, 2020). Especially in the current geopolitically uncertain times, when it is absolutely necessary to looking for new alternatives of many sources of minerals. In this context, waste is a treasure that has a lot of untapped potential, which increases raw material and energy security (Domaracká, Taušová, Čulková, Pavolová, Bakalár, Seňová, Shejbalová-Muchová, Teplická, Kowal, 2020).

In 2020, the share of landfilling in the Slovak Republic was 48%, the share of recycling, including backfilling was 44% and the energy recovery of waste was 8%. Due to the influence of European legislation, this trend must change by 2035 when landfilling to max. 10%, recycling min. 65%, the rest could be used for energy recovery. The application of material and energy recovery of waste results in the absolute minimization of waste generation. Another positive is the recovery of electricity, heat, as well as the return of materials back to the life cycle in the form of secondary raw materials, where primary raw materials and energy resources are saved. In European countries, energy recovery is an integral complement to waste management as well as energetics. At the same time, it is an essential part of the waste hierarchy, because not producing any waste is an impossible fiction. If we talk about the circular economy in terms of municipal waste, each European produces about 500 kg of waste per year. Less than half of it is 46% recycled, 27% is incinerated and 24% is landfilled (Cehlár, Tauš, Šimková, Taušová, Šimko, 2022).

## 2. CURRENT SITUATION IN THE FIELD OF WASTE IN SLOVAKIA

If we talk about the Slovak Republic, in 2020, 1 person produced an average of 446 kg of waste in 1 year, and this indicator has a significantly rising character. In 2019 it was an average of 421 kg of waste per 1 year person (Valenčíková, 2021), for comparison, in 2001 it was 239 kg of waste/person/year and compared to 2018 it is an increase of 7 kg/person / year, compared to 2017 up to 43 kg/person/year. The largest production of municipal waste *per capita* was achieved in the Trnava region (555.8 kg/inhabitant), which is directly proportional to the economic strength of the region. The smallest municipal waste production *per capita* was recorded in the Košice region (328.8 kg/capita) (https://ec. europa.eu, 2022).

The production of municipal waste on the territory of the Slovak Republic in the years 2011–2020 showed a fluctuating development trend with an average year-on-year increase of 66,705 t / year and significant regional disparities (see Figure 1). At the same time, it can be stated that the Bratislava region had the highest production in the given period with an average annual production of 300,827 t/year (except in 2018 and 2019, when the highest production was recorded in the Nitra region). On the contrary, the lowest production was

recorded in the Banská Bystrica region with an average annual production of 207,557 t/year until 2017, when the lowest production was recorded in the Trenčín region (http://statdat.statistics.sk, 2022).

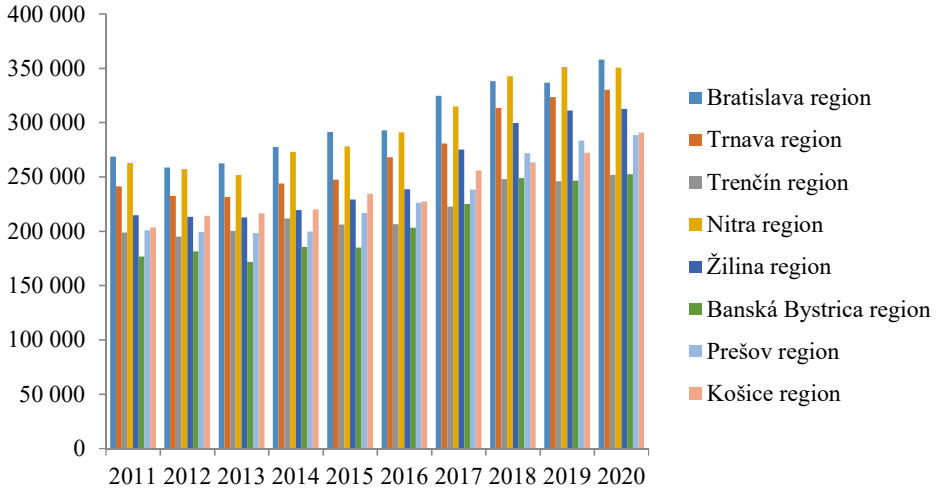


Figure 1. Development of municipal waste production in the regions of the Slovak Republic [t/year]

Source: own processing based on http://statdat.statistics.sk

A detailed analysis of year-on-year movements in municipal waste production revealed that the highest year-on-year average increase in the observed period was recorded in the Žilina region with 9,780 t/year and the lowest year-on-year average municipal waste in the Trenčín region with 5,315 t/year (http://statdat.statistics.sk). The data were analyzed with respect to year-on-year changes in municipal waste production in individual regions of the Slovak Republic with respect to the 10-year average (some years also showed negative values). Regarding the material recovery of municipal waste, based on a detailed analysis, it can be stated that in 2011–2020 the Žilina region had the highest average quantities of material recovery of municipal waste with an average annual material recovery of 38,542 t/year. However, the highest average year-on-year increases were recorded in the Bratislava region at 10,639 t/year (see Figure 2.).

A different development was recorded in the lowest values of material recovery of municipal waste, while it was found that:

- in 2011, 2013, 2014 and 2015, the least municipal waste was recovered in the Bratislava region,
- the lowest year-on-year average value in the years 2011–2020 was reported by the Trenčín, Banská Bystrica and Prešov regions,
- the highest year-on-year average value in the years 2011–2020 was reported by the Žilina, Trnava and Košice regions,
- The Bratislava region has almost doubled its material recovery of municipal waste in the last two years (2019–2020) almost twice (http://statdat.statistics.sk, 2022).

It follows from the above that the highest share of material recovery of municipal waste was recorded in the Bratislava and Košice regions at almost the same level of 27% per year and the lowest in the Trenčín region at 21% per year (http://statdat.statistics.sk, 2022).

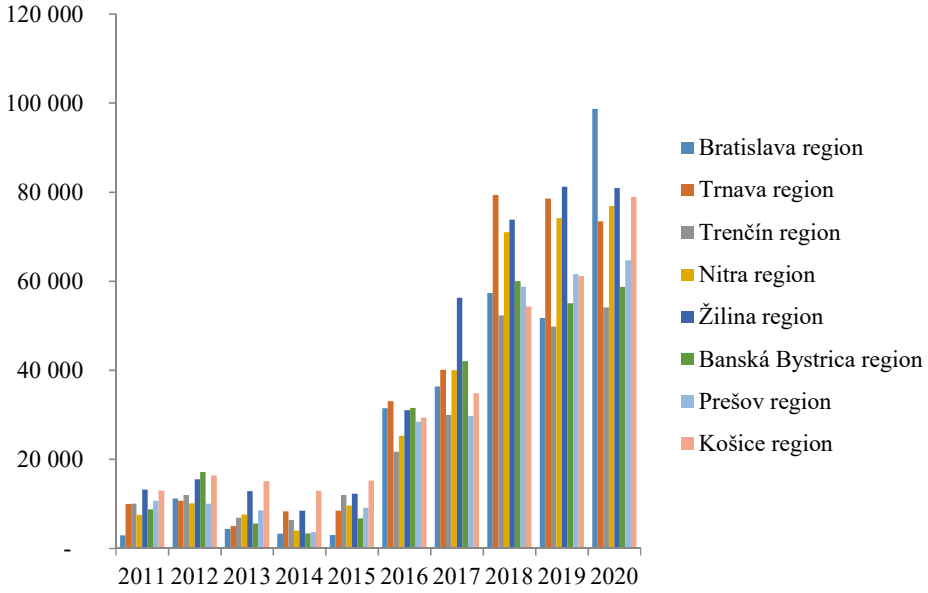


Figure 2. Development of the amount of material recovery of municipal waste in the regions of the Slovak Republic [t/year]

Source: own processing based on http://statdat.statistics.sk

As can be seen from the graph (see Figure 2.), the Košice and Bratislava regions have the highest share of material recovery of municipal waste (data are applied from http://datacube.statistics.sk/). The Košice region has few landfills, as well as low currently allowed free landfill capacities. The largest capacities are available in the Banská Bystrica and Trnava regions, and the Prešov and Trenčín regions are relatively in the middle of this division. The most landfilled waste is in the Trnava region, which reflects the presence of the highest rate of waste generation, as well as the high concentration of industry in the west of the Slovak Republic.

The dependence between the existence of the Waste-to-energy plant, the lower weights of waste that ends up in landfills and the fact that the Košice and Bratislava regions are making more material use is probably reaffirmed. It should be noted that this is not just a landfill for municipal waste, because in the context of landfilling individual regions in the regions, it was not possible to separate industrial and municipal waste on the basis of the data provided.

### 2.1. Energy recovery in Slovakia and the impact on landfilling

Energy recovery of waste is carried out only in the Bratislava and Košice regions. Statistics for 2020 show energy recovery for individual facilities in the total amount of

187,795 tons of municipal waste. However, it must be said that Bratislava recovers only municipal waste from Bratislava to the maximum extent possible. In Košice, municipal waste from the city of Košice, part of Prešov, individual municipalities of the adjacent region, as well as industrial waste from certain areas of Slovakia is recovered (see Figure 3.).

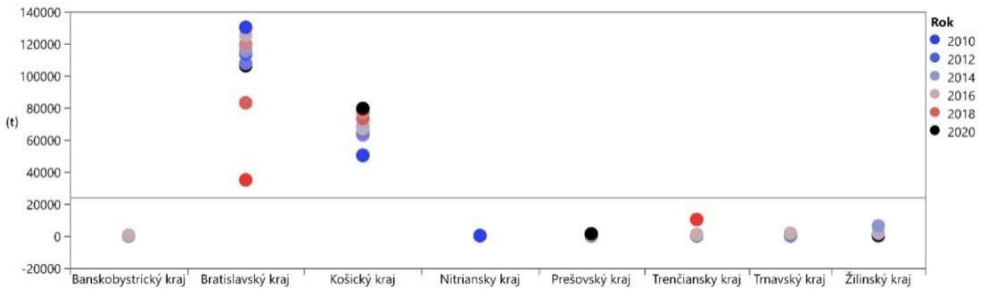


Figure 3. Energy recovery waste in the Slovak Republic

Source: own processing by authors of the waste study TUKE based on http://statdat.statistics.sk

The graphs, the source of which is data from the Statistical Office, relate to municipal waste management for 2020 and support the same hypothesis as in the case of analyzes from EU countries. Namely that the rate of energy recovery of waste has a direct impact not only on the reduction of landfilled waste, but also on the rate of waste sorting and recycling. In the case of Slovakia, this is confirmed by the development of the amount of energy recovered waste, recycled municipal waste and landfilled municipal waste in the Bratislava and Košice regions (see Figure 4.). The unevenness of the amount of energy recovered waste in individual years corresponds to all the above indicators.

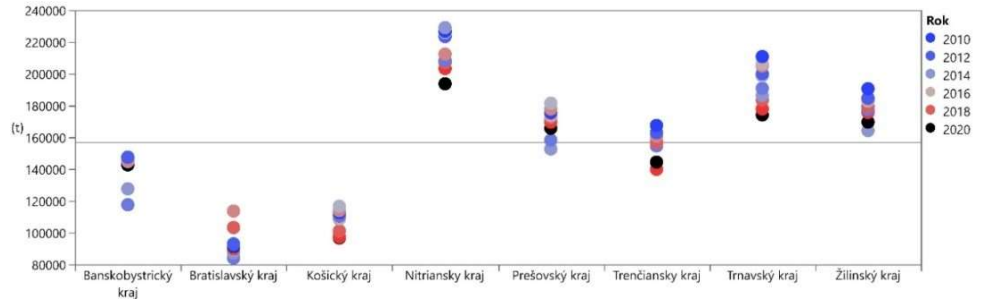


Figure 4. Amount of landfilled waste in the regions of the Slovak Republic

Source: own processing by authors of the waste study TUKE based on http://statdat.statistics.sk

From the above analyzes, it can be deduced that increasing the share of energy recovery has an impact on the increased rate of waste sorting and subsequent recycling. It is not

directly energy recovery, but probably the culture that energy recovery facilities as such bring to the region.

The set of waste management measures in a given country, we can call it the "evolution of waste management" has the need to reduce the share of landfill, increase the share of energy recovery, thus a natural need to push much more the topic of waste separation at source, followed by more successful recycling of materials (which goes hand in hand). They are also building capacities for material recovery of municipal waste) and awareness-raising in this topic to society as another environmental step towards fulfilling today's popular "zero waste" principle.

Thus, the synergistic effects of diversion from landfilling, by building capacity for energy recovery, demonstrably lead to the building of recycling capacities and to the fulfillment of the principles of the circular economy into the waste management of individual EU countries.

## 3. PRINCIPLES FOR THE FUTURE DEVELOPMENT OF ENERGY EVALUATION

According to data from the Statistical Office in 2020, approximately 80,000 tons of waste in the Košice region are energy recovered, what is a share of 27%. Given the amount of landfilled waste with a share of 33% disposal, the potential for more than double the needs of energy recovery is already created today, while achieving an almost minimal share of landfilling, the so-called "Zero waste to landfill" approach. Over the last 10 years, waste

Table 1. Development of production and potential of energy recovery in the current and with the "zero waste to landfill" approach

| **Region** | **Prešov** | **Košice** | |
|---|---|---|---|
| **Year 2020/tons** | **288 350** | **290 727** | |
| **Year** | **Potential** | **Waste to energy plant Košice** | **Potential** |
| **2021** | 168 915 | 82 218 | 170 308 |
| **2022** | 158 839 | 77 108 | 160 148 |
| **2023** | 151 514 | 77 879 | 155 759 |
| **2024** | 144 028 | 75 633 | 148 240 |
| **2025** | 136 376 | 70 278 | 137 501 |
| **2026** | 134 679 | 74 067 | 135 789 |
| **2027** | 132 934 | 77 925 | 134 030 |
| **2028** | 131 141 | 78 704 | 132 222 |
| **2029** | 129 299 | 79 491 | 130 365 |
| **2030** | 127 407 | 80 286 | 128 457 |
| **2031** | 125 464 | 81 089 | 126 498 |
| **2032** | 123 469 | 81 900 | 124 487 |
| **2033** | 121 422 | 82 719 | 122 423 |
| **2034** | 119 322 | 83 546 | 120 306 |
| **2035** | 117 168 | 84 381 | 118 134 |
| **Together** | **2 021 979** | **1 187 222** | **2 044 669** |
| **Sum** | **2 021 979** | **3 231 891** | |

Source: own processing.

generation in the Slovak Republic has increased unevenly on average by about 3.5% year-on-year. Waste generation by 2035 was considered at a level of 1% year-on-year growth each year, given the economic potential and the strategy to reduce waste generation (see Table 1.). After recalculations, the production of municipal waste in the Košice region for 2035 was modeled at the level of 337 thousand tons. The recycling rate was indicated to meet the needs by 2035 (also according to Green Deal) to the level of 65%, landfilling minimized to max. 10%. The potential for energy recovery of municipal waste by 2035 has climbed to almost 120 thousand tons per year, which cumulatively means at today's loading ratio of 1.2 resp. at the so-called "Zero waste to landfill" approach approx. 2 mil. tons of non-landfilled waste.

In terms of adjacent production possibilities, it is also possible to consider the production of the Prešov region, where the potential is already today for almost 170 thousand tons of municipal waste per year, by 2035 for about 120 thousand tons, while maintaining a recycling rate (65%) and a landfill ratio (10%). Cumulatively, there is potential for another 2 mil. tons (see Table 1.).

### 3.1. Waste energy potential

Based on the current and future production of waste in individual regions, it is clear that hundreds of thousands of tons of waste have considerable energy potential (see Table 2.).

Table 2. Potential for energy production from 1 ton of mixed municipal waste (MMW)

| **Region** | **Prešov** | | **Košice** | | | |
|---|---|---|---|---|---|---|
| **Energy production** | Heat production MWh | Electricity generation MWh | Heat production MWh | Electricity generation MWh | Heat production MWh | Electricity generation MWh |
| **From 1t of MMW** | **2,68** | **0,85** | **2,68** | **0,85** | **2,68** | **0,85** |
| **Year** | **Potential** | **Potential** | **Waste to energy plant Košice** | **Waste to energy plant Košice** | **Potential** | **Potential** |
| **2021** | **452 693** | **143 578** | 220 343 | 69 885 | 456 425 | 144 762 |
| **2022** | **425 687** | **135 013** | 206 650 | 65 542 | 429 197 | 136 126 |
| **2023** | **406 058** | **128 787** | 208 717 | 66 197 | 417 434 | 132 395 |
| **2024** | **385 994** | **122 424** | 202 696 | 64 288 | 397 284 | 126 004 |
| **2025** | **365 488** | **115 920** | 188 345 | 59 736 | 368 501 | 116 875 |
| **2026** | **360 940** | **114 477** | 198 499 | 62 957 | 363 916 | 115 421 |
| **2027** | **356 264** | **112 994** | 208 838 | 66 236 | 359 201 | 113 926 |
| **2028** | **351 459** | **111 470** | 210 926 | 66 898 | 354 356 | 112 389 |
| **2029** | **346 522** | **109 904** | 213 036 | 67 567 | 349 378 | 110 810 |
| **2030** | **341 451** | **108 296** | 215 166 | 68 243 | 344 266 | 109 189 |
| **2031** | **336 243** | **106 644** | 217 318 | 68 925 | 339 016 | 107 524 |
| **2032** | **330 898** | **104 949** | 219 491 | 69 615 | 333 626 | 105 814 |
| **2033** | **325 412** | **103 209** | 221 686 | 70 311 | 328 095 | 104 060 |
| **2034** | **319 783** | **101 424** | 223 903 | 71 014 | 322 420 | 102 260 |
| **2035** | **314 010** | **99 593** | 226 142 | 71 724 | 316 598 | 100 414 |
| **Together** | **5 418 903** | **1 718 682** | **3 181 755** | **1 009 139** | **5 479 713** | **1 737 969** |

Source: own processing by authors of the waste study TUKE.

The advantage of mixed municipal waste is its calorific value, which is at the calorific value level of brown coal until recently mined in the conditions of the Slovak Republic. The right combination of types and amounts of waste ensures smooth combustion without the need to add fossil fuels. The table below shows the calculation of energy gains from energy recovery of waste in individual years related to the expected production of waste.

In the green columns is the recalculation to the potential of the current share of energy recovery for the Košice region. In recent years, Waste-to-energy plant in Košice produced an average of approximately 48,000 MWh of electricity, as the existence of only 1 turbine producing electricity does not use all the potential of waste for production.

As energy production from waste has not yet been included in the emissions trading scheme at European level, it is a resource that is not subject to additional charges as in the production of energy from fossil fuels, which means further savings in terms of the producer price of energy. This is mainly due to the presence of a biological component in the waste, which originates in the component of biomass, animal fraction and the nature of municipal waste.

### 3.2. Benefits of a "zero waste to landfill" approach

Expected amounts of potentially energy-recovered waste in the Košice region, resp. in eastern Slovakia mean:

- Landfill savings and conservation;
- Electricity and heat production and the independence of waste generators from the landfill fee;
- Own, stable energy source without external limitation of raw material inputs – diversified energy security of the region;
- Independent energy source from commodity prices (gas, electricity, heat, ...) on world markets, hydrogen production potential;
- An energy source not yet covered by the Emissions Trading Scheme;
- A fully emission control source with the strictest BAT limits by the environmental authorities;
- Low heat production costs compared to the costs of standard fossil fuel dependent heating sources;
- Solving the problem of fulfilling the binding goals of the Slovak Republic towards the EU in the field of waste management and avoiding infringements for non-fulfillment of landfill targets;
- Only 1–3% of flue gas dust from the original volume of waste;
- The slag from the process is widely used, for example, in construction.

## 4. CONCLUSION

The presented data and the conclusions drawn from them can also be confirmed by several relevant data. In 2021, a team of scientists and experts in circular economics from the Technical University in Košice prepared an analysis of the state of waste management and the potential of the circular economy model in Slovakia, which confirmed the regional needs for material and energy recovery and recommended the following:

Completion of bio-waste recycling and non-recyclable waste capacities; completion of the Waste-to-energy plant - to be implemented into the Waste Management Program for the years 2021–2025 – i.e. expansion of current capacities in Bratislava, or in Košice, and the

construction of new ones directly in the regions with the highest waste production and the highest share of landfilling – Trnava region, Nitra region, Trenčín region and Žilina region.

From the above, it can be stated that the analysis confirmed the current regional needs, as new lines for ZEVO are in the process of environmental impact assessment in Košice and Bratislava. In the approved materials "Waste Management Program of the Slovak Republic for the years 2021–2025", the government confirmed this direction, whereas, in order to divert waste from landfills, it envisages the use of existing and at the same time building new capacities for energy recovery, which is in line with the waste analysis and the EU vision for the next decade. Only in this way can Slovakia achieve the goals of the Green Deal by 2035, because a vision of a world without any waste is an unattainable illusion.

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