Levegő Munkacsoport

Methane emission reduction opportunities related to the waste sector in Hungary

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Content

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Executive summary

Methane is a highly effective contributor to the greenhouse effect, and thus to the negative socio-environmental and economic impacts of global climate change, because it remains in the atmosphere for a shorter time than carbon dioxide, but has a much greater impact over this shorter period. It is therefore very important to look at ways to reduce anthropogenic methane emissions in every country. This study analyses the potential for reducing methane emissions in Hungary in the waste sector, with a focus on landfills and bio-waste and food waste.

While the waste sector accounts for less than a quarter of total methane emissions in the EU, and agriculture for more than half, the waste sector is the largest emitter in Hungary, accounting for 42% of total emissions, compared to 34.3% for the second largest agricultural sector. This is mainly due to the fact that landfilling is still the most common waste treatment method in Hungary (55% of municipal solid waste was disposed of this way in 2022), and methane emissions associated with the waste sector are mainly related to methane released from organic matter that is landfilled and decomposes rapidly. And while methane emissions associated with landfilling have been on a downward trend at national level since the mid-2000s (since 2005, the amount of municipal waste landfilled has fallen by 50%, with a corresponding reduction in methane emissions of 18.8% [768 kt CO_2e]), there is still great potential for improvement: significant progress could be made by capturing the methane generated and, more importantly, diverting bio-waste from landfills.

As for methane gas capture in landfills, it is a viable solution that could be considered as a conventional abatement method, but there are several arguments against its preference: it is costly, inefficient, causes air pollution and, although it can be used for energy production, it requires bio-waste, which should be diverted from landfills as much as possible for environmental reasons: prevent it from being generated or otherwise recycled (composting, anaerobic digestion).

Following the principle of waste hierarchy, it is therefore recommended that, for this type of waste, too, priority should be given to prevention, followed by redistribution, recycling, composting or anaerobic digestion, and mechanical-biological treatment. As far as Hungary is concerned, in addition to a number of civil and institutional initiatives (Maradék nélkül program, Hungarian Food Bank, Budapest Bike Maffia, Food not Bombs, Munch), it is important to highlight that in 2024 the separate collection of bio-waste (in addition to garden waste, food waste) was launched under the coordination of Mohu – although for the time being only as a pilot project, with the involvement of a fraction of the population and with limited communication activities, thus with limited social support.

As for the potential emission reductions that can be achieved through these actions, different estimates can be made based on different projections and assumptions. Based on the EEA's projection of an annual reduction of 2.4% per year, a reduction of about 653 thousand tonnes CO_2e, or about 18%, could be achieved by 2030 compared to the base year 2022. Using a calculator from ReFED, a US non-profit organisation working to reduce food waste, the GHG footprint associated with food waste could be reduced from 2.9 million tonnes of CO_2e by 628 thousand tonnes in a realistic future scenario, and methane emissions of 32.5 thousand tonnes by roughly 30%, which translates into CO_2e savings of 761 thousand tonnes and 258 thousand tonnes over 20 and 100 years respectively.

	current scenario	**future scenario (realistic)**	**net savings**
Total GHG footprint (thousand tonnes CO_2e)	2,937.863	2,310.255	628.607

methane footprint (thousand tonnes CH_4)	32.536	22.996	9.540
methane footprint 100-year time scale (thousand tonnes CO_2e)	880.090	622.038	258.052
methane footprint 20-year time scale (thousand tonnes CO_2e)	2,594.721	1,833.920	760.802

Table 1: Emission reduction potential for food waste in a realistic scenario

In the optimistic scenario, the potential for emission reductions is obviously even more favourable: the calculator estimates total GHG savings of 973 thousand tonnes, while the methane footprint is more than 14 thousand tonnes lower, which means savings of 387 thousand tonnes of CO_2e over a 100-year time horizon and 1.14 million tonnes of CO_2e over a 20-year time horizon.

	current scenario	**future scenario (realistic)**	**net savings**
Total GHG footprint (thousand tonnes CO_2e)	2,938.863	1 965.610	973.253
methane footprint (thousand tonnes CH_4)	32.536	18.211	14.325
methane footprint 100-year time scale (thousand tonnes CO_2e)	880.090	492.620	387.470
methane footprint 20-year time scale (thousand tonnes CO_2e)	2,594.721	1,452.366	1,142.355

Table 2: Emission reduction potential for food waste in an *optimistic scenario*

It can therefore be concluded that in Hungary, greenhouse gas emissions related to the waste sector, and in particular methane emissions related to municipal solid waste landfilling, are an area where, with appropriate intervention, the country's contribution to global climate change can be effectively and rapidly reduced. This will require the expansion of selective collection of organic waste; the promotion of composting (local and centralised) and anaerobic digestion (biogas production); the reduction of landfilling and the recovery of landfill gas; and the promotion of waste reduction programmes at Community level. At national level, if separate collection and more efficient processing of organic waste implemented, zero waste regulations and measures are introduced, and a supportive legislative environment is created, up to 75-90% of the bio-waste generated could be diverted from landfills, and methane emissions could be greatly reduced.

1 Introduction

The waste sector is a significant contributor to greenhouse gas emissions globally and in Hungary, in particular methane emissions from landfilling (and carbon dioxide and other pollutants from incineration). This paper focuses on the methane emissions from the waste sector in Hungary and the opportunities for reducing them, highlighting the key sources, trends and available solutions. In the waste management sector, curbing methane emissions from the decomposition of organic matter is a particularly important issue, as this greenhouse gas is a much more potent contributor to global warming than carbon dioxide in the short term.

The study presents Hungarian waste management statistics, showing that landfilling has remained the most dominant waste management method in Hungary over the past decades, albeit with a decreasing share. This leads to very high methane emissions associated with the sector, as landfills are among the main sources of methane, especially when the organic matter content is high.

The study discusses different options for reducing emissions from the waste sector. For example, the development of landfill gas collection systems to capture and use methane for energy production. However, it is even more important to focus on other waste treatment methods, such as composting and biogas production, based on efficient separate collection of bio-waste. The document distinguishes between preventive and reactive methods, pointing out that preventive solutions, such as reducing food waste, can be the most effective strategy.

The Hungarian waste management sector faces further challenges to meet the EU's targets, in particular the 2030 targets for methane emissions. The study outlines realistic and optimistic emission reduction scenarios that would allow for the diversion of bio-waste from landfills by 70-80% or even 90%.

The study stresses that creating the right legislative environment and transforming waste management, with a greater emphasis on prevention, recycling and biological treatment, can have long-term economic and environmental benefits.

2 Characteristics of methane emissions linked to the waste sector

2.1 Methane emissions from landfilling

Of the different waste treatment methods (landfilling, incineration and recycling), landfilling is the one with the highest methane emissions. Waste placed in landfills is compacted and capped, which leads to anaerobic digestion, releasing mainly carbon dioxide and methane. The methane released from landfills is the result of the decomposition of organic waste, mainly food waste, in an oxygen-depleted environment. Although methane has a shorter lifetime compared to other greenhouse gases (e.g. CO_2), it is highly potent (~20 times more potent than CO_2 over a 10-year time horizon) and therefore it is worth examining methane emission reduction options, and one of the most effective ways is to reduce emissions associated with landfilling.

In Hungary, municipal solid waste generation in 2022 accounted for 3.911 million tonnes, about 406 kg per capita. The vast majority of this waste, around 55%, was disposed of in landfills (33% was recycled and 12% was burned with energy recovery).[1]

These two facts (the predominance of landfilling as a waste management method in Hungary and the associated methane emissions with high greenhouse effect) clearly show that there is great potential for transforming waste management (including a stronger focus on prevention), which can contribute to reducing the negative impacts of climate change relatively effectively and in the short term.

2.2 Other emissions related to waste generation and treatment

From a waste management perspective, significant GHG emissions are associated with waste transport, incineration, waste water treatment and even some emissions from composting. It is beyond the scope of this study to go into all these in detail, but incineration, as one of the largest emitters, is worth having a look.

As far as incineration is concerned, its contribution to the greenhouse effect is mainly through its CO_2 emissions. However, also with regard to carbon dioxide, a distinction can be made between fossil (e.g. plastics) and non-fossil (e.g. from the incineration of organic waste) sources. As far as European reporting obligations are concerned, EU Member States should also distinguish between waste incinerators that produce heat or electricity and those that do not – in the latter case, emissions are accounted for in the waste sector, but in the former case they are accounted for in relation to the energy sector. As far as Hungary is concerned, according to the detailed National Inventory Report (NIR) 2024, prepared by Hungaromet, the fossil carbon fraction in municipal solid waste has increased from 5% in 1990 to around 17-18% in the 2010s, and is currently around 12%. Based on the data reported in the NIR waste incineration with energy generation contributed 218 thousand tonnes of CO_2e to total GHG emissions in 2021.[2]

At EU level, incineration is the most common waste treatment method, and in some Member States landfilling rates have been reduced at the cost of a huge increase in incineration capacity. This has resulted in more than 40 million tonnes of fossil CO_2 emissions from the incineration of mixed municipal waste in 2017 (this figure excludes the impact of other GHGs such as methane and nitrogen

[1] https://www.ksh.hu/stadat_files/kor/hu/kor0029.html

[2] HungaroMet (2024) National Inventory Report for 1985-2022, Hungary. https://legszennyezettseg.met.hu/kibocsatas/hivatalos-jelentesek

oxides and the incineration of commercial and industrial waste, which accounted for about half of all waste incinerated).[3]

A recent study by IPEN and several other organisations on the impact of incinerators on the environment also highlights that incinerators emit significant amounts of greenhouse gases, mainly carbon dioxide, at levels that vary depending on the composition of the waste. On average, burning one tonne of waste releases 0.7-1.7 tonnes of CO_2 into the atmosphere. This high level of carbon dioxide emissions during the incineration process is mainly due to the incineration of fossil materials such as plastics in the waste. In addition, the global increase in plastic waste is projected to be accompanied by an increase in demand for the treatment of this type of waste by incineration, which could be responsible for higher CO_2 emissions by 2050 than the burning of conventional fossil fuels.[4]

The study stresses that incineration (a.k.a. WtE, Waste-to-Energy) is an energy-intensive process and produces more greenhouse gases per unit of energy than other conventional energy sources. However, other emissions should not be overlooked: incinerators emit significant amounts of pollutants even when using the best available techniques. Dioxins, for example, are persistent pollutants that cannot be completely removed by incinerators. Emissions of dioxins from state-of-the-art installations may be lower – even below regulatory limits – but the actual level of pollution is typically uncertain, as monitoring measurements are usually based on short sampling periods and ignore peak levels during start-up and shut-down phases of incineration, when emissions are generally higher, and also ignore emissions of heavy metals, including mercury, cadmium and lead. In particular, mercury emissions, which are prone to fluctuations, are difficult to monitor continuously. Although advanced filtering and cleaning technologies can capture some of these metals, significant amounts can still be released into the atmosphere. The accumulation of these metals and chemicals in the surrounding environment poses risks to ecosystems and human health. The report also points out that even modern filtration systems cannot fully capture fine particles (particulate matter), which can carry other hazardous substances, exacerbating health risks.[5]

2.3 EU and national trends

The European Commission is assisted by the European Environment Agency (EEA) in preparing the EU's greenhouse gas emissions inventory and in implementing quality control and assurance of the inventories reported to the EU by the Member States. Their website provides detailed data on EU and national methane emissions. Based on the latest data for 2022, 410 million tonnes of carbon dioxide equivalent (CO_2e) methane emissions have been recorded in the 27 EU Member States across all sectors, with the majority of these emissions being attributable to the agricultural sector (56.1%), with the second largest share (23.7%) coming from the waste sector (data in subsection 2.3 are from the EEA website).[6]

[3] ZWE (2019) The impact of Waste-to-Energy incineration on climate. (by Janek Vähk) https://zerowasteeurope.eu/wp-content/uploads/edd/2019/09/ZWE_Policy-briefing_The-impact-of-Waste-to-Energy-incineration-on-Climate.pdf

[4] Arnika / IPEN / TFA / CREPD / CEJAD (2024) Waste incineration and the environment (ed.: Jelínek et. al.) https://ipen.org/sites/default/files/documents/waste_incineration_and_the_environment.pdf

[5] Ibid.

[6] https://climate-energy.eea.europa.eu/topics/climate-change-mitigation/greenhouse-gas-emissions-inventory/data

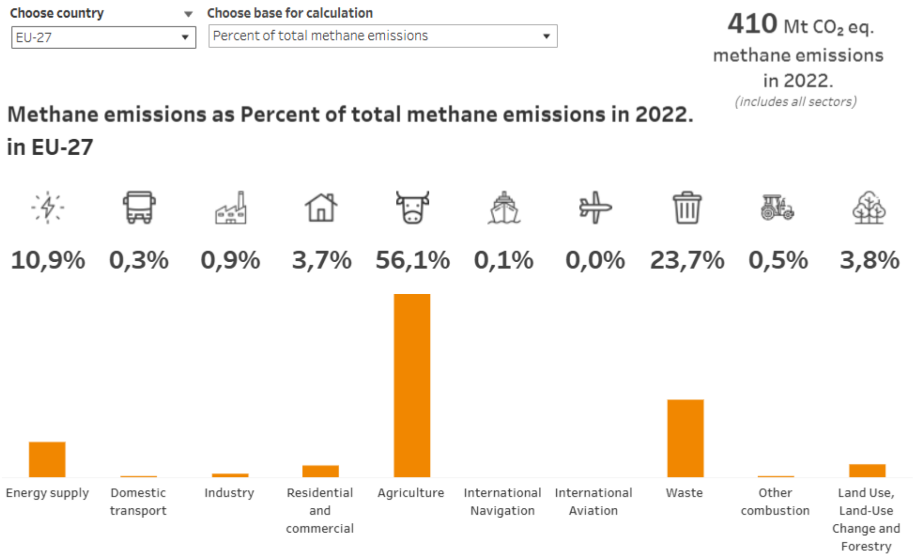

Figure 1: Sectoral breakdown of methane emissions in the EU-27, 2022 Source: EEA[7]

For Hungary, the waste sector was responsible for by far the largest share of the 9 Mt CO_2e of methane emissions in 2022, 42%, followed by agriculture with 34.3% and the energy sector with 16.2%. [8]

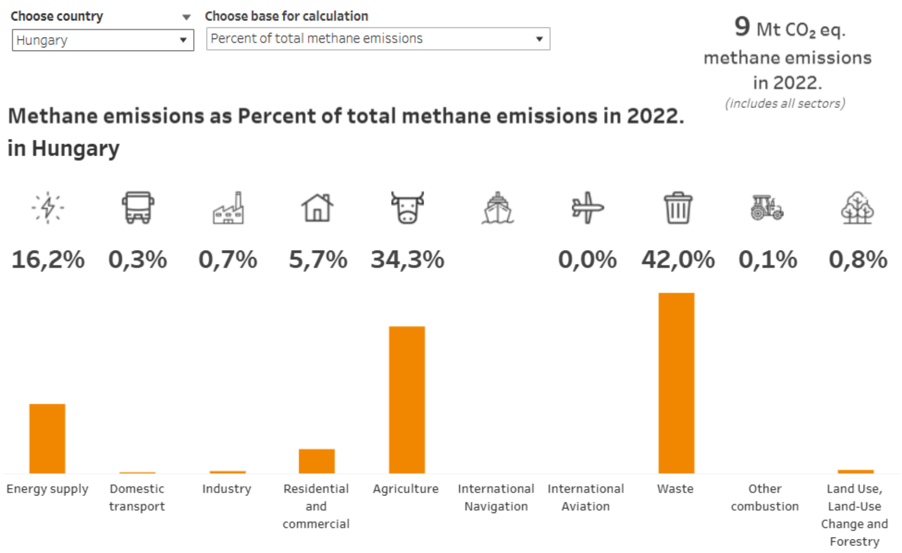

Figure 2: Sectoral breakdown of methane emissions in Hungary, 2022 Source: EEA[9]

Also from data available on the EEA website, it can be seen that in the 1990s, some 173 thousand kilotonnes of CO_2e of methane production in the European Union was associated with the waste sector, and this figure has fallen by around 41% to 97 thousand kt by 2022.[10]

In Hungary, a significantly smaller decrease of only 7% was recorded over the same period (1990: ~4000 kt CO_2e, 2022: ~3700 kt CO_2e). It is important to note, however, that while at EU level the trend has been decreasing since 1992, in Hungary methane emissions related to the waste sector increased

[7] Ibid.
[8] Ibid.
[9] Ibid.
[10] Ibid.

until 2003. Since then, however, there has been a downward trend (in absolute terms, about 1000 kt since 2005, a decrease of 21%).[11]

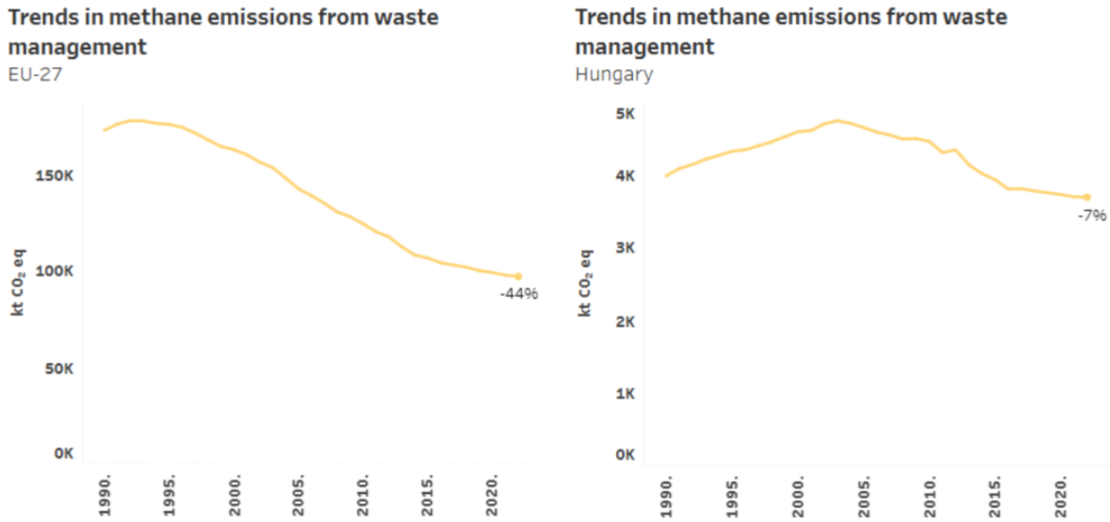

Figure 3: Methane emissions from the waste sector in the European Union and Hungary, 1990-2022
Source: EEA[12]

A deeper look at the methane emissions associated with the waste sector shows that the largest source of methane in the sector in the EU is landfilling (~80%), followed by residential and industrial wastewater treatment (~15%) and biological treatment of solid waste (~4%).[13] In absolute , compared to the 1990 base year, the largest reduction in emissions by 2022 compared to the 1990 base year was associated with solid waste landfilling (~60 thousand kt CO_2e, a reduction of 44.4%), with a third largest reduction in emissions associated with wastewater treatment (20e kt CO_2e, 55.4%). There has been a minimal increase since 1990 for industrial waste and open burning of waste (131 kt CO_2e, 30.6%), and a similar situation for the biological treatment of solid waste (4434 kt CO_2e, 855%).[14]

[11] Ibid.
[12] Ibid.
[13] cf.: https://www.eea.europa.eu/publications/methane-emissions-in-the-eu
[14] https://climate-energy.eea.europa.eu/topics/climate-change-mitigation/greenhouse-gas-emissions-inventory/data

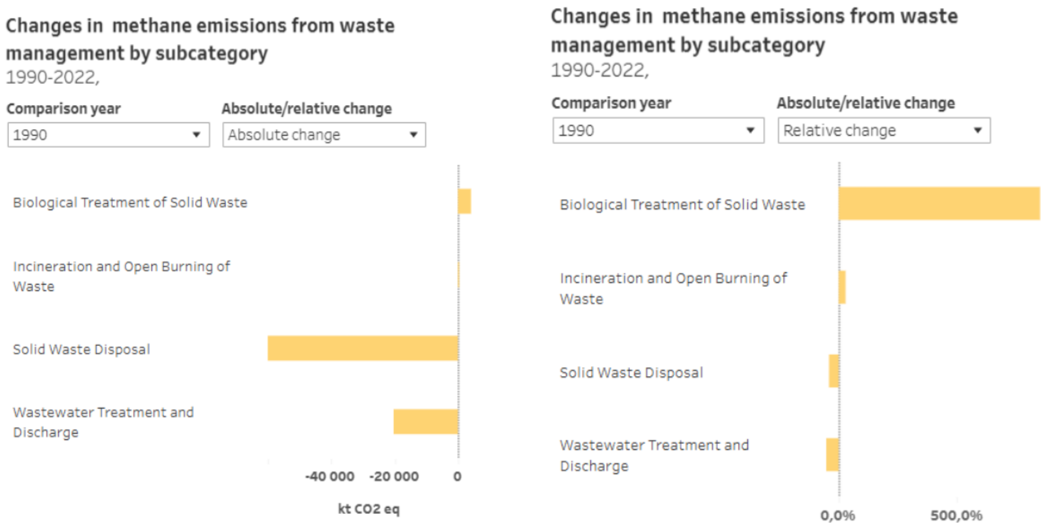

Figure 4: Change in methane emissions in the waste sector in the European Union by different waste treatment technologies, absolute and percentage, 1990-2022 Source: EEA[15]

Over a shorter time horizon, comparing the period 2019-2022, there are obviously smaller differences. Both the biological treatment of solid waste and incineration were associated with emission increases of 9-9% at EU level, corresponding to 409 and 46 kt CO_2e respectively. However, solid waste landfilling and waste water treatment showed larger emission reductions of 2903 kt CO_2e and 641 kt CO_2e (-3.7 and -3.8%).[16]

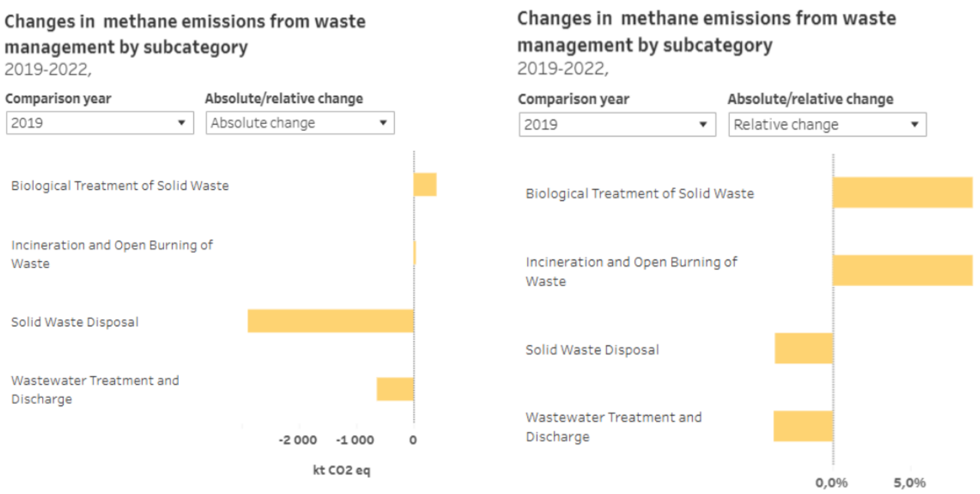

Figure 5: Change in methane emissions from the waste sector in the European Union by different waste treatment technologies, absolute and in percentage terms, 2019-2022 Source: EEA[17]

Trends were different in Hungary. Between 1990 and 2022, there was no significant change in methane emissions related to incineration, but emissions related to the biological treatment of solid

[15] Ibid.
[16] Ibid.
[17] Ibid.

waste and landfilling increased overall: by 112 kt and 345 kt respectively. The decrease in total methane emissions from the waste sector, as mentioned above, is due to wastewater treatment, which showed a decrease of 74.4%, or 752 kt CO_2e. However, it is important to note that compared to 2005, methane emissions related to solid waste landfilling also decreased by 768 kt CO_2e (18.8%).[18]

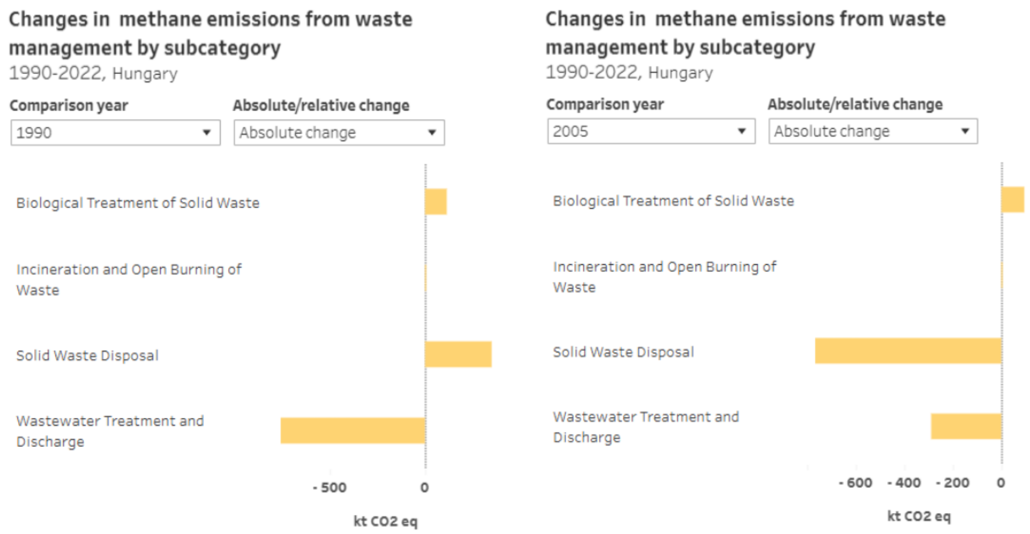

Figure 6: Methane emissions from the waste sector in Hungary by different waste treatment technologies, in absolute terms, 1990-2022 and 2005-2022. Source: EEA[19]

The reduction of methane emissions from landfilling at EU level is also due to the fact that the legislative framework[20] is increasingly pushing Member States to reduce the amount of untreated organic waste going to landfills and to use landfill gas in newly opened landfills. At present, the vast majority of municipal solid waste generated in many Member States (including Hungary) is landfilled, so in order to reduce the amount of waste going to landfills below the 10% limit set by the EU Directive by 2035, other waste management methods (re-use, selective collection and recycling, biological treatment, energy recovery) need to be promoted.[21]

Based on the available data and taking into account trends, further reductions in methane emissions can be expected, experts say. According to the EEA website on the waste sector, *"GHG projections reported by Member States indicate that total CH_4 emissions will continue to decline, but at a faster rate (2.4% per year until 2030) than in the 30 years since 1990."*[22]

[18] Ibid.
[19] Ibid.
[20] cf: EU Landfill Directive, see:
[21] https://climate-energy.eea.europa.eu/topics/climate-change-mitigation/greenhouse-gas-emissions-inventory/data
[22] https://www.eea.europa.eu/publications/methane-emissions-in-the-eu

3 Detailed presentation of Hungarian statistics related to the waste sector

In Hungary, more than 80% of municipal solid waste was still landfilled in the mid-2000s, but this dropped to around 50% by the mid-2010s, and then It has been around 50-55% until 2022 (the latest year for which data is available). The total amount of waste decreased from ~4.6 million tonnes to ~3.9 million tonnes until 2022, with a decreasing and stagnating trend (in the seven-year period 2013-2019, the Central Statistical Office reported values between 3.7 and 3.8 million tonnes, but afterwards the amount of waste returned to between 3.9 and 4.1 million tonnes.)

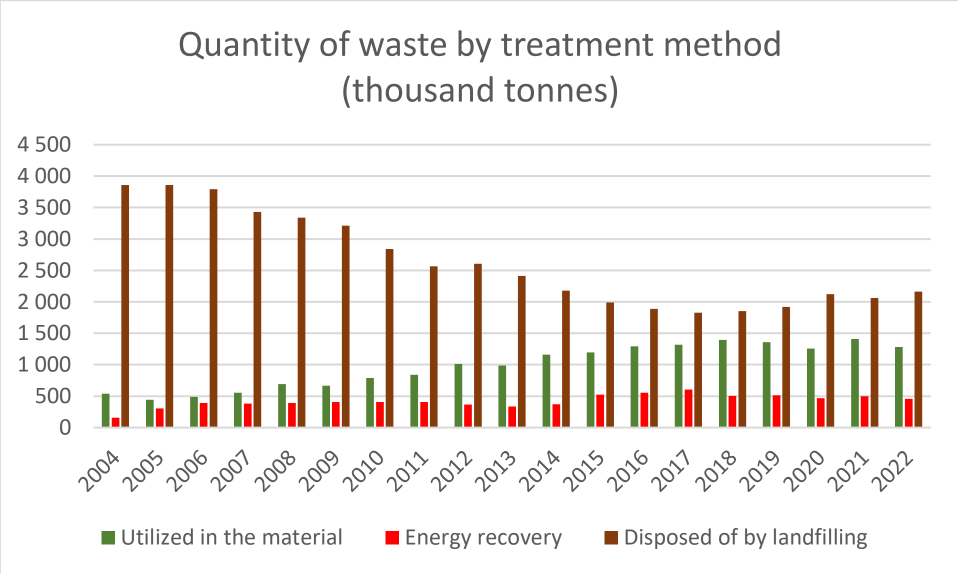

Figure 7: Waste by treatment method in Hungary 2004-2022 Source: KSH[23] , Own ed.

As pointed out on the HungaroMet website, *"the decomposition processes in landfills are rather slow, which means that the amount of waste landfilled many years ago has a significant influence on the current level of emissions. Since 2005, the amount of waste landfilled has decreased significantly (municipal waste landfilled has decreased by 50%), so methane emissions have also started to decrease."[24]*

[23] https://www.ksh.hu/stadat_files/kor/hu/kor0029.html

[24] https://legszennyezettseg.met.hu/kibocsatas/agazati-kibocsatasok/hulladek

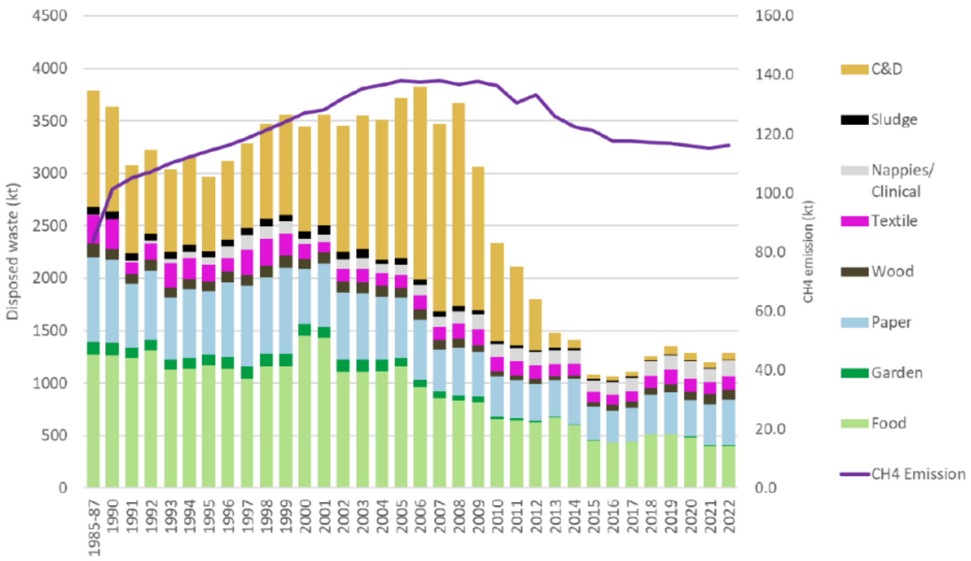

Figure 8: Landfilled waste and methane emissions in Hungary, 1990-2021 Source: HungaroMet[25]

As shown in the figure above, and as described in the NIR, in addition to municipal waste, the disposal of industrial waste is also taken into account when estimating methane emissions associated with landfilling.[26]

The decrease in the amount of waste landfilled per year since 2005 is also shown in the following graph, which shows that in 2022, the largest share of waste landfilled was mixed solid waste (mainly municipal), followed by inert waste (from incineration).[27]

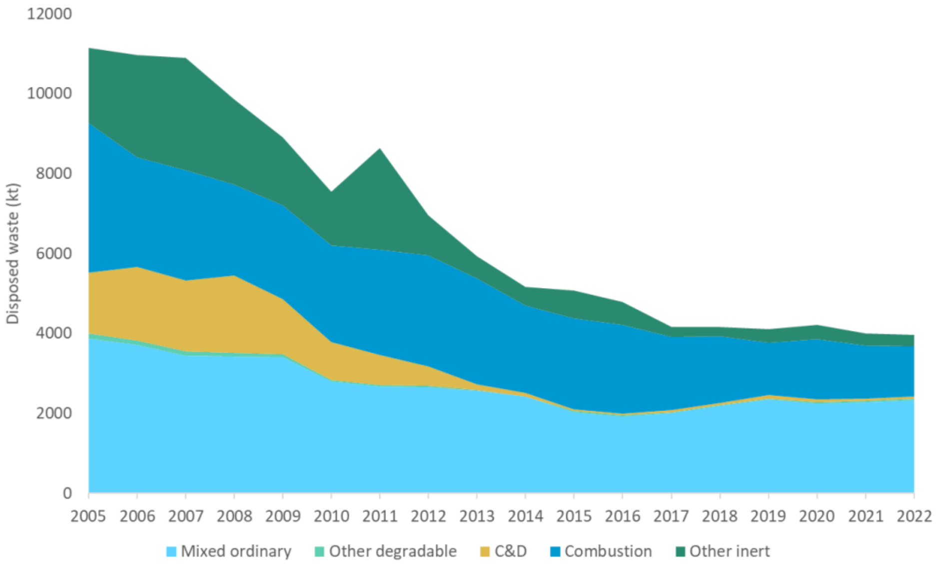

Figure 9: Trends in the amount of waste going to landfill in Hungary by type of waste, 2005-2022 Source: HungaroMet[28]

[25] HungaroMet (2024)
[26] Ibid.
[27] Ibid.
[28] HungaroMet (2024)

The number of landfills has fallen sharply since 2000 to meet EU standards. Modernisation efforts have resulted in a reduction from around 2,700 landfills to 701 in 2005, 340 in 2005, 213 in 2008 and 69 in 2011. In addition to the closure of obsolete landfills, those that are still operating have been modernised, so that the proportion of landfills that are not properly managed and fall into category D1 – "Landfilling to or into the ground (e.g. landfilling of waste)"[29] – has fallen from 50% to 1% in 10 years from the mid-2000s, and since 2017 it has fallen to 0%. At the same time, the share of properly managed landfills in category D5 – "Landfilling with technical protection (e.g. disposal in covered, insulated cells, separated from the environment and from each other)"[30] – has increased from 50% to 100%.[31]

	D1	D5
2004	50%	50%
2005	48%	52%
2006	34%	66%
2007	36%	64%
2008	44%	56%
2009	29%	71%
2010	17%	83%
2011	35%	65%
2012	12%	88%
2013	2%	98%
2014	1%	99%
2015	1%	99%
2016	1%	99%
2017	0%	100%
2018	0%	100%
2019	0%	100%

Figure 10: Distribution of D1 and D5 landfills in Hungary, treated and adequately treated, 2004-2019
Source: HungaroMet[32]

The total greenhouse gas emissions associated with the waste sector in 2022 were 3.8 million tonnes of CO_2e, accounting for 6% of Hungary's GHG emissions. The largest share, 87%, was related to solid waste landfilling, 9% to wastewater treatment, 4% to biological treatment of solid waste and 1% to incineration without energy recovery (GHG emissions related to energy production are included in the inventory report as energy sector GHG emissions). Between 2004 and 2019, according to the Hungarian Central Statistical Office (KSH), an average of 1,250 kt of waste was treated with energy recovery or incinerated without energy recovery in Hungary, and only 8% of this was incineration without energy recovery.[33]

[29] cf. Decree 43/2016 (28.VI.) of the Ministry of Finance on the list of disposal and recovery operations related to waste management, see https://net.jogtar.hu/jogszabaly?docid=a1600043.fm
[30] Ibid.
[31] HungaroMet (2024)
[32] Ibid.
[33] Ibid.

4 Solutions to reduce methane emissions

4.1 Capturing methane from landfills

Capturing methane gas from landfills is a well-established method of reducing methane emissions in waste management, but it is often not very effective, especially in the early stages of waste decomposition. It is also worth noting that landfills release not only methane but also carbon dioxide and other gases.

In Hungarian law, the relevant definitions are defined in the "Decree 20/2006 (IV. 5.) of the Ministry of Public Works and Water Management[34] on certain rules and conditions related to landfilling and waste disposal". According to this regulation, landfill gas is "the gas mixture formed in the landfill during the biological, chemical decomposition of landfilled waste".

The proportions of gases vary, but methane is typically around 55% of the total, while carbon dioxide is around 45% (and other trace gases may be present to a lesser extent).[35]

Waste going to landfills starts and decomposes at different rates depending on the type of waste. For example, more decay-prone waste (e.g. food) starts to decompose almost immediately, while for many other types of organic waste (e.g. garden waste) the process is slower, and in other cases it is particularly slow (wood waste).

When a landfill reaches its maximum receiving capacity (or for other reasons, such as having to comply with new, stricter legislation than some Member States, including Hungary when it joined the EU), the landfill must be closed. The upper containment layer should only be temporary if the gas formation is still ongoing and the amount of gas produced justifies treatment. As stated in the above-mentioned legislation, *"a permanent top containment system may be constructed when the stabilisation process in the waste body is virtually complete."* In other words, as long as the biological and chemical processes lead to the formation of landfill gas and there is a risk of the landfill subsiding, only a temporary landfill closure system can be implemented.

The upper containment layer allows partial capture of the gas from the landfill through a network of wells and pipes, which can then be used for energy production. When the gas is burnt, methane is oxidised to carbon dioxide (a less efficient but longer-lived greenhouse gas). Similarly, some of the methane that escapes from the landfill through the overburden can also be oxidised to carbon dioxide as it passes through the overburden. The part of the resulting methane gas that is not oxidised is released to the atmosphere as methane.[36]

It is worth emphasising that large quantities of methane can be released into the atmosphere even before the landfill is closed and capped. A study in the United States in 2023 estimated that 58% of the fugitive (i.e. directly emitted to the atmosphere) methane emissions from municipal solid waste going to landfills will come from food waste. The authors of the study estimate that 61% of the methane emissions from food waste going to landfill cannot be captured by the systems and equipment designed to contain them and are released into the atmosphere. This is largely due to the

[34] See: https://net.jogtar.hu/jogszabaly?docid=a0600020.kvv

[35] ZWE (2024) Reducing waste management's contribution to climate change From post-landfilling methane capture to pre-landfill methane prevention. (ed. Dominic Hogg)

[36] Ibid.

fact that rapidly decomposing food waste often decomposes before the methane capture network or system is even built or the build-up process is complete.[37]

Capturing gases from landfills is therefore unreliable and allows large amounts of fugitive methane emissions. In the long term, in addition to the amortisation of the pipes used to collect these gases, the inefficiency of extracting energy from the low methane gas mixture and the air pollution resulting from the combustion of the gas is problematic. Moreover, the construction of landfill gas collection systems is extremely expensive compared to other methane abatement solutions and in some respects sends the wrong message. Just as in the case of incinerators, the more waste that is produced, the more energy the incinerator can produce, so too in the case of landfills, the more methane can be recovered from the landfill by landfilling organic waste that could have been returned to the soil by other means (e.g. composting).[38]

It can be concluded that food waste has a very high impact on methane emissions from landfills due to its fast decomposition rate. And since 50% of the carbon in food waste is converted to landfill gas within approximately 3.5 years, only improving the efficiency of the methane gas collection system cannot significantly reduce these emissions.[39]

The traditional approach focuses on capturing as much of the gas released from landfills as possible, and minimizing the amount of gas that escapes from the landfill through the surface once it is sealed, or oxidation of the gas that is not captured. In other words, as little landfill gas as possible should be allowed to leave the facility uncontrolled. In addition, of course, there is a positive and not unimportant co-benefit in generating as much energy as possible from captured gas – but this becomes less feasible and less economical as time goes on after the landfill is closed. Thus, in the later years after covering the landfill, the focus may shift from energy production to flaring of the generated gas.[40]

In the case of landfills for non-hazardous waste with a mixed composition, i.e. with a significant content of both organic and inorganic substances (so-called category B3), the above-mentioned legislation states that an active landfill gas collection system must be installed and provides for the treatment of the gas, stating:

> *5.1 Where landfill gas may be generated from landfilled waste in the landfill pond, regular removal, collection and treatment of landfill gas shall be ensured. In all cases, a gas treatment system shall be provided for the treatment of gases generated from biodegradable components in Category B3 landfills.*
>
> *5.2 In a landfill of category B3, not only shall drainage be provided, but also, as long as the gas generated can be economically recovered, the landfill gas shall be used. If recovery is not economically viable, safe disposal of the gas (e.g. by flaring) must be ensured.*

In other words, in the latter case, the methane in the landfill gas is not used for energy recovery, but only becomes carbon dioxide. But even if the gas is recovered, as shown above, this becomes less and less efficient as the degradation process progresses. Studies in the UK, for example, found that a

[37] US EPA (2023) Quantifying Methane Emissions from Landfilled Food Waste, (ed. Krause et. al.). https://www.epa.gov/system/files/documents/2023-10/food-waste-landfill-methane-10-8-23-final_508-compliant.pdf
[38] GAIA (2022) Zero Waste to Zero Emissions, How Reducing Waste is a Climate Gamechanger. https://www.no-burn.org/wp-content/uploads/2022/10/executive-summary-ENG.pdf
[39] US EPA (2023)
[40] ZWE (2024)

landfill basin would capture only around 52% of the methane over its entire life cycle – and this estimate was later revised even lower, recognising that the amount of gas produced in the early years may be higher than previously calculated.[41]

Reducing methane emissions from landfills receiving municipal solid waste could therefore be effectively achieved by preventing food waste from being dumped there.[42]

4.2 Other solutions to reduce the amount of waste that is generated and landfilled, and thus potentially methane-emitting

4.2.1 Food waste hierarchy

The European Union's Waste Directive states that "*The first objective of any waste policy should be to minimise the negative effects of the generation and management of waste on human health and the environment. Waste policy should also aim at reducing the use of resources, and favour the practical application of the waste hierarchy.*"[43] Member States have therefore had to develop their respective legislation in such a way that waste management gives priority to prevention, followed in turn by the following stages: preparation for re-use; recycling; other recovery, such as energy recovery; and disposal.

Zero Waste Europe (ZWE), in partnership with the Zero Waste International Alliance (ZWIA), has taken this further by trying to take into account social, economic and logistic factors necessary for the transition to a circular economy.[44] This is how the Zero Waste Hierarchy was born, which now had seven levels, as follows:

1. Refuse/rethink/redesign
2. Reduce and reuse
3. Preparation for re-use
4. Recycling/composting/anaerobic digestion
5. Material and chemical recovery
6. Residuals management
7. Unacceptable (including landfilling and all forms of incineration)[45]

[41] Ibid.
[42] US EPA (2023)
[43] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008L0098
[44] cf.: https://zerowasteeurope.eu/press-release/press-release-a-zero-waste-hierarchy-for-europe/
[45] See more at: https://zerowasteeurope.eu/2019/05/a-zero-waste-hierarchy-for-europe/

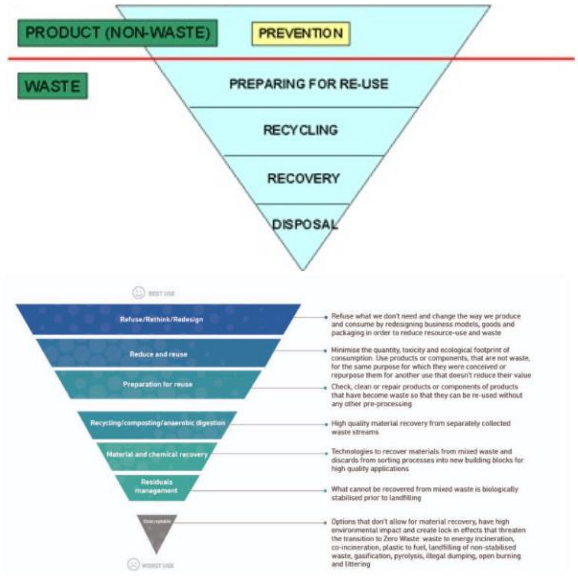

Figure 11: The Waste Hierarchy and the Zero Waste Hierarchy. Source: Zero Waste Europe[46]

This has been reworked and rewritten since then, and the latest version 8.0 is currently available on the ZWIA website.[47] But one can find not only in a general, more comprehensive sense, but also in a narrower version tailored to food waste, the so-called food waste hierarchy, given that food waste is substantially different from other types of waste.

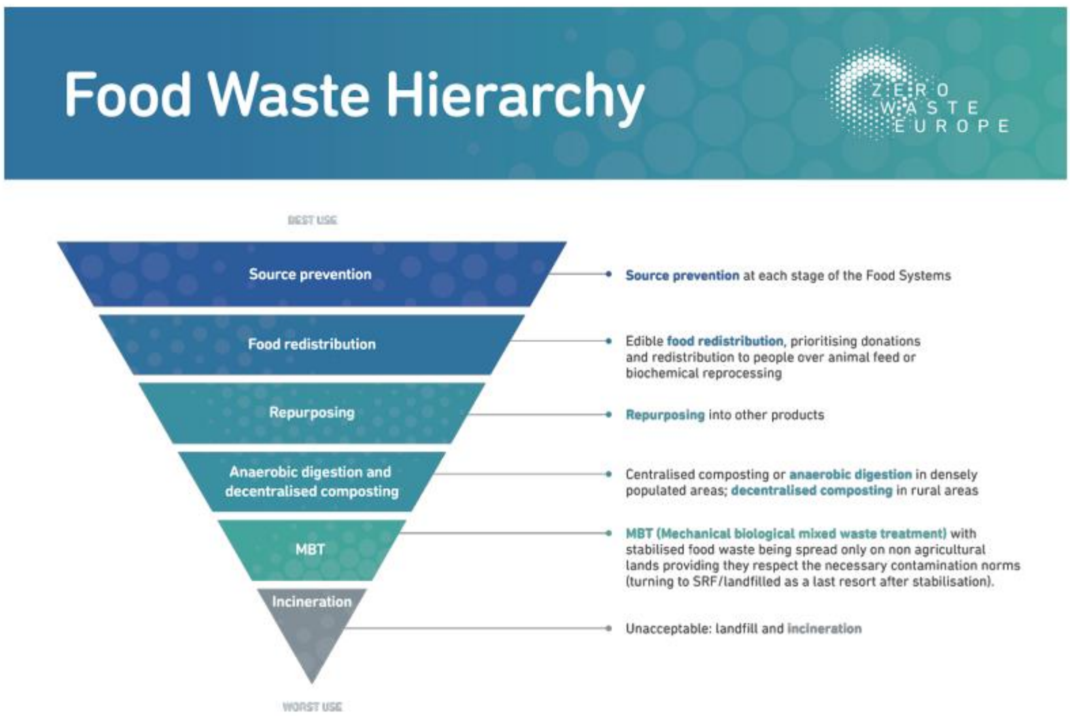

Figure 12: Food waste hierarchy. Source: Zero Waste Europe[48]

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[46] https://zerowasteeurope.eu/press-release/press-release-a-zero-waste-hierarchy-for-europe/
[47] See https://zwia.org/zwh/
[48] https://zerowasteeurope.eu/library/food-systems-a-recipe-for-food-waste-prevention/

This hierarchy is designed to help prevent the generation of food waste; to help redistribute or donate food that cannot fulfil its primary purpose; and to help recycle food that becomes unfit for consumption by composting or anaerobic digestion, avoiding landfilling and incineration."[49]

The levels of the food waste hierarchy are:

1. Source prevention at each stage of the food systems.
2. Edible food redistribution, prioritising donations and redistribution to people over animal feed or biochemical reprocessing.
3. Repurposing into other products.
4. Centralised composting or anaerobic digestion in densely populated areas; decentralised composting in rural areas.
5. Mechanical-biological mixed waste treatment (MBT) with stabilised food waste being sporead only on non-agricultural lands probiding they respect the necessary contamination norms (tudning to SRF/landfilled as a last resort after stabilisation).
6. Not acceptable: direct dumping and incineration.

Following the logic of the hierarchy, EU and national legislation should prioritise food waste prevention. This includes all stages of the food chain, such as primary production and primary processing; processing (including transport and packaging); wholesale and retail; catering and food service (including canteens, health care and HoReCa); and the household level.[50] The latest statistics for 2022 (consistent with previous data) show that the largest share of food waste in the EU (54%, or 72 kg per capita per year) is attributable to households, with the remaining 46% attributable to other levels of the food chain.[51]

Where prevention is not possible, donation or redistribution of food that can still be consumed is the right way forward – primarily for human consumption, of course, but the use of organic waste as animal feed has also long been a known and practised method of recovery worldwide, particularly in rural areas. In this way, valuable nutrients are not lost and, in addition, some substitutes for fodder crops are also available. As pointed out by Condamine et al. in their 2022 study, " *The methane reduction potential of animal feed has yet to be robustly quantified, but one lifecycle analysis found that this treatment method outcompetes compost and anaerobic digestion in terms of its overall GHG emissions reduction performance. However, precautions must be taken to avoid potential disease transmission, and industrial agriculture is, of course, a major source of GHG emissions."*[52]

Food that is not suitable for consumption should, if possible, be processed according to the hierarchy's recommendations (e.g. by upcycling, like making jam from damaged fruit). If this is not possible, other methods of recovery (with preference for composting) are recommended.[53] These recovery methods are discussed in later sub-chapters.

There is also a so-called Organic Waste Hierarchy, which is similar to the food waste hierarchy described above in a number of ways. Here too, prevention at all levels of the supply chain is at the

[49] Zero Waste Europe (2021) Reducing food waste at local level – A guide for municipalities to reduce food waste within local food systems, (by Condamine et al.). https://zerowasteeurope.eu/library/reducing-food-waste-at-the-local-level/

[50] ZWE, Slow Food (2019) Food Systems: a 'recipe' for food waste prevention – A strategic guide (ed. Pierre Condamine). https://zerowasteeurope.eu/library/food-systems-a-recipe-for-food-waste-prevention/

[51] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Food_waste_and_food_waste_prevention_-_estimates

[52] GAIA (2022) Zero Waste to Zero Emissions - How Reducing Waste is a Climate Gamechanger (ed. Tangri et al.

[53] ZWE, Slow Food (2019)

top, followed by food rescue (redistribution, transformation) or use as animal feed, followed by material recovery (composting or anaerobic digestion) on a small scale in a decentralised way, and then on a medium to large scale in a centralised way. Since some organic matter always remains in the mixed waste, the next step is its biological stabilisation, which can be either simpler mixing and aeration techniques or more complex material recovery and biological treatment (MRBT) systems. Finally, at the bottom of the hierarchy, before incineration and other thermal treatments, which fall into the unacceptable category, is the use of organic waste as a biologically active cover for remediation, i.e. as a bioactive cover layer at landfills, which can contribute greatly to reducing landfill methane emissions (by 63% on average) through the methane-digesting microbes found in compost and organic waste. Such a layer can even reduce the amount of methane in the atmosphere.[54]

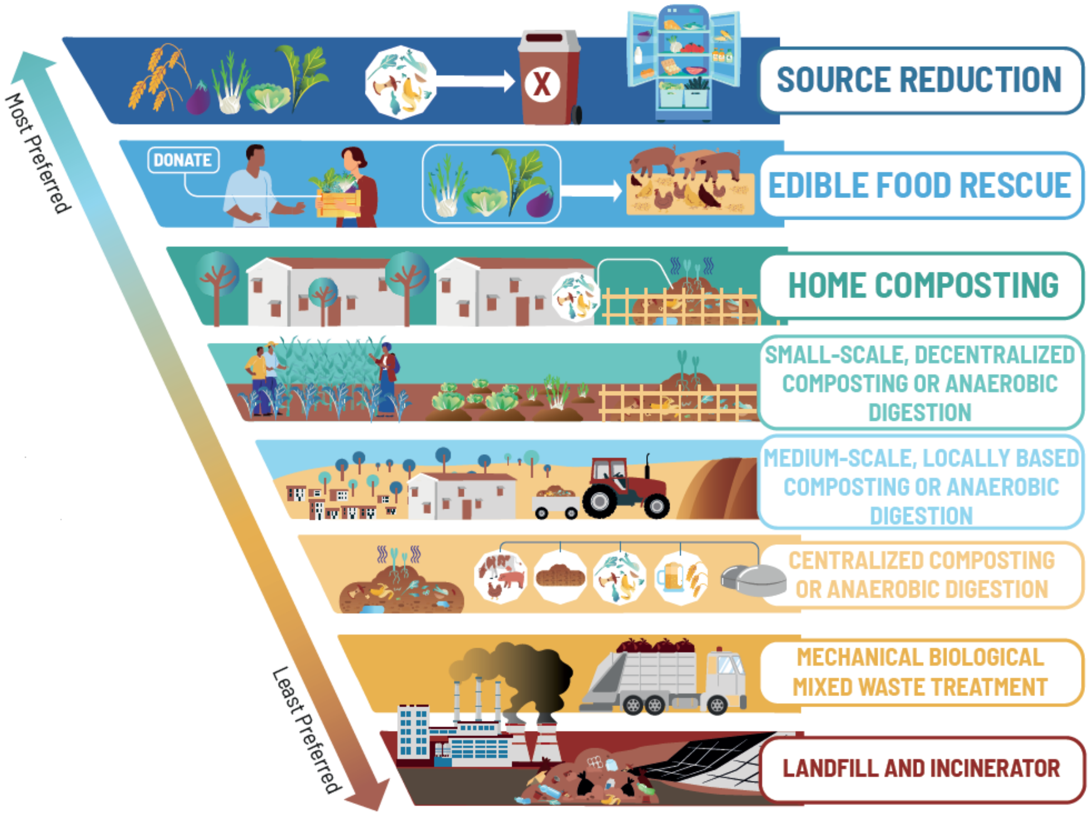

Figure 13: The Organic Waste Hierarchy: the hierarchy that promotes food waste reduction and community development. Source: GAIA/Institute for Local Self-Resilience[55]

4.2.2 Waste prevention and food rescue

When it comes to waste prevention, it's a cliché that the best waste is the one that is not produced. This expresses exactly what has been said in the previous chapters, namely that the primary focus should be on waste prevention – whether organic or inorganic.

The relevant Zero Waste Europe Strategic Guide stresses that effective progress requires the mandatory implementation of food waste prevention programmes and binding food waste reduction

[54] GAIA (2024) Environmental Justice Principles for Fast Action on Waste and Methane.
[55] Ibid.

targets at Member State level, as well as a comprehensive definition of food waste that includes all levels of the food chain.[56]

The guide makes recommendations for different levels of the food chain.

In the context of primary production and processing, the guide encourages a review of the overall agricultural and fisheries regulations, which could help to improve market conditions and thus avoid food losses for economic reasons. In addition, promoting improvements in agricultural techniques can contribute to long shelf-life, while for retailers and consumers, awareness-raising can help them to buy products of unusual quality (e.g. shape, appearance).[57]

For processing, the guide recommends, among other things, shortening the supply chain to reduce delivery time and improving related infrastructure, while for wholesale and retail, the guide recommends, among other things, rethinking the "Best before" and "Use by" labels to improve clarity, promoting food donations and rethinking legislation on hygiene and marketing. The re-sizing of portions and the development of different portion sizes; regular training of staff; and the mandatory takeaway packaging of food waste in the catering sector could help prevention, while at household level, the promotion of food donation and promotion of good practices in purchasing are among the measures recommended.[58]

Food waste prevention programmes and initiatives in Hungary

According to research data published by the National Food Safety Office (Nébih) in 2024 and published in 2023, nearly 600 thousand tonnes of food waste is generated in households in Hungary every year (62 kg per capita), of which 247 thousand tonnes (25.8 kg per capita) is pure waste, i.e. it could be prevented. Based on historical data, we can see that since 2016 the amount of food waste generated in households has decreased by 22%, i.e. by an average of about 6 kg per person per year. However, after successful years in 2021 and 2022, the trend in waste reduction reversed in 2023 – although food waste is still significantly below 2016 levels. The Nébih researchers considered as avoidable waste the unused food that could have been avoided by taking more care (e.g. buying or preparing smaller quantities). This accounted for 41.64% of all food waste.[59]

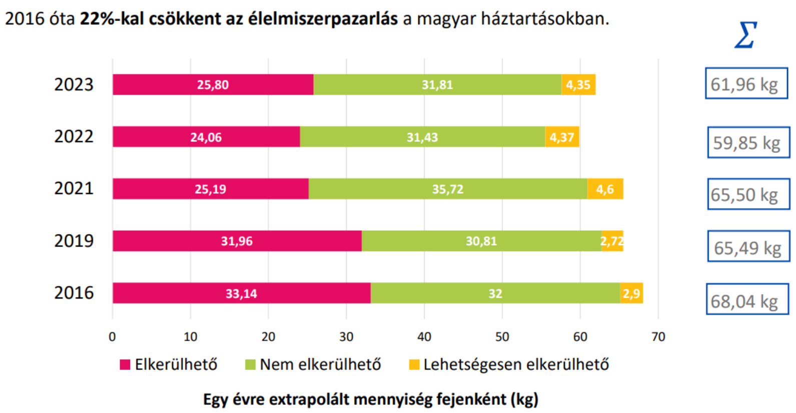

Figure 14: Trends in food waste in Hungary 2016-2023. Source. Nébih[60]

[56] ZWE, Slow Food (2019)
[57] Ibid.
[58] Ibid.
[59] https://portal.nebih.gov.hu/documents/10182/21442/Kutatasi+length+Summary+Household+Food+Waste+Felmeres+2023.
[60] Ibid.

The consumption of natural resources and the environmental burden of producing and disposing of such large quantities of surplus food as waste place a heavy burden on society, both environmentally and economically. According to research by the Nébih, 47% of uneaten food ended up in the rubbish bin, 8% ended up in the drain and 15% was consumed by pets. Nearly 2% of all food waste went to waste collection points and about a quarter was composted. The proportion of food waste composted (25.8%) has increased significantly since 2016, when it was less than 19%. However, there is still room for significant improvement, as more than 41% of the total food waste could have been composted, according to the survey.[61]

It is also worth briefly discussing the difference between avoidable and non-avoidable food waste. The latter include, for example, inedible fruit and vegetable parts, eggshells, tea bag contents, coffee grounds, and inedible animal parts, as well as fats used for frying (see figure below), which are generated during the processing, preparation and consumption of food and are not suitable for human consumption. The majority of these are compostable (except for grease and animal waste, which are not recommended for home composting). In contrast, avoidable food waste is that which is most often generated unintentionally, through carelessness or through bad habits or unusual circumstances. In addition to spoiled vegetables and fruit, which are still suitable for composting, there is a high proportion of processed (whether individually or bought as such), prepared (fried, cooked) and spoiled food, which is also not recommended for home composting.

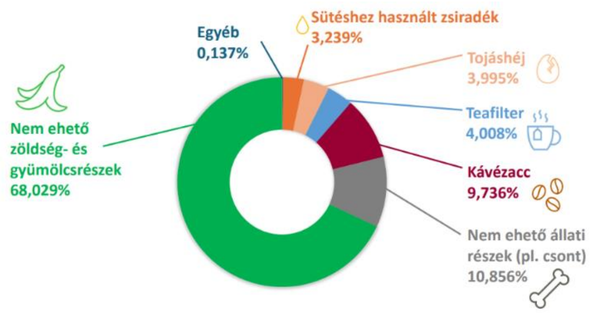

Figure 15: Composition of unavoidable food waste in Hungary in 2023. Source: Nébih[62]

However, even though the relevant EU directive states that, taking into account the waste hierarchy, waste prevention takes precedence over recovery in terms of policy objectives, only one paragraph of the Hungarian legislation deals with the prevention of food-derived bio-waste. The legislation states here that the *"relevant awareness-raising and education among the general public shall be carried out with the contribution of the series of lectures nationwide, run by the National Food Chain Safety Office".*[63]

Despite the legislative gaps, food waste reduction programmes and initiatives have received increasing attention in Hungary over the last decade. These programmes and initiatives aim to raise consumer awareness, minimise food waste and recycle surplus food that can no longer be sold.

Without claiming to be exhaustive, the following paragraphs briefly describe some examples in Hungary aimed at reducing food waste and saving food that can still be used by those in need.

MARADÉK NÉLKÜL:

One such programme is Nébih's internationally recognised Maradék nélkül (No Leftovers) programme, which was launched in 2016 with the support of the European Union's LIFE programme. The

[61] Ibid.
[62] Ibid.
[63] https://njt.hu/jogszabaly/2023-559-20-22

programme aims to change consumer habits, minimise food waste and promote more efficient use of food by providing educational materials, guides, tips and tricks. On their website, they stress that the easiest way to reduce food waste is not to increase the amount of material resources available for this purpose, but to be more aware and more mindful.[64]

In addition to educational and informative materials, the programme includes a national household food waste survey (see above), which, in addition to providing data on food waste, can help conscious consumers to recognise how they can waste less food, plan and buy more consciously, by analysing the quantitative and qualitative composition of the generated food waste.[65]

HUNGARIAN FOOD BANK ASSOCIATION:

Founded in 2005, the Hungarian Food Bank Association is one of the largest non-profit food rescue organisations in Hungary. Food that cannot be sold in hypermarkets, factories, processing plants and farmers' shops for whatever reason but is still edible is collected by the Food Bank's charitable partner organisations and distributed to those in need.[66]

The supermarket food rescue distributes mainly bakery products, vegetables and fruit to people in need. According to a list on the Food Bank's website , more than 700 stores were involved in their supermarket food rescue in 2024, including Tesco, Aldi, Auchan, Metro, Lidl, Foodora Market, KFC.[67]

They accept donations of food from manufacturers that are aesthetically defective, close to expiry or not on the market, which would otherwise be destroyed.[68] From the catering sector, leftover ready-to-eat meals, packaged food and unused ingredients are collected and distributed through credible charities.[69]

In the year 2023, the rescue of leftover unserved food in educational institutions was also launched, and a methodology for the rescue and delivery of safe ready meals to the deprived was developed with the Nébih.[70]

As one can read on their website, since their launch, they have distributed more than 117 thousand tonnes of food across the country – around 7.5 to 10 thousand tonnes per year for the last 8 years.[71]

[64] https://maradeknelkul.hu/mit-tehetesz/tudj-meg-tobbet/
[65] https://maradeknelkul.hu/haztartasi-elelmiszerhulladek-felmeres-2024/
[66] https://www.elelmiszerbank.hu/hu/tevekenysegunk/az_elelmiszerbank_operativ_mukodese.html
[67] https://www.elelmiszerbank.hu/hu/tevekenysegunk/aruhazi_mentes.html
[68] https://www.elelmiszerbank.hu/hu/tevekenysegunk/mentes_a_gyartoktol.html
[69] https://www.elelmiszerbank.hu/hu/tevekenysegunk/keszetelt_mentunk_vendeglatasbol.html
[70] https://www.elelmiszerbank.hu/hu/tevekenysegunk/etelt_mentunk_iskolakbol.html
[71] https://www.elelmiszerbank.hu/hu/eredmenyeink.html

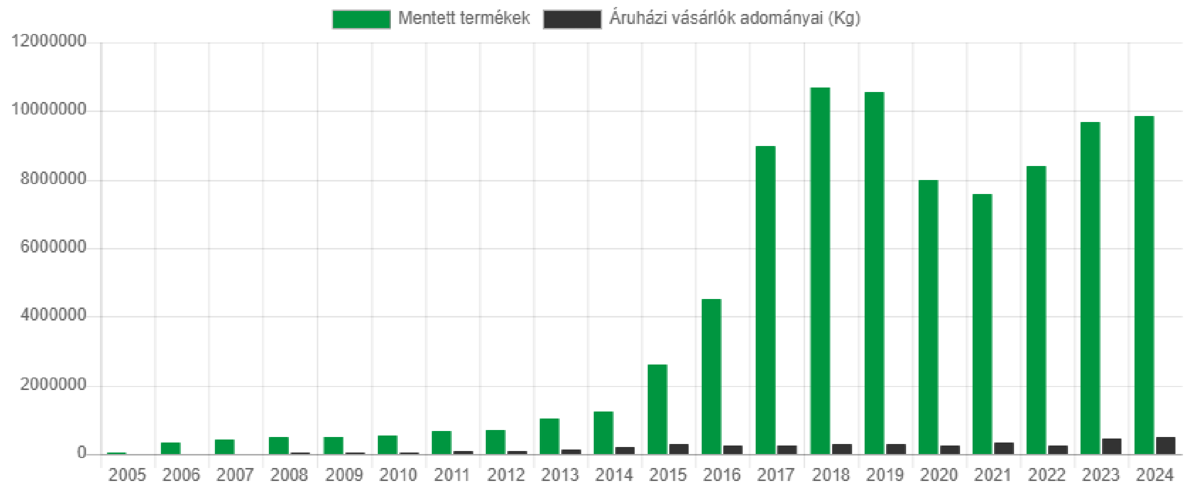

Figure 16: Amount of food saved by the Food Bank, 2005-2024[72]

BIKE MAFIA ASSOCIATION:

The Bike Maffia Association was founded in 2011 and its main activity is to support people and groups in need and the institutions that help them.[73] Through their emergency food rescue project, volunteers deliver packaged hot meals and other food still fit for consumption to institutions supporting people in need.[74]

FOOD NOT BOMBS:

Food Not Bombs has international roots, but also operates in Hungary, in two locations, Budapest and Debrecen. This community is a great example of grassroots activism.

Every Saturday afternoon, the Budapest community collects from two markets the fruits and vegetables that are no longer for sale from familiar vendors, and the next day, depending on the weather, they hold a vegan or vegetarian community cookout in the Auróra Community Climate Garden or Auróra Community House in Budapest's 8th district.[75]

The green waste from the processing of fruit and vegetables is sent to the composter in the climate garden, and the resulting compost enriches the soil in the garden.[76]

Based on the few initiatives listed above, we can see that the fight to reduce food waste can be organized in several ways: from a legally defined program (Maradék Nélkül) to highly organized non-profit organizations (Hungarian Food Bank Association), to sacrificial volunteer work (Budapest Bike Maffia), to completely volunteer-based community food rescue operations with minimal organization (Food Not Bombs).

Also worth mentioning are groups on social media platforms (e.g. Facebook) specifically created to save food or reduce waste, and the initiative called **Munch**. Munch uses a mobile app to connect consumers with its partners (bakeries, restaurants, cafés, stores of well-known food chains and small

[72] Ibid.
[73] https://bikemaffia.com/bemutatkozas/kik-vagyunk/
[74] https://bikemaffia.com/projektek/etelmentes/
[75] https://www.facebook.com/foodnotbombsbudapest/
[76] https://auroraonline.hu/klimakert/

businesses), who sell unsold, good quality food at low prices (with a minimum 50% discount). They claim to have counted two million rescued food parcels in Hungary alone.[77]

It is therefore clear that by disseminating domestic good practices and adopting international good practices[78] , substantial reductions in waste and hence emissions can be achieved.

4.2.3 Separate collection of bio-waste

Separate collection of bio-waste at municipal level is one of the best ways to divert food waste from landfills and incineration. As the executive summary of the GAIA study cited earlier says: *"Source-separated collection and treatment of organics can reduce methane emissions from landfills by 62%, even with moderate ambition. Mechanical recovery and biological treatment of residual waste and biologically active landfill cover are good complementary measures to source separated organic waste collection; in tandem, these strategies can reduce methane emissions by an average of 95%."*[79]

This has been recognised by the European Union, so from 1 January 2024, the separate collection of biodegradable waste and the promotion of recycling (composting, fermentation) is mandatory at Member State level.

Bio-waste is a broader concept that includes not only food and kitchen waste generated in households and other places (e.g. restaurants, offices, etc.), but also green waste from gardens and parks. It is essentially organic material (unprocessed or processed) that is naturally generated and can be returned to the soil. And because the generation of food waste (e.g. vegetable and fruit peelings) is essentially unavoidable, but not feasible for everyone to manage on site, the collection of food waste is often a priority in bio-waste collection schemes.[80]

Although different countries are taking different approaches to comply with the Directive and not all are working towards maximum transposition into national legislation, it is important that such systems are widely adopted as soon as possible, as this will reduce greenhouse gas emissions (especially methane) and, if used in composting, can also contribute to improving soil health. A further benefit is that a well-functioning system can divert not only food waste from landfills and incinerators, but also other inorganic, recoverable waste that might not be recovered due to contamination by food waste.[81]

A study by Wanderley et al. (2022), published by Zero Waste Europe, identifies the best ways to collect bio-waste, taking into account a number of aspects. They point out that the introduction of a new system should ideally be preceded by thorough preparatory work based on research and surveys, as well as significant awareness-raising activities and a public communication campaign. It is also stressed that the distinction and separate collection of garden waste and food waste is strongly recommended, as the materials and types of waste have different characteristics (density, moisture content, seasonality, which also affect the frequency of collection, odour, need for compaction). It is also noted that the design of the system should take into account the nature of the municipality, the typical types

[77] https://munch.eco/hu/blog/2024/06/19/dupla-annyi-etelt-mentettek-meg-a-magyar-emberek-ketmillio-pazarlastol-megmentett-csomag-a-munch-on-keresztul/

[78] cf.: https://humusz.hu/hirek/peldamutato-intezkedesek-europaban-az-elelmiszer-hulladek-mertekenek-csokkentese-erdekeben

[79] GAIA (2022b): Zero Waste to Zero Emissions – How Reducing Waste is a Climate Gamechanger. Executive Summary. https://www.no-burn.org/wp-content/uploads/2022/10/executive-summary-ENG.pdf

[80] ZWE (2022) How to best collect bio-waste – Guidance for municipalities on the best performing methods to separately collect bio-waste (ed. Wanderley et al.) https://zerowasteeurope.eu/library/how-to-best-collect-bio-waste/

[81] Ibid.

of buildings, the economic structure and the characteristics of waste production, which may justify the use of several models operating in parallel.[82]

However, the most important finding of the study is certainly that the collection of food waste through individual responsibility and door-to-door collection is the most effective: based on international examples, it is much more efficient than the use of open or closed containers on the streets. The use of a ventilated kitchen collection container of 5-10 litres and a secondary container of 20-120 litres, depending on the size and type of house, is recommended. (In addition to households, it is of course essential to cover catering establishments and markets, where different containers, collection methods and frequency may be justified.) With a well-designed system, the percentage of contaminants in food waste can be very low, even below 1%. In addition, system performance should be assessed in relation to the proportion and amount of waste collected and the percentage of bio-waste in the mixed waste. Door-to-door collection therefore has lower pollution, higher amounts of bio-waste collected and lower amounts of mixed waste per capita, which means that such systems are typically not only more efficient but also cheaper.[83]

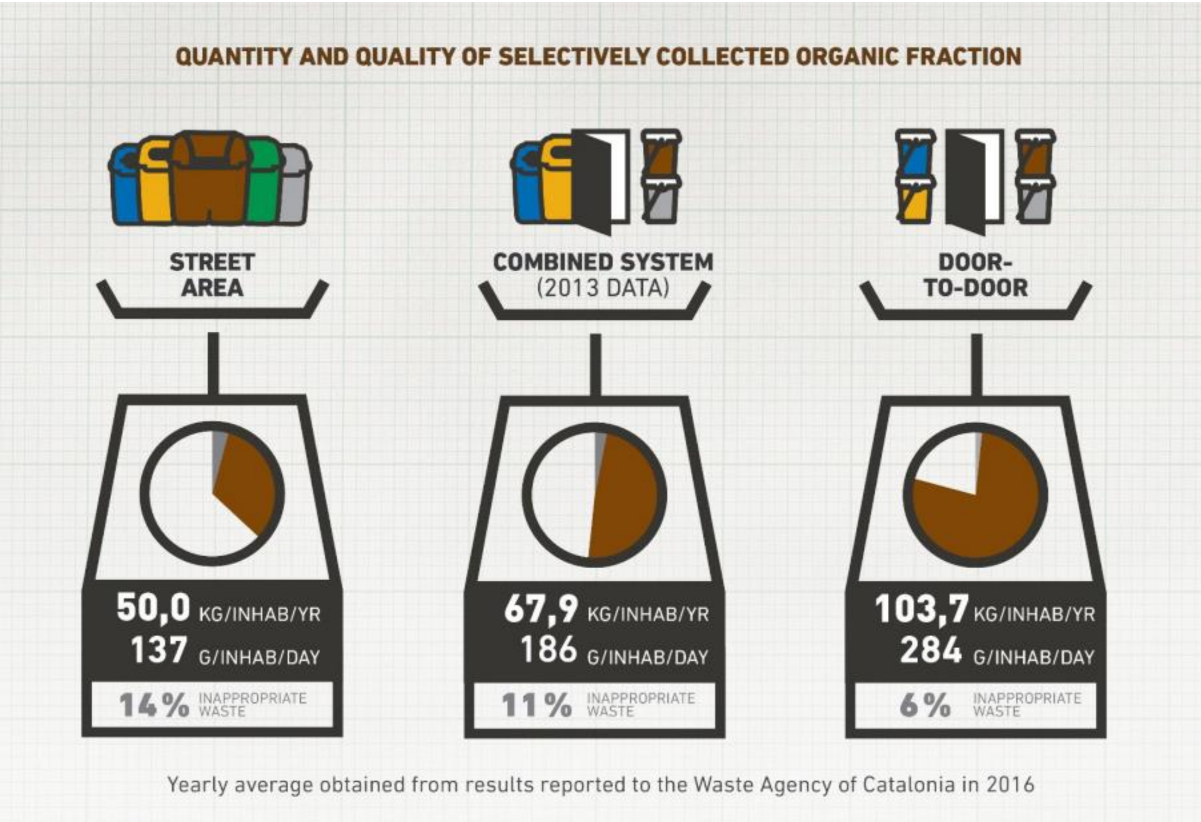

Figure 17: Comparison of different bio-waste collection schemes in terms of quantity and quality of collected bio-waste in Catalonia. Source: ZWE[84]

Bio-waste collection system in Hungary

On 14 December 2023, the Government Decree 559/2023 (XII. 14.) on the activities related to the prevention of biodegradable waste generation, the detailed rules of waste management activities related to biodegradable waste and the rules of classification of compost produced from bio-waste[85]

[82] Ibid.
[83] Ibid.
[84] https://zerowasteeurope.eu/wp-content/uploads/2024/11/How-to-best-collect-bio-waste-EN.pdf
[85] Ld.: https://njt.hu/jogszabaly/2023-559-20-22

was published in Hungary, which, in response to the EU obligation, briefly covers prevention and regulates the details related to the collection of bio-waste.

As a prelude to the publication of the legislation, it is worth mentioning that – in view of the upcoming deadline of 31 December 2023 for separate collection – Humusz Szövetség, a non-governmental organisation that is committed to composting and the proper management of bio-waste, issued a position paper on the subject in February 2023. It drew the attention of legislators and the public to the need to see organic materials – or green goods – not as waste but as a valuable source of nutrients, and to make sure that they are returned to the natural cycle as efficiently as possible. The resolution, which is supported by a number of NGOs, stresses the need to promote and expand home and community composting, to review the legislative framework in this context and to recommend separate, door-to-door collection of bio-waste.[86]

Subsequently, a draft version of the related legislation was published for public consultation on 26 June 2024, followed by the final version in December, which echoed the proposal's suggestions in several points. Under the new legislation, community composting is no longer allowed exclusively for condominium communities, correcting a long-standing, unworkable regulatory anomaly (not in line with everyday practice). Also positive from an environmental point of view is the fact that the legislation makes door-to-door collection of bio-waste the main obligation of the concession company. Also in line with the recommendations made in the ZWE study referred to above, residents will be provided with 5 and 120 litre collection containers.

MOHU Mol Hulladékgazdálkodási Zrt. is responsible for the organisation of the bio-waste collection system as a concession company, while waste collection and bin distribution is carried out by waste management service providers and local waste transport companies as subcontractors.

The effectiveness of the system is reduced by the fact that, on the one hand, it is not nationwide: in the first phase, the concession company plans to make it available to around 460,000 people in two districts of Budapest and in certain condominium areas in 13 other municipalities; on the other hand, the designated blocks of flats are not obliged to join.[87] Mohu plans to launch the second phase in 2025, when they will take biowaste from 1.5-2 million people. This means that national coverage will still not be achieved, only in metropolitan areas will collection be complete, and small communities, especially villages, could be left out, despite the EU directive requiring member states to ensure that by 31 December 2023, bio-waste is either separated and recycled at source, or is collected separately and is not mixed with other types of waste.[88]

The fact that the legislation was published at the end of 2023 also has a negative impact on effectiveness, so there was very little time for public communication and awareness-raising, and in 2024 there was only limited awareness-raising.

According to the information provided by the concession company in October 2024, only about a third of the 460,000 people planned to be involved in the first round have been convinced to join the new system, and their estimates of the amount of biowaste generated per capita (50-90 dkg per week) have also proved to be an overestimate according to initial experience (30 dkg). However, as regards the amount of pollutants, they are positive that the percentage of contaminated bins is less than 8%.[89]

[86] For the position paper see: https://humusz.hu/biohulladek_allasfoglalas
[87] See the information page on the new system: https://mohu.hu/biohulladek
[88] cf..: https://eur-lex.europa.eu/legal-content/HU/TXT/?uri=CELEX:32018L0851
[89] cf.: https://telex.hu/belfold/2024/10/21/mohu-biohulladek-barna-kuka-tapasztalatok-szelektiv-gyujtes

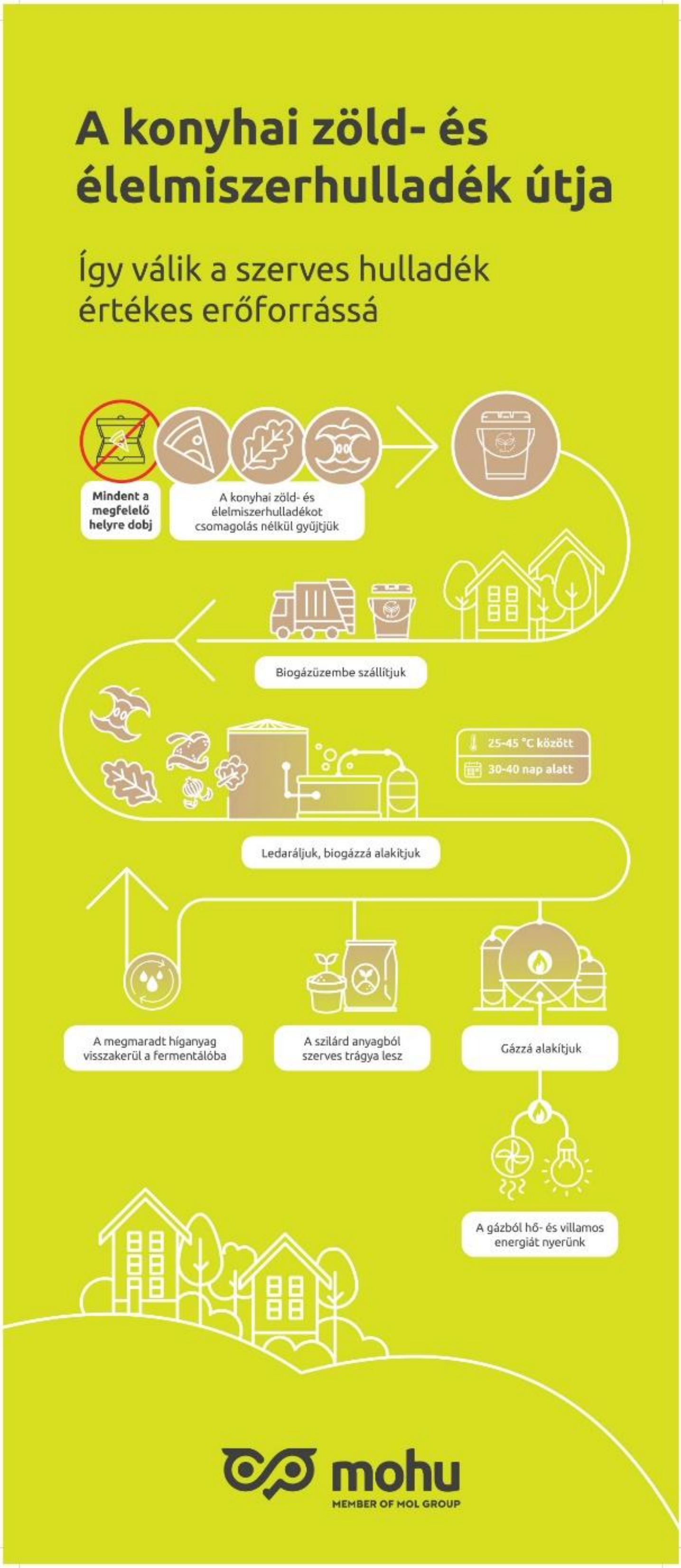

Figure 18: Flowchart showing the collection and processing of bio-waste from the website of Mohu. Source: MOHU[90]

[90] https://mohu.hu/hu/biohulladek

4.2.4 Composting

One of the key waste policy objectives of the European Union, linked to the creation of a circular economy model and the fight against climate change, is to reduce landfilling, including the biodegradable organic content of municipal waste going to landfills, which will reduce the amount of methane-rich landfill gas produced by the decomposition of high organic waste. One method to divert organic waste from landfills and thus reduce methane emissions is composting[91]

Composting is a way to keep organic matter in the cycle. Composting turns organic waste into a soil-enriching plant nutrient source. In the composting process, organic waste is transformed into compost by micro-organisms in the presence of oxygen. The end product is a dark, friable, earthy material rich in nutrients that are easily utilized by plants and is an excellent soil amendment.[92]

Composting is a process that mimics the natural cycle of organic matter: in nature, dead organic matter gradually decomposes and is then turned into humus. Separate collection of organic waste is an essential condition for composting. The process is simple to manage, requires little investment and can cope with high dry matter content.[93]

In order to ensure a proper composting process, attention should be paid to the proper air supply of the composting mixture, the right nutrient composition (i.e. the ratio of carbon/nitrogen) for the microbiological processes to start, the right water content in the composted mass, a favourable pH range and a sufficiently high temperature of at least 65 degrees Celsius. The time factor is also important: compost takes months to mature.[94]

According to the CORE Interreg Europe website "Komposztálj velünk!" (Compost with us), which promotes composting, the average household produces between 150 and 200 kg of kitchen and garden waste per year, which is recommended for composting at the garden or community level.[95]

As shown in the organic waste hierarchy in chapter 4.2.1, the best solution is to compost organic waste as close as possible to the place of generation in a decentralised way, through local or community composting. Where this is not possible, large-scale composting may be considered, including the addition of an anaerobic digestion stage.

The Zero Waste International Alliance (ZWIA) document comparing composting and anaerobic digestion of organic waste also stresses that the last step in anaerobic treatment of organic waste should be composting under aerobic conditions, thus reducing the possibility of further fermentation. If the final product of anaerobic digestion is used directly for soil enrichment, it will result in diffuse methane emissions (among other things). However, taking into account the quality of organic waste and the infrastructure conditions, it can be argued that in some cases anaerobic digestion with energy production can be an appropriate first step in the composting process, where the carbon content of

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[91] https://humusz.hu/sites/default/files/Dokumentumok/komposztalas/a_komposzt_is_ertek.pdf
[92] https://komposztaljvelunk.hu/wp-content/uploads/2024/07/CORE_Komposztalj_Velunk_A4_reszletes_utmutato.pdf
[93] https://humusz.hu/sites/default/files/Dokumentumok/komposztalas/a_komposzt_is_ertek.pdf
[94] Department of Waste Management and Technology of the Ministry of Environment and Water (2003): Zöld és biohulladékok komposztálása
[95] https://komposztaljvelunk.hu/wp-content/uploads/2024/07/CORE_Komposztalj_Velunk_A4_reszletes_utmutato.pdf

the organic material being digested can be used as a renewable energy source in the form of biogas or biomethane.[96]

Organic waste can be composted in centralised or decentralised composting plants, locally at community composting points, in small gardens through home composting, or using indoor composting.[97]

In composting plants, the raw materials are first prepared by chopping, screening, mixing the different raw materials and sometimes by selecting foreign materials. The next stage is maturation, which can take place in an open system in open-air composting heaps without energy input, in a closed system in fermentation reactors, or in a partially closed system, with pre-fermentation in closed fermentation reactors and post-fermentation in open space. The final stage is the packaging and sale of the finished compost.[98]

Centralised composting plants are served by automated equipment installed at a fixed location, while decentralised plants are served by mobile equipment.[99]

Community composting and garden composting are both feasible methods of composting on site. Community composting involves composting organic waste from several households in composting bins set up by the community and using the compost on site. Community composting typically reduces the amount of waste going to landfills, as a significant proportion of the organic fraction is composted.[100]

Programmes to promote composting are therefore an effective strategy to reduce the amount of organic waste going to landfill and thus the resulting methane emissions. According to some sources, composting can reduce methane emissions from landfilling by up to 99%.[101]

Good practices in Hungary

Composting has also come to the fore in the Hungarian legal environment in recent years. According to the Government Decree 559/2023 (14.12.2023) on the management of biodegradable waste, *"If technically feasible, environmentally beneficial and economically proportionate, composting of organic material of plant origin shall be carried out home or in the community."*[102]

There are more and more good examples of different forms of composting in Hungary that encourage the local, environmentally friendly management of organic waste at community and individual level.

Composting at home, in small gardens, is the most appropriate solution in garden housing areas, and can be promoted through public awareness programmes, information, composting frames and garden tools provided by municipalities.

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[96] https://zerowasteeurope.eu/wp-content/uploads/2019/11/zero_waste_europe_ZWIA_policy_paper_composting_and_anaerobic_digestion_en.pdf
[97] Department of Waste Management and Technology of the Ministry of Environment and Water (2003)
[98] Ibid.
[99] Ibid.
[100] https://humusz.hu/komposztalj/kozossegi-komposztalas
[101] Changing Markets Foundation/EIA /GAIA (2022) Methane Matters – A comprehensive approach to methane mitigation.
[102] https://njt.hu/jogszabaly/2023-559-20-22

In the case of community composting points, a larger composting system run by local municipalities, NGOs or voluntary groups is shared by people in the area. These composting points are often located in housing estates or community gardens where residents do not have the opportunity to set up their own small-scale composting facilities. The advantage of composting points in community gardens is that members can use the compost produced locally to enrich the soil of the community garden.

In Budapest, community composting points have been set up in public parks or at composting points run by NGOs. The gardening division of Budapest Public Utilities Nonprofit Ltd., also known as FŐKERT, has set up several community composting points in different parts of Budapest.[103]

The community composting point, run by the aforementioned NGO, Humusz Szövetség is located in the garden of their headquarters, where residents of the neighbourhood can take their organic kitchen waste. Registration is required to use the compost point[104] , but many community compost points are free to use 24/7. Humusz Szövetség has played a prominent role in promoting composting in the country since its foundation in 1995. In addition to running the compost point, they provide awareness-raising, publications and educational programmes, and their website also contains a detailed database of community composting opportunities in Hungary, compiled by volunteers of the organization.[105]

Among the initiatives outside the capital city, the one definitely worth mentioning is the Komposzt Futár programme launched on 10 October 2022 by MASZK Association in Szeged. Through the online channels of their Community House called Megálló, Szeged residents can contact bicycle couriers who will pick up their compostable kitchen and green waste at a prearranged time. A community garden is also located in the garden of the Community House, so there is no problem in receiving incoming organic kitchen waste.[106]

But it is not only NGOs that can help promote composting. The Australian-based Sharewaste app also includes sites in Hungary. After registration, the app connects users (even individuals) who can accept compost with those who want to compost.[107] However, this app discontinued on 31 December 2024 due to lack of resources and capacity.

In addition to the outdoor composting options, there are also several indoor composting options, so that people who do not have a community composting point near their home can also compost. One option is indoor worm composting, where organic matter is composted in buckets using worms specially designed for composting, at temperatures between 10 and 27 degrees Celsius in a shaded, oxygenated environment.[108]

Another option for indoor composting is to use a composting bin made of clay called "Com-Pot". The container should be filled once a week with organic waste and dry matter mixed with the bacterial culture that comes with the container. The mature humus will then take six months to form.[109]

[103] https://fokert.budapestikozmuvek.hu/kozossegi-komposztalas
[104] https://humusz.hu/sites/default/files/komposzt_utmutato_final.pdf
[105] https://humusz.hu/kozossegi-komposztpontok
[106] https://humusz.hu/hirek/komposztfutar-szegeden/30090
[107] https://greendex.hu/sharewaste-a-komposztaloapplikacio/
[108] https://humusz.hu/komposztalj/belteri-komposztalas
[109] https://greenguide.hu/gilisztaktol-kozossegi-pontok-komposzt-kisokos-varoslakoknak/

A third option is the anaerobic pre-composting Bokashi "composter", which can be used for chopped kitchen waste, and also for higher protein food waste, as a fermentation process is taking place. For this reason, the end product must be buried into the ground.[110]

4.2.5 Biogas production

Biogas is a gas produced by the anaerobic decomposition of organic matter by methane-producing bacteria. It is approximately 70% methane and 30% carbon dioxide. It can be produced naturally or artificially. It is produced naturally in bogs and swamps, manure lagoons and landfills, and can be produced artificially in biogas production reactors. It can be based on any solid or liquid organic waste.[111]

The formation of biogas is a two-step process: the organic compounds in it are first broken down into simpler compounds during the acid phase and then into their constituents during the methanogenic phase. The process is more efficient if the two phases take place in separate reactors. The efficient production of biogas requires, in addition to the starting organic material and an oxygen-free environment, appropriate temperature equilibrium, continuous stirring, a sufficiently chopped organic material, and an appropriate ratio of methanogenic to acidogenic bacteria. During biogas production, pathogenic organisms are destroyed and the by-product can be used as organic fertiliser. Biogas can be used in thermal (gas heaters, gas burners), mechanical (gas engine, gas turbine) and complex ways (gas engine or gas turbine with or without generator, heat exchanger).[112]

The publication " A megújuló energiaforrások hasznosítása az önkormányzatok számára" (The use of renewable energy sources for municipalities), written by the author of Energia Központ, sees the use of biogas as a way to solve the problems of sewerage, sanitation, municipal cleanliness and local energy production as an integrated development task, in a cost-effective and environmentally friendly way (by reducing the amount of methane released into the atmosphere).[113]

The publication divides the options into four main groups: landfill biogas (landfill gas), biogas from sewage sludge, compostable feedstocks or slurry. According to the publication, *"properly installed landfills can produce 280 m^3 of biogas from 1 tonne of waste in 10 years"*, from which 1.5 kWh of electricity and 3 kWh of heat can be generated from 1 m^3 of biogas. The methane content of landfill gas is around 50 per cent. The landfill gas, which is passively generated in the deeper layers of the landfill during the decomposition of the organic matter content of the landfill waste, is accessible through perforated plastic pipes, so-called biogas extraction wells, which are led into the landfill. In the design phase of new landfills, it is recommended that the area be piped before landfilling to recover biogas.[114]

Biogas from municipal waste water treatment can also be used, which contains a higher proportion of methane than landfill gas, around 70%. Biological digestion of sewage sludge is not only beneficial in terms of biogas production: pathogens are destroyed and the amount of material going to landfill is reduced. Biogas can also be produced from slurry from livestock farming, which is widespread in Hungary; the digested organic manure left over after gas production, cleaned of infectious micro-organisms, can be returned to the land for local use.[115]

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[110] Ibid.

[111] Monoki & Barna (2001): Környezetbarát Energiák. In: Zöldike Könyvsorozat. NIMFEA Természetvédelmi Egyesület. Szarvas.

[112] Ibid.

[113] Zoltán Vass (2002): Csináljuk jól! A megújuló energiaforrások hasznosítása az önkormányzatok számára. Energiahatékonysági és Energetikai Környezetvédelmi Ügynökség Kht. Budapest.

[114] Ibid.

[115] Ibid.

Biogas can be produced in municipal biogas reactors from plant waste, food by-products and compostable organic waste produced by the public, provided that compostable organic material is collected separately from municipal waste collection.[116]

The above examples show that there are many possibilities for the local production and use of biogas, adapted to local conditions.

By using the highly potent greenhouse gas methane as a fuel, we capture the emissions that would be released into the atmosphere from the decomposition of organic waste, thus reducing its impact on global climate change.

The installation of a facility for anaerobic digestion of organic materials may be an ideal choice in densely populated areas where there is a lot of organic waste but not enough space for large-scale composting plants. The disadvantages of such facilities are that they have a higher initial cost than composting plants and require more expertise to operate. However, as the GAIA (2024) study points out, cheaper, smaller-scale anaerobic digestion units have been successfully deployed in rural, remote locations in several countries where access to energy networks is less secure.[117]

The GAIA publication (2024) also lists other disadvantages and risks. These include, for example, landfilling of the fermentate resulting from the dismantling process, flaring instead of biogas, the use of fossil fuels to reach the right temperature in biogas reactors, or the marginalisation of other renewable energy sources. It is also problematic if anaerobic digestion inadvertently encourages continued waste production in agriculture, undermining alternatives such as waste reduction or composting. However, given a clean feedstock and adequate capacity, it can be seen as a beneficial waste management option to be implemented as part of a strategy that prioritises waste prevention.[118]

The Zero Waste Europe and Zero Waste International Alliance publication comparing composting and anaerobic digestion, cited earlier, also emphasises the zero waste approach and also recommends composting as a first choice where feasible. The document recommends anaerobic digestion where land constraints prevent composting, or where it is preferable in densely populated urban areas where food waste is generated in large quantities. Anaerobic digestion can then be a first step before composting for efficient management of organic matter, energy production and soil improvement.[119]

The document stresses that in anaerobic digestion, ensuring the quality of the input is critical to prevent the accumulation of contaminants in the fermentate. Only clean, separately collected organic matter should be processed in the production of safe, high quality soil amendments. The preference for composting over anaerobic digestion is typically more cost-effective for communities, and it is therefore worth reserving the latter for cases where composting is not feasible.[120]

In summary, both anaerobic digestion of organic waste and composting can be valuable in waste reduction and responsible resource management schemes.

4.2.6 Waste to Energy (and its downsides)

As we have seen in the case of the so-called zero waste hierarchy, the zero waste movement rejects the incineration of waste by default, with and without energy production. The situation is obviously

[116] Ibid.
[117] GAIA (2024)
[118] Ibid.
[119] Ibid.
[120] Ibid.

similar for organic waste, as we have shown for the food waste hierarchy and the organic waste hierarchy.

One of the most common arguments against incineration is the high investment, maintenance and operating costs.[121] It is highly polluting (releasing environmentally and health damaging dioxins, heavy metals, PFAS and other compounds).[122] It has a negative impact on climate change due to its high level of carbon emissions[123] – although it diverts organic matter from landfill, thus preventing methane emissions, it produces more greenhouse gas emissions per unit of energy produced than any other energy source (e.g. coal-fired power plant).[124] The fact that 25-30% of the weight of the waste incinerated is left as ash or slag, which can only be disposed of in landfills, and is often (or should be) classified as hazardous waste, makes its management even more delicate.[125] The need to feed the incinerator once it has been built so that it can be operated economically is a motivation for waste production and against reducing consumption. In addition, bio-waste, especially food waste, typically has a high moisture content, which reduces incineration efficiency, and the lower temperatures result in higher emissions of pollutants, which have to be neutralised and filtered at high cost.[126]

The landfilling and incineration of waste is clearly a linear economic model, which runs counter to the EU's objective of a circular economy. This study examines the potential reduction of a specific GHG, methane, therefore the arguments against incineration should be focused on its negative impact on climate change. Vähk (ZWE, 2019) concludes that waste incinerators emit more greenhouse gases per unit of electricity generated than any other power plant. It is estimated that the incineration of 1 tonne of waste results in approximately 0.7-1.7 tonnes of CO_2 emissions[127] (as already discussed in section 3.2).

It can therefore be concluded that incineration is not a climate-friendly waste management option, even if it generates energy. However, the question may arise whether in the long term the GHG emission potential of landfilling or incineration is higher.

The long-term emission potential of practices incompatible with zero waste strategies

While methane stays in the atmosphere for 10-15 years, carbon dioxide stays in the atmosphere for about 50-200 years, but the former is more than 20 times more potent greenhouse gas than the latter. Therefore, it is important to consider a sufficiently long time horizon when assessing the emission potential of landfills and incinerators (while noting that the question of which alternative has a greater negative impact on climate change should not be overlooked, we should also note that the so-called zero waste options have a significantly smaller carbon footprint and are therefore more beneficial from a climate perspective).

In his analysis, Hogg (ZWE, 2024) argues that converting methane and other greenhouse gases to carbon dioxide equivalents is an unnecessary step. Instead, he argues that it is better to focus on the impact of greenhouse gases on global temperature change, as this provides a more meaningful basis for comparing their long-term effects.

Enzo Favoino, one of the editors of that study, also compared the long-term contribution of the two disposal methods, incineration and landfilling, to global temperature change in a presentation at the

[121] UNEP (2019) Waste to energy - Considerations for informed decision-making: https://api.developmentaid.org/api/frontend/cms/file/2019/08/WTEfull-compressed.pdf
[122] Arnica / IPEN / TFA / CREPD / CEJAD (2024)
[123] Ibid.
[124] Neil Tangri (2023) Waste incinerators undermine clean energy goals,
[125] GAIA (2018) facts about waste-to-energy incinerators.
[126] GAIA (2024)
[127] ZWE (2019)

online webinar[128] on 21 October 2024. The slides projected during the presentation (see below) show that while landfilling (without gas recovery) is dominated by methane emissions in the short term and CO_2 in the long term, incineration is dominated by CO_2 in both the short and long term. Favoino points out that waste incineration (which releases both fossil and non-fossil CO_2) is always a greater contributor to climate change, i.e. to the greenhouse effect, in the long term.

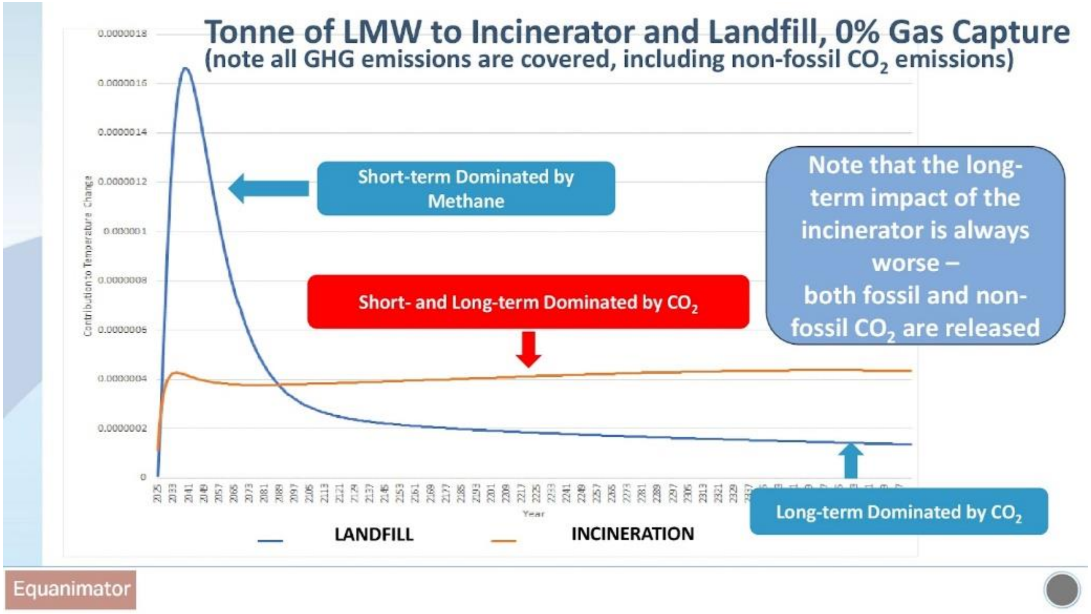

Figure 19: Contribution of one tonne of residual mixed waste to temperature change in the long term for landfilling and incineration. Source: Favoino[129]

In the case of biological stabilisation, the emission peak from methane emissions in the early years can be reduced to a virtual minimum (about half of the emissions from incineration) and, of course, emissions associated with landfilling can be reduced by the use of landfill gas. Likewise, the waste treatment method called MRBT (material recovery and biological treatment) has a very low emission potential compared to conventional treatment methods.

Zero Waste Europe's study highlights that, over a time horizon of around 50 years, and assuming a 50% recovery of landfill gas, the temperature increase associated with landfilling remains significant. In order to keep the landfill-related temperature impact stable at a lower level than incineration without prior stabilisation of the waste, a minimum gas recovery of 80% is required over the entire operational lifetime of the landfill.[130]

According to Hogg (ZWE, 2024) and Favoino, landfilling therefore contributes less to global temperature rise in the long term than incineration, because incineration not only emits non-fossil carbon, but also fossil carbon (e.g. from plastics) through the release of carbon dioxide. As Hogg puts it, this does not change even if the energy produced by incineration is taken into account. By treating the mixed residual waste before landfilling, the emissions peak that characterises landfilling in the early years can be avoided, since if the organic waste is separated and stabilised, methane emissions from the decomposition process in landfills can be minimised. This solution is therefore preferable to

[128] Waste Incineration: challenges & solutions, 21 Oct 2024 https://www.plasticpollutioncoalition.org/event/waste-incineration-challenges-and-solutions
[129] Favoino, 2024
[130] ZWE (2024)

either incineration or landfilling based on gas recovery in terms of negative impact on climate change.[131]

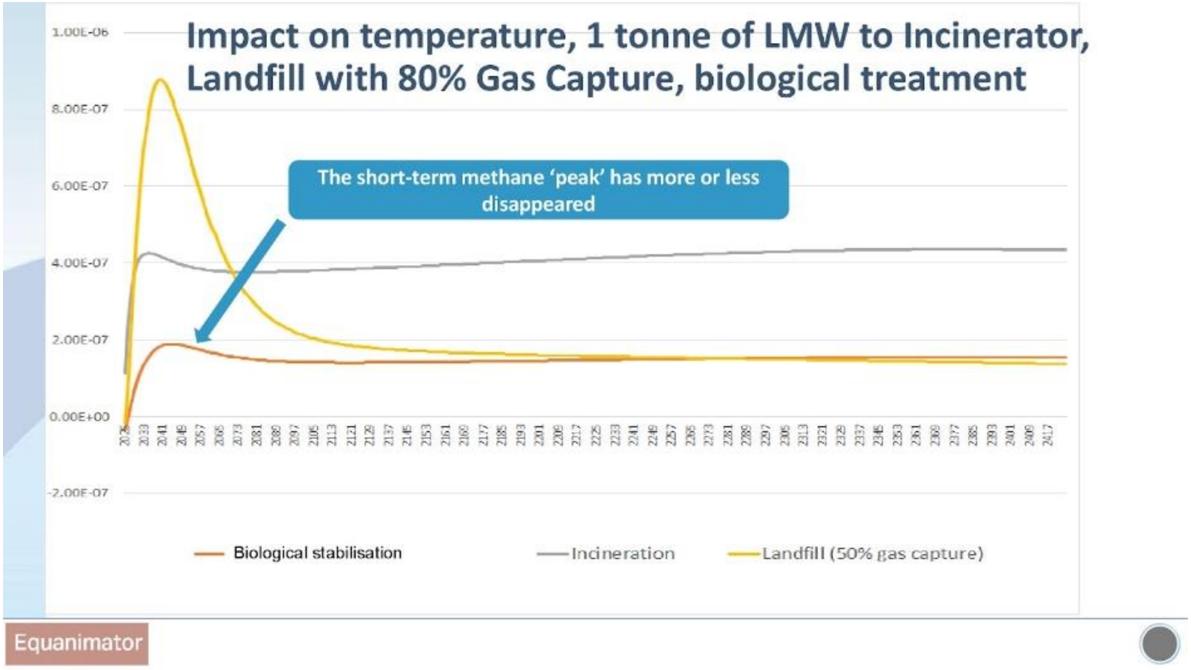

Figure 20: Contribution of one tonne of residual mixed waste to temperature change in the long term under biological stabilisation, landfilling and incineration. Source: Favoino[132]

Favoino also stressed in his above-mentioned presentation that the increasingly efficient recovery of landfill gas is certainly welcome, but that managing landfills to achieve high recovery rates over the lifetime of the landfill is a very difficult task. However, the solution is not a radical ban on organic waste from landfills, which could lead to a sectoral shift towards incineration, but the promotion/prescription of biological pre-treatment before landfilling and the use of active capping, which would minimise methane emissions.

4.3 Comparison of prevention-based and reactive treatment solutions

As mentioned earlier, there are various estimates in the literature of the amount of methane and CO_2e emissions that can be prevented by different zero waste and reactive treatment solutions.

For example, the GAIA 2024 study, citing the 2012 work of Leejiah J. Dorward, argues that one tonne of food waste prevention is associated with 0.8-4.4 tonnes of CO_2e emissions avoided, and a comprehensive food waste prevention programme could reduce global GHG emissions by up to 2-5%.[133]

The GAIA 2022 study provides an estimate for composting: according to Walsh (GAIA, 2022c), a high quality, well-designed (i.e. aerated in an oxygen-rich environment) composting programme – which can include home, community and centralised composting – reduces the amount of methane that would otherwise be emitted from landfills by an average of 78%.[134]

[131] Ibid.
[132] Favoino, 2024
[133] Allen & Guajardo (GAIA, 2024b) Cutting Methane Emissions through Zero Food Waste Systems,
[134] GAIA (2022c): A Key to Rapid Methane Reductions: Keeping Organic Waste From Landfills (by Bill Walsh)

Another option is anaerobic digestion, as described in the previous chapter, which can produce biogas. This gas is much less polluted than landfill gas and has a higher calorific value. In addition, the leakage rate is typically much higher and can vary greatly from landfill to landfill.[135]

Therefore, gas recovery from landfills, but also the capping of landfills with a biologically active layer, can be considered as reactive treatment. Walsh (GAIA, 2022c) points out that the largest methane emissions are associated with active, functioning landfills, while emissions from closed landfills account for only 9% of the total.[136]

The active overlay can be compost material or a mixture of organic matter left over from the MRBT-type treatment mentioned above. This type of cover can greatly reduce the environmental impact of landfills: as described in a study by Walsh (GAIA, 2022c), microbial communities that form in biologically active cover can digest methane that is emitted from landfills, reducing landfill emissions by up to 63% on average, as already mentioned in section 4.2.1. According to other sources (GAIA, 2022), MRBT treatment can lead to methane emission reductions of 80-90 or even more at landfills. In fact, depending on the environmental conditions, it may even generate "negative" emissions by removing methane from the atmosphere. Walsh also stresses that it is cheap and simple to implement compared to other technologies, such as landfill gas recovery systems, and does not encourage the waste operator to emit and then capture methane.[137]

[135] Ibid.
[136] Ibid.
[137] Ibid.

5 Analysis of the methane emission reduction potential in Hungary

Hungary's National Waste Management Plan for 2021-2027[138] (OHT) predicts preventive measures and a reduction in the amount of biodegradable waste generated by the population, highlighting that recovery is the clear objective for this type of waste. Progress has been made, they say, but there are still serious shortcomings, which call for further "ambitious measures". As the document puts it: *"In line with the WFD[139], Hungary is developing an action plan to reduce food waste from primary production, processing and manufacturing, retail and other distribution of food, restaurants and food service, and households as a contribution to the UN Sustainable Development Goal to **reduce global food waste per capita at retail and consumer level by 50% by 2030** and to reduce food losses along production and supply chains."*

Chapter 4.7.3 of the OHT, outlining the lines of action, and its findings are also highly relevant to the present study, so it is worthwhile to address them in more detail.

The OHT sets a strategic goal to move away from landfilling as the most common treatment method for municipal solid waste to the recovery of **7-800 thousand** tonnes of biodegradable waste**, instead of 2-300 thousand tonnes per year.** This requires the development and capacity increase of closed composting technology, as well as the maintenance, renovation and improvement of existing bio-waste treatment capacity, they say. This could help to reduce associated methane emissions, as "***inadequate composting currently accounts for 8% of methane emissions from waste management***" (the authors used 2018 data). They also emphasise the mandatory introduction of a separate biowaste collection system, the development of a methodology for measuring food waste, the promotion of home and community composting, and the implementation of national awareness-raising activities.[140] Let's see what the document sets out in more detail.

<u>Separate collection</u>

The plans laid down in the OHT for the implementation of a separate collection system (e.g. distribution of brown collection containers of 120 litres or larger, development of a door-to-door system, definition of the conditions necessary for the creation of logistical improvements) have already been partially implemented, albeit as pilot projects, in designated condominium zones in certain areas of the country, as described in chapter 4.2.3. As regards the collection system, the OHT also emphasises the importance of raising awareness and providing the public with adequate information, since the success of the system depends to a large extent on the acceptance and motivation of the public using it. The document also draws attention to the need to further extend the green waste collection system, which is already in place in many places, and to increase its efficiency by encouraging both public service providers and the public. According to the OHT, the way to achieve this is through **the purchase of hundreds of waste collection vehicles and** the provision of **appropriate containers to some 4.2 million households.**[141]

<u>Uniform measurement methodology</u>

In relation to the development of a common methodology for measuring the level of food waste, the OHT highlights the problem that this type of waste is often collected together with other waste. In this respect, it would obviously be a step forward if separate collection were more widespread and, as

[138] National Waste Management Plan 2021-2027 (OHT, 2021) Ministry of Innovation and Technology.
[139] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
[140] OHT (2021)
[141] Ibid.

mentioned above, in addition to the proportion and quantity of waste collected, it would also be useful to examine the percentage of bio-waste in the mixed waste stream and how this percentage is changing.[142]

Composting

In line with the literature described above, the OHT also aims to promote composting at different levels (whether home composting, including in educational institutions, community composting or centralised composting), taking into account geographical conditions.[143]

Awareness raising + Quality assurance

The OHT makes a number of suggestions on how to raise awareness and marketing activities to ensure that there is a real market for compost produced from bio-waste collected under the public service, including needs assessments of target groups (e.g. organic farmers), advertising, publicity, sponsorships, open days and hotlines, etc.

This also requires the development of a quality assurance system, which, together with economic and legal instruments, will help to promote the use of compost in agriculture and reduce the use of fertilisers. The difficulties that are still very real (e.g. high unit costs, storage, procurement, distribution) can be addressed through financial incentives and logistical support, thus moving towards more sustainable agricultural practices.[144]

Capacity development

The OHT proposes to build green waste composting capacity on a decentralised model, to assess the utilisation of existing composting capacity, to develop anaerobic treatment capacity for food waste and to promote energy recovery. Furthermore, it draws attention to the expected increase in the biological treatment capacity of existing mechanical-biological treatment plants due to the separate collection of bio-waste.[145]

The document, as mentioned above, provides an estimate of the amount of capacity expansion needed, based on 2018 figures. As they write, of the ~2.4 million tonnes of mixed municipal waste generated annually that year, 411,600 tonnes was bio-waste and 288,000 tonnes was food waste, based on compositional analyses. To summarise: as presented in Chapter 4, the latest data for 2022 indicate ~2.6 tonnes of municipal solid waste disposed of by incineration or landfilling. Moreover, as discussed in section 4.2.2, Nébih's research estimates 594 thousand tonnes of food waste per year in 2023 for the total population, 47.6% of which are disposed of in the landfill, i.e. approximately 280 thousand tonnes in 2023, 8 thousand tonnes less than in 2018.

As the OHT notes, a 50% reduction in **food waste** generation should be achieved by 2030.[146] This means that *"**further improvements are needed to manage 160,000 tonnes/year of waste generated,** mostly through investments in anaerobic treatment and energy efficiency."*[147]

[142] Ibid.
[143] Ibid.
[144] Ibid.
[145] Ibid.
[146] see SDG target 12.3: https://sdg12hub.org/sdg-12-hub/see-progress-on-sdg-12-by-target/123-food-loss-waste and https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=LEGISSUM%3Aev0010
[147] OHT (2021)

In 2018, in addition to food waste, around 120 thousand tonnes of green waste was collected in mixed waste, according to the OHT, and a further 360 thousand tonnes was generated from public services and other sources, of which around 285 thousand tonnes was recycled through composting. This implies that an additional 200 thousand tonnes of green waste per year should be composted locally, centralised or in an industrial way.[148]

5.1 Forecasts and projections

As mentioned in Chapter 2.3, the EEA projects that total methane emissions will continue to decline, but at a faster rate (-2.4% per year until 2030) than in the 30 years since 1990, according to the GHG projections reported by Member States. Of course, this is only an approximate estimate and is not Member State-specific, but it is worth looking at what this would mean in numerical terms for Hungary. If we take the most recent annual figure (3,698 thousand tonnes of CO_2e methane emissions), assuming a constant decline of 2.4% in the coming years, we get 3,045 thousand tonnes of CO_2e emissions in 2030, i.e. a reduction of around 653 thousand tonnes of CO_2e, which is a reduction of around 18% compared to the base year 2022.

In earlier chapters of this study, we have already highlighted some estimates related to different emission reduction measures. Let's look at them again!

A comprehensive study (2022) by the Changing Markets Foundation, EIA and GAIA, based on an extensive literature review, examines three types of intervention options and identifies very high emission reduction potentials. The study shows that composting can achieve an average reduction of 78% in methane emissions from municipal solid waste; complementing this with bio-stabilisation of residual mixed waste, 90%; and "topping" these two with a biologically active landfill cover, on average 95%. (Assuming 80% for composting, and 70-70% for stabilisation and capping.) And for the waste sector as a whole (assuming that 61% of total waste sector emissions come from municipal solid waste), the study projects average reduction potentials of 48%, 55% and 59% respectively.[149]

Intervention	Mean reduction in methane emissions from MSW	Mean reduction in methane emissions from entire waste sector (61% of waste sector emissions are from MSW)[152]
Composting	78%	48%
Composting + bio-stabilisation of residuals	90%	55%
Composting + bio-stabilisation + biologically active cover	95%	58%

Figure 21: Average methane emission reduction potential of different measures. Source: Changing Markets Foundation/EIA/GAIA[150]

[148] Ibid.
[149] Changing Markets Foundation/EIA/GAIA (2022)
[150] Ibid.

In recent years, GHG emission reductions have become an increasingly important issue in the United States. A 2023 study by the US Environmental Protection Agency (US EPA) quantifying methane emissions from food waste going to landfills found that for every 907 tonnes of food waste landfilled, about 34 tonnes of fugitive methane emissions are released, equivalent to 838 million tonnes of CO_2e. They calculated that, compared to business as usual, reducing the amount of food waste by 50% in 2015 (i.e. if 23 million tonnes, half of the real 2015 figure of 46 million tonnes had been landfilled each year between 2015 and 2020) would have reduced cumulative fugitive methane emissions by 77 million tonnes of CO_2e by 2020. To put this in perspective, in 2020, food waste going to landfill was responsible for around 55 million tonnes of CO_2e emissions.[151]

Also in the United States, emissions from food landfills are being investigated by ReFED, a US non-profit organisation working to reduce food waste. It is also worth making calculations based on the data and estimates outlined in the previous chapters[152] using the organisation's calculator[153] . The calculator is, of course, based on US conditions, so it should not be based on a one-to-one comparison with Hungary, but the estimated GHG emission reduction values are definitely worth considering.

	Current situation (tonnes)	**Realistic scenario (tonnes)**	**Optimistic scenario (tons)**
Prevention		100,000	160,000
Donate	9,600	15,000	16,000
Animal feed	91,000	80,000	54,000
Composting	153,000	210,000	246,000
Anaerobic digestion	11,000	24,300	35,000
Drain/sewer	50,000	25,000	15,000
Burning	33,400	16,700	8,000
Deposit	246,000	123,000	60,000

Table 3: Food waste prevention scenarios

For the data entered in the calculator, a value for prevention can only be entered if an alternative scenario is outlined. As shown in the table, the realistic scenario assumes that 100,000 tonnes of food waste can be prevented, while the optimistic scenario predicts 160,000 tonnes. In terms of donations, we also assumed a strong year compared to the Food Bank's best year (2018: 11 thousand tonnes), and the optimistic scenario is minimally higher than this (15 and 16 thousand tonnes). As for animal feed, this could of course be part of a "zero waste" oriented prevention system, where the aim is to divert from landfill and incineration, but as it is lower down the food waste hierarchy, the projections are lower than the base year, assuming that some of the food waste that was previously donated will be realised at a higher level. In terms of composting, the optimistic scenario assumes the maximum amount that can be composted by Nébih, while the realistic scenario assumes slightly less. In the case of anaerobic digestion, it is assumed that the recovery capacity approximately doubles or triples. Food waste going down the drain is halved and roughly halved to a third in the two scenarios, while incineration and landfilling are assumed to halve and roughly halve to a quarter respectively.

Plugging in all these values, the ReFED calculator shows that the total associated GHG footprint in the current scenario is 2.9 million tonnes CO_2e, while in the realistic future scenario it is 2.3 million tonnes,

[151] US EPA (2023)
[152] cf. data reported in the Nébih study and Food Bank 2024 donation data
[153] The calculator is available at: https://insights-engine.refed.org/impact-calculator and the accompanying methodological guide is available at:

which means 628 thousand tonnes less emissions. For methane emissions, the calculator gives 32.5 thousand tonnes in the current scenario, of which roughly 30% can be saved (9.5 kt CH_4). The calculator also shows the emission savings (net benefits) in terms of CO_2e over 20 and 100 years. Over a 20-year time horizon, this is roughly 30% of the 2.6 million tonnes of CO_2e in the realistic scenario, (761,000 tonnes), and over a 100-year time horizon, compared to 880 thousand tonnes (current scenario), the methane emissions are 622,000 tonnes of CO_2e, a "benefit" of 258,000 tonnes.

	current scenario	**future scenario (realistic)**	**net savings**
Total GHG footprint (thousand tonnes CO_2e)	2,937.863	2,310.255	628.607
methane footprint (thousand tonnes CH_4)	32.536	22.996	9.540
methane footprint 100-year time scale (thousand tonnes CO_2e)	880.090	622.038	258.052
methane footprint 20-year time scale (thousand tonnes CO_2e)	2,594.721	1,833.920	760.802

Table 4: Emission reduction potential for food waste in a realistic scenario

In the optimistic scenario, the potential for emission reductions is obviously even more favourable: the calculator estimates total GHG savings of 973 thousand tonnes, while the methane footprint is more than 14 thousand tonnes lower, which means savings of 387 thousand tonnes of CO_2e over a 100-year time horizon and 1.14 million tonnes of CO_2e over a 20-year time horizon.

	current scenario	**future scenario (realistic)**	**net savings**
Total GHG footprint (thousand tonnes CO_2e)	2,938.863	1,965.610	973.253
methane footprint (thousand tonnes CH_4)	32.536	18.211	14.325
methane footprint 100-year time scale (thousand tonnes CO_2e)	880.090	492.620	387.470
methane footprint 20-year time scale (thousand tonnes CO_2e)	2,594.721	1,452.366	1,142.355

Table 5: Emission reduction potential for food waste in an *optimistic scenario*

But it is also worth mentioning a more recent example, the city of Partizánske, Slovakia, with a population of 20,000, where separate collection of kitchen and garden waste, promotion of home composting and implementation of tailored collection strategies for single-family households and multi-family buildings have been implemented with impressive results. After 8 years, 95% of single-family households compost at home, and in that time the amount of mixed (non-recyclable) waste generated by these households has decreased by 36% (118 kg/person). In blocks of flats, more than 49 kg of kitchen waste per inhabitant was collected just two years after the introduction, and the pollution of the collected bio-waste was minimal: 0.07%. The impact of the two measures was an 18% reduction in mixed waste for the total population in 8 years.[154]

Across Europe, there are many examples of successful door-to-door collection of bio-waste (e.g. Milan, with a population of 1.4 million, but also Paris, Porto, Pontevedra and Ljubljana).[155] However, Hungary is in a unique situation in that, since 1 July 2023, waste management, and more specifically collection and management of municipal solid waste, has been the responsibility of a concession

[154] ZWE (2024b) The story of Partizánske. (by Moňok et al.). Available from:
[155] for more information see:

company, MOHU MOL Hulladékgazdálkodási Zrt. Municipalities are therefore not currently responsible for the management of household waste – and this should remain the case until the end of the 35-year concession period. It is too early to predict the impact of all this, but the new set-up suggests that there may be a shift away from local solutions towards centrally defined standards and centralised systems.

Overall, however, the best results can be expected if the different stakeholders (be they local residents starting community composting, the companies carrying out the waste treatment or the concession company itself) can act in harmony in a supportive legal environment. Several parallel actions can be taken to reduce methane emissions from the waste sector quickly and effectively.

5.1.1 Realistic scenario

1. **Improving and promoting the uptake of separate organic waste collection:**
    - Expansion of existing separate collection schemes, especially for kitchen waste (including the development of organic waste collection infrastructure, acquisition of containers, transport vehicles, new waste collection routes)
2. **Promote composting and anaerobic digestion:**
    - Promoting and encouraging home and community composting.
    - Installation of small urban and metropolitan composting and biogas plants capable of decomposing organic waste in large quantities.
    - Using EU funding to expand and develop biogas technologies.
3. **Landfill capping and landfill gas recovery:**
    - Covering existing landfills with a biologically active layer and improving gas collection systems.
    - Regulation to monitor and reduce methane emissions from landfills, including through fines to encourage efficiency improvements.
4. **Supporting waste reduction programmes at community level:**
    - Introduce education programmes and incentives for the public to reduce waste.
    - Community-wide campaigns to reduce food waste.

All these measures will result in 70-80% of the bio-waste generated being diverted from landfills.

5.1.2 An optimistic scenario

1. **Introduction of full organic waste collection and processing:**
    - Compulsory organic waste collection for all households throughout the country, or effective promotion of home composting where this is not economically or logistically feasible.
    - Strengthening the rules on organic waste collection, setting up a Pay-As-You-Throw system[156] that takes into account the amount of waste generated, and building the necessary processing capacity.
2. **Maximising industrial composting and biogas recovery:**
    - Establishment of high-capacity composting facilities.
    - Bio-labelling and agricultural use of the resulting compost (as it contributes to keep carbon in the soil, reduces the use of fertilisers, reduces the need for labour and irrigation due to better structured and water-retentive soils, etc.).

[156] The Pay-As-You-Throw model, which is based on the amount of waste thrown away, means that the cost of waste is set for each household in proportion to the amount of waste it produces (and in particular the amount of residual waste that is sent to landfill or incineration), thus encouraging waste reduction.

    - Developing high-capacity anaerobic digestion plants and introducing new technologies to recover the methane produced.
    - Using the collected methane for energy purposes, such as district heating or electricity generation, thereby reducing the use of fossil fuels.
3. **Implement and promote policies and measures based on the Zero Waste principle:**
    - Strictly limit food waste through legislation, e.g. mandatory rescue and distribution of food close to its expiry date.
    - Obliging businesses that produce food waste to transfer it to biogas production or composting.
4. **Public support for green technologies and tax incentives:**
    - Providing grants and funding for technological innovations that reduce methane emissions.
    - Tax incentives for waste recycling and biogas production companies.
5. **Landfill capping and gas collection systems:**
    - Complete closure and rehabilitation of the largest methane emitting landfills.
    - Use of appropriate technologies to minimise landfill emissions (in particular bio-layer cover), which can be continuously monitored and managed.

All of these measures can divert up to 90% of the bio-waste generated from landfills.

6 Costs

Although the costs of a series of measures aimed at reducing greenhouse gas and specifically methane emissions linked to the waste sector can be considerable[157], the magnitude of the costs will depend on the intensity of the programmes to be implemented, the technological solutions used and the efficiency of the project management (i.e. the professional competence of MOHU, the coordination between MOHU and other actors in the waste sector, etc.)

However, it is also useful to look at the overall costs together with the benefits, and a more nuanced picture can be obtained by taking into account the positive impact of the new systems and the cost savings. As a joint publication by the Changing Markets Foundation, EIA and GAIA, Methane Matters, points out, *"Organics represent the largest component of global waste streams; organic waste prevention and source separation, therefore, can greatly reduce the volume of material sent to landfills or incinerators. This in turn avoids the costly construction of new disposal infrastructure. When it comes to alternative treatment options, composting is cost-effective, has low start-up costs and requires less land area than landfills. In countries where governments are expanding waste services, the low cost of composting can free up funds for expanded waste collection coverage. Finished compost can also be sold to help cover operational costs. Decentralised treatment can save further resources spent on collection, transportation fuel and traffic, and large infrastructure."*[158]

The 2024 publication of Zero Waste Europe also demonstrates that at municipal level, the introduction of a bio-waste collection system (which can greatly reduce the amount of bio-waste going to landfill and thus the methane emissions from anaerobic digestion) can be a profitable measure. In the town of Partizánske, measures to promote the new bio-waste collection system and composting have reduced the amount of waste going to landfill from 93.6% in 2012 to 55.4%. And the cost of collection and recovery was offset and even exceeded by savings (lower landfill fees and less frequent collection of mixed waste) and revenue (payment from the national Environmental Protection Fund for the amount of kitchen waste collected). Even without the contribution from the Environmental Fund, the new system has resulted in savings for the municipality that exceed the costs incurred: the city budget has made a net gain of €9,000 thanks to the savings.[159]

The UNEP and CCAC (2021) publication reviews the results of several other analyses and examines the potential costs of feasible methane emission measures in the waste sector. They refer to three other analyses that estimate similar emission reduction potentials (29-36 million tonnes per year, of which 10-20 million tonnes can be avoided at relatively low cost) but very different costs. Indeed, the magnitude of the costs or having net negative costs depends to a large extent on the starting assumptions. For example, the proportion of organic waste that is considered to be separable or recoverable at source, or the rate at which open dumps are estimated to be eliminated in economically peripheral countries. Whether the savings from recovery are deducted from investment and maintenance costs, and indeed what discount rate is used. It also matters whether the very expensive measures associated with waste water treatment are included in the analysis.[160]

For example, one of the analyses cited in the UNEP and CCAC study (by the US EPA) estimates that 27% of global emissions reductions are associated with a negative cost, while another (by the IIASA)

[157] cf. ReFED's table estimating the costs and avoided methane emissions of food waste recycling, transfer and prevention measures for the United States: https://refed.org/uploads/refed-methane-report-final.pdf (p. 11.)
[158] Changing Markets Foundation/EIA /GAIA (2022)
[159] ZWE (2024b)
[160] UNEP & CCAC (2021) Global Methane Assessment - Benefits and Costs of Mitigating Methane Emissions (by Ravishankara et al.

estimates that 62% are associated with a negative cost. The latter draws attention to the potential of municipal waste for separate collection and diverting organic waste from landfill – the cost of which, even without taking into account environmental impacts, is considered negative, i.e. the savings outweigh the costs. The average value of methane emission reductions associated with this measure is estimated at ~US$ 8500 per tonne, with a global mitigation potential of ~16 million tonnes per year. In contrast, the former study identifies the capture and recovery of landfill gas as the emission reduction potential with the largest net negative cost. By generating electricity, this has an average cost of -1750 USD per tonne of methane emissions prevented. The largest negative cost is the recovery of landfill gas for direct use, at an average of -US$ 3100 per tonne, for which the authors estimate a mitigation potential of 2.2 million tonnes per year. Among the other measures related to the waste sector, the analysis cites flaring of landfill gas and composting as typically low-cost measures, while the average costs of anaerobic digestion, waste-to-energy, mechanical-biological treatment and paper recycling are higher.[161]

[161] Ibid.

7 Conclusions

Globally, the waste sector is responsible for about 20% of anthropogenic methane emissions, while in Hungary the share is 42%. Therefore, in Hungary, greenhouse gas emissions related to the waste sector, and in particular methane emissions related to municipal solid waste landfilling, is an area where, with appropriate intervention, the country's contribution to global climate change can be effectively and rapidly reduced.

The way to do this is through the following steps:

1. Reduce organic matter in mixed waste as much as possible[162] by
   - food rescue programmes,
   - preventing food waste,
   - promoting the local management of organic matter, such as home and community composting,
   - the effective implementation and extension of selective collection of organic materials (this is the largest contributor to minimising the amount of organic material in municipal waste);
2. strict and effective implementation of the pre-treatment obligation of the EU Landfill Directive, preferably by biological treatment (avoiding also methane from organic matter and fossil CO_2 emissions potentially released by incineration);
3. Requirement for subsequent composting of materials that have undergone anaerobic digestion.

By taking these steps, Hungary's methane emissions can be significantly reduced in the coming years.

[162] At legislative level, it is recommended to set a maximum limit for organic matter in residual waste (kg/person/year)

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