Nothing left behind:

modelling Material Recovery and Biological Treatment's contribution to resource recovery and fighting climate change

Study
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Equanimator Ltd for Zero Waste Europe
zerowasteeurope.eu

Contents

Executive summary

There are a number of jurisdictions across the EU where the existing EU landfill restrictions push Member States to consider alternative ways of dealing with the waste leftover after source separation has sought to segregate materials for recycling. We refer to this waste as 'leftover mixed waste', or LMW.

There is interest in understanding which options exist that are not thermally based, notably, so as to avoid incineration. In addition, there is interest in understanding how to deliver an improved climate outcome relative to incineration, the climate credentials of which worsen in the absence of carbon capture (utilisation) and storage, as the carbon intensity of appropriate counterfactual sources of electricity and heat generation decline.

One of the important gaps in respect of understanding such technologies is the possible cost that might be implied by resorting to them. This study seeks to fill that gap by providing costings of a system which has been specified so as to:

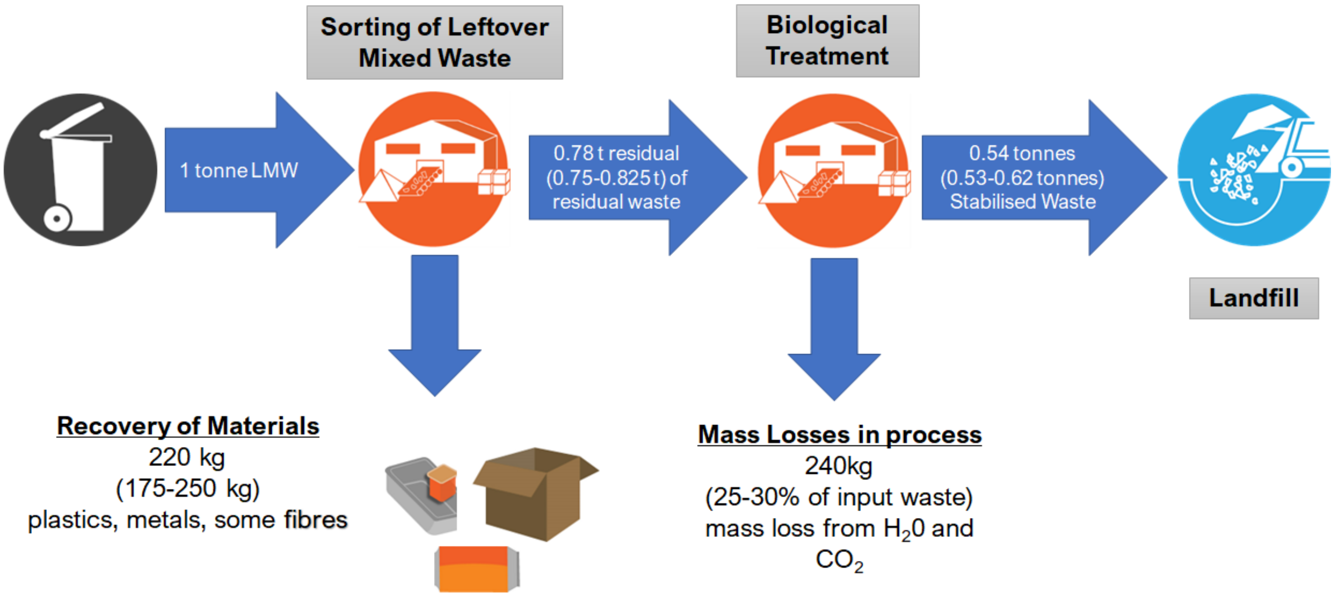
- Sort, from LMW, materials for which there are functioning recycling markets today, and some for which markets are in development;
- Incorporate an aerobic biological treatment step aimed at biologically stabilising the output from the sorting plant such that when landfilled at suitably operated sites, the likelihood of fugitive methane being released into the atmosphere is significantly reduced;
- Maintain flexibility within the overall system for managing LMW. This is reflected in:
    - The capability of the mechanical sorting plant, which is somewhat future-proofed,
    - The 'separate stages' into which the Material Recovery and Biological Treatment (MRBT) facility has been decomposed (to allow for spatial separation of the mechanical and biological steps), and also
    - The choice of aerobic biological treatment systems (which may have a lower unit capital cost than anaerobic systems). Aerobic systems also demonstrate flexibility to being 'switched' from treating residual waste to treating materials collected via separate collection (thereby, becoming 'double duty sites').

The resulting mass flow for the facility that was specified is as shown in Figure E-1.

Key results

Table E-1 shows the key results for the situation where the central values for the revenue derived from sale of materials and the costs of landfilling are used. These are shown for two scales of Material Recovery and Biological Treatment systems; 100 thousand tonnes (100 kt), and 200 thousand tonnes (200 kt). They also show different values according to whether Member States have lower or higher costs of labour, electricity and land.

Figure E-1: Mass Flow for MRBT Process



Note: figures outside parentheses are for modelled facility, figures within parentheses are estimated range of outcomes for this configuration under reasonable variations in composition

Table E-1: Summary Figures Using Central Values for Revenue and Landfill Costs (€/tonne)

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt MRBT		
Leftover Mixed Waste Sorting (excl Revenue)	55	71
Biological Treatment (excl Revenue)	42	52

Revenue (central value)	-37	-37
Landfill Costs (central value = €110/tonne)	59	59
TOTAL	**119**	**145**

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
200 kt MRBT		
Leftover Mixed Waste Sorting (excl Revenue)	39	50
Biological Treatment (excl Revenue)	37	46
Revenue (central value)	-37	-37
Landfill Costs (central value = €110/tonne)	59	59
TOTAL	**98**	**118**

As expected, costs are higher for the 100 kt system than for the 200 kt one. The way the net costs are 'built up' is also of interest. The costs for the MRBT facilities are €97-€123 per tonne for the 100 kt system, and €76-€96 per tonne for the 200 kt system. The role played by the revenues, and the landfill costs in determining the final 'net total' costs is very important. It is evident that higher gate fees of lower revenues will increase the net total costs, and vice-versa.

We highlight this in Table E-2. Because the central values are chosen to be 'central', the swings are symmetrical, and because the scale of the system is assumed not to affect these values, the absolute magnitude of the swings around the central values are the same for both scales of system. Depending on revenues and landfill costs, the total net costs can move by +/- €36 per tonne. Landfill fees alone can lead to system costs varying by +/- €27 per tonne.

Table E-2: Effect of Changing Assumptions Regarding Revenue and Landfill Costs (€ per tonne)

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt MRBT		
Total Costs, central assumptions	119	145

With Low revenue	128	154
With High Revenue	110	136
With Low landfill costs	92	118
With High landfill costs	146	172
With High Revenue, Low Landfill Costs	83	109
With Low Revenue, High Landfill Costs	155	181

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
200 kt MRBT		
Total Costs, central assumptions	98	118
With Low revenue	107	127
With High Revenue	89	109
With Low landfill costs	71	91
With High landfill costs	125	145
With High Revenue, Low Landfill Costs	62	82
With Low Revenue, High Landfill Costs	134	154

Typically, landfill fees might be better understood locally, and are less likely to vary than revenues (i.e. they are unlikely to show the same volatility as revenues). The revenue movements account for the remaining +/-€9 per tonne movement. Risks associated with the effect of any unanticipated changes in landfill fees are more likely to be covered off effectively within a procurement process (if the operation of the MRBT system is 'contracted out' by a municipality) than the risks associated with commodity price swings. These might have to be dealt with via a form of 'gain share' (between the contracting parties), or other suitable mechanism.

One of the features of the MRBT system is that it requires – relative to incineration – a fairly low capital commitment. Capital costs are not expected to vary significantly across Member States. In Table E-3, therefore, we show variation across the configurations for which we had data. These show that for 100 kt and 200 kt scales, even at the high end, capital costs are well under half of what would be expected for an incineration facility. Note that no allowance is made for capital costs of landfills receiving stabilised residual waste.

Table E-3: Variation in System Capital Costs (expressed per tonne of throughput)

System Throughput	Low (€ per tonne of System Throughput)	High (€ per tonne of System Throughput)
100 kt	296	377
200 kt	242	304

LMWS as a Plastics Recycling Facility

It is interesting to consider these in the context of fees paid by producers under extended producer responsibility schemes (EPR), and especially where these already respect the principles set out under Article 8a of the Waste Framework Directive.

What we show below is the costs of the LMWS, the revenues, and the Net Cost of the LMWS. We have then assumed that of the plastics sorted by the LMWS, 70% actually make their way into a recycling process (that is, we estimate a 30% loss in moving from the sorting output to the point where the material can replace virgin flake/pellets). The results are as shown in table E-4. At the 100 kt level, the costs per tonne of plastics recycled are €226 per tonne for the Lower Cost Member State, rising to €550 per tonne for the Higher Cost Member State. At this scale, the LMWS is likely very competitive in a Lower Cost Member State, but the situation is more balanced in the Higher Cost Member State (i.e. existing EPR fees for plastics are likely to be similar). At the 200 kt throughput, things appear very different: in both Lower and Higher cost Member States, LMWS becomes one of the lower cost means of accessing plastics for recycling. It is worth noting that not all the plastics sorted will necessarily be 'packaging', but the EPR fees provide a reasonable benchmark for the costs of plastics recycling.

Table E-4: Costs of LMWS When Considered from the Perspective of Plastic Recycling

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt Leftover Mixed Waste Sorting		
Leftover Mixed Waste Sorting (excl Revenue)	55	71

Revenue (central value)	-37	-37
TOTAL	**14**	**34**
TOTAL (per tonne plastic*)	**226**	**550**
Component costs/revenues	**“Lower Cost” Member State (€/tonne)**	**“Higher Cost” Member State (€/tonne)**
200 kt Leftover Mixed Waste Sorting		
LMWS (excl Revenue)	39	50
Revenue (central value)	-37	-37
TOTAL	**2**	**13**
TOTAL (per tonne plastic*)	**32**	**210**

** Assumes 70% of Plastic Extracted is Recycled*

LMWS as a Facility for Treating Leftover Mixed Waste (LMW)

Another way of considering the value of the LMWS facility is to consider the costs in terms of the amount of waste that no longer has to be treated as ‘residual waste’. In principle, this could be calculated as the cost per tonne of material extracted by the LMWS. However, so as to demonstrate a conservative approach, we have based the calculations on the assumption that 80% of what is extracted no longer has to be treated as residual waste (note that the prices received for the sorted material are intended to reflect what would be received where the buyer anticipates having to pay for some disposal, so we are, to some extent, double counting the cost of managing waste that is not actually recycled).

As with plastics, we show the costs of the LMWS, the revenues, and the Net Cost of the LMWS. We then express these costs in terms of the amount of Leftover Mixed Waste (LMW) removed, and hence, residual waste reduction (assumed to be 80% of the total quantity sorted). The results are as shown in Table E-5. At the 100 kt level, the costs per tonne of LMW removed are €81 per tonne for the Lower Cost Member State, rising to €196 per tonne for the Higher Cost Member State. At this scale, in Lower Cost Member States, the LMWS is likely very competitive with all LMW/residual waste treatment other than, in some Member States, landfilling (recall that our low and high landfill gate fees are €60 per tonne and €160 per tonne respectively). Again, the situation is more balanced in the Higher Cost Member State (i.e. existing fees for treating LMW/ residual waste are likely to be below €196 per tonne in most, though by no means all, cases).

At the 200 kt scale, things again appear very different: in both Lower and Higher Cost Member States, with LMWS becoming a means to avoid cost in the management of LMW/residual waste. The figures of €12 per tonne and €75 per tonne justify use of LMWS simply as a way of reducing the cost of the management of LMW/residual waste.

Table E-5: Costs of LMWS When Considered from the Perspective of Waste Treatment, 100k Facility

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt Leftover Mixed Waste Sorting		
Leftover Mixed Waste Sorting (excl Revenue)	55	71
Revenue (central value)	-37	-37
TOTAL	**14**	**34**
TOTAL (per tonne residual waste removed)	**81**	**196**
Component costs/revenues	**"Lower Cost" Member State (€/tonne)**	**"Higher Cost" Member State (€/tonne)**
200 kt Leftover Mixed Waste Sorting		
Leftover Mixed Waste Sorting (excl Revenue)	39	50
Revenue (central value)	-37	-37
TOTAL	**2**	**13**
TOTAL (per tonne residual waste removed)	**12**	**75**

** Assumes 80% of Material Extracted Does Not become Residual Waste*

Policy-related Matters

There are a number of policies that are worthy of consideration if the intention is to encourage (rather than prevent) the type of system we have proposed.

Landfill and Incineration Taxes

Landfill and incineration taxes are, with few exceptions, too often designed rather crudely. In those Member States where MRBT systems are being appraised, it is sensible to consider, or re-consider, the way in which different approaches to managing waste should be addressed by taxation (and by restrictions – see below). In Member States where landfilling of waste that has not been subject to biological stabilisation is still prevalent, introducing the same type of differential as was previously established in Austria makes good sense. Schemes could, for example, ensure the existence of tax differentials between stabilised and unstabilised waste of the order €70 per tonne. Ensuring incineration is either taxed, or included in the EU-ETS (or both, if the tax targets pollutants other than greenhouse gases, such as NOx) also makes sense.

Landfill Restrictions

Over 20 years ago, both Germany and Austria included, alongside requirements for waste to be biologically stabilised prior to landfilling, restrictions in relation to the calorific value of what could be landfilled. This effectively guaranteed the splitting of a light, over-size, high calorific fraction at MBT facilities whenever any of the output was destined for landfill. For plastics in particular, it became important to landfill as little as possible, the result being that they would be sent either to incineration facilities or to cement kilns. The effect of this is to channel the fossil carbon in waste, as far as possible, to combustion, rather than allowing the fossil carbon to be sequestered in a landfill (or better still, be recycled, as in LMWS) . Unfortunately, some Member States have followed the Austrian and German example in more recent years. That line of thinking, whatever its merits may have been at the time, now seems outdated. Italy considered such a measure for many years but eventually withdrew its intent in 2015

Many landfill restrictions were introduced in response to a well-intended, but poorly drafted, Directive on Landfill, which is a matter of some regret. It was partly (though not only) for these reasons that we indicated, in a previous report for Zero Waste Europe, to end the argument regarding the supposed superiority of incineration over landfilling by:[1]

- Removing the R1 criterion;
- Ensuring that the practice of sending waste to landfill that has not been (biologically) stabilised is eliminated;

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[1] Equanimator (2021) *Rethinking the EU Landfill Target*, Report for Zero Waste Europe, October 2021, zerowasteeurope.eu/library/rethinking-the-eu-landfill-target.

- As long as all landfilled waste is biologically stabilised, removing the landfill restriction in Article 5(5) of the Landfill Directive; and,
- Requiring implementation of LMWS prior to landfilling or incineration.

Making such changes is not necessary for the removal of counterproductive restrictions, based on calorific value, on what can or cannot be landfilled: they would, however, remove the impetus for all such restrictions that come, or are perceived to come (there is no requirement in EU legislation to restrict landfilling on the basis of calorific value) from the EU level (even if they are not actually then repealed by Member States). This would allow facilities to be sensibly specified to optimise performance with regard to cost and environmental performance, taking into account the prevailing market situations for various outputs, as well as the cost of landfilling.

Inert Materials

In our MRBT system, no glass was considered to be sorted by the sorting system (it could have been, but the process is costly) and now inert materials were extracted at the biological treatment step. The argument for doing so is enhanced where regulations allow for use of such materials. In principle, subject to meeting relevant standards and reflecting a proportionately precautionary approach, there may be potential for making use of inert materials:

- Where sufficiently well-treated, for recycling, such as is possible for glass;[2]
- Where sufficiently well-treated, for beneficial use/recovery in construction applications;
- Where appropriate, and where their use replaces the use of other materials, in (landfill) site engineering, or in activities in relation to landfill cover.

A further option might be landfilling at sites permitted to receive inert wastes only, subject to acceptance criteria being met.

These applications will require different treatments to achieve the necessary quality standards, and for those uses linked to landfills, liability for fees and taxes would need to be considered.

Stabilised Residual Waste

The previous point – regarding the use of inert materials – is a natural corollary to the potential for making some restricted use of a stabilised organic fraction from MRBT sites that has been further refined, amongst other things, to sort out inert materials.

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[2] See, for example, Połomka J, Jędrczak A, Myszograj S. (2020) Recovery of Stabilizer Glass in Innovative MBT Installation—An Analysis of New Technological Procedure, Materials (Basel). 2020 Mar 17;13(6):1356.

Almost 20 years ago, the 2nd Draft Working Document of the Biological Treatment of Waste, as it had been prepared up until its withdrawal (partly because, at the time, the requirement for separate collection of biowaste was deemed to be 'a step too far'), envisaged the setting of a standard for 'Stabilised Biowaste'. Consistent with Article 11a(4) of the Waste Framework Directive, this material could not be considered to contribute towards recycling targets. It could, though, have the merit of establishing a clear delineation between what could, and could not count towards recycling and composting targets, whilst also recognising that there may be value in making use of organic matter derived from MRBT processes, subject to precautionary limits being met, and only in clearly delineated circumstances (and not in others), and with restrictions on application rates.

Concluding Remarks

The study has highlighted the potential for a system for dealing with leftover mixed waste in a responsible manner, and at an acceptable cost. The sorting component justifies itself in its own right through, under the central scenario, its contribution to recycling, and by avoiding costs of dealing with residual waste (it reduces the quantity to be managed). In conjunction with the biological treatment step, it offers potential for a flexible system which captures additional materials from landfill, and because it also more or less eliminates methane from landfills, it offers an approach which contributes positively to climate mitigation.

Whilst such a facility is undoubtedly relevant to the EU context, and the costings are oriented to the EU situation, the wider applicability of this system, suitably adapted to the relative factor costs prevailing in hosting countries, makes it an essential tool in greenhouse gas mitigation strategies across the globe. Some such systems are already operational in other countries, but given the poor level of development of waste management systems in many parts of the globe, adaptations on the theme of MRBT have enormous potential to reduce climate change emissions in the coming years and help countries leapfrog the stage where they are supposed to move from open dumps to sites engineered mainly to capture landfill methane from the biodegradable material landfilled.

Importantly for the EU and for other countries, as well as being highly flexible, such systems can be installed in a relatively short period of time: time is of the essence.

Introduction

Interest is growing in the potential to treat leftover mixed waste using approaches which perform well in environmental terms, but which include no thermal treatment. In referring to 'leftover mixed waste' (LMW), we are speaking about the mixed waste that remains following source separation of recyclable and compostable fractions by citizens (see Figure 1). Previously, Zero Waste Europe has highlighted the potential role that could be played by so-called Material Recovery and Biological Treatment (MRBT) approaches.[3]

This approach combines the use of advanced sorting systems applied to LMW (with a view to extracting additional material for recycling) with biological treatment of the remaining residual waste aimed at stabilising the waste prior to its being landfilled. Stabilisation, or bio-stabilisation, of waste is the process by which, through a process akin to composting, the parts of residual waste which tend to generate methane when they are landfilled are used as a substrate by microorganisms. The microorganisms consume organic molecules containing carbon so that at the end of the stabilisation process, the remaining material has limited remaining capacity to biodegrade, and also degrades more slowly. This process leads to the evolution of CO_2 of non-fossil origin, but avoids the generation of the methane that would otherwise have been generated had the material been landfilled without being subject to the (biological) stabilisation process. Other reports have highlighted the potential benefits of this approach.[4]

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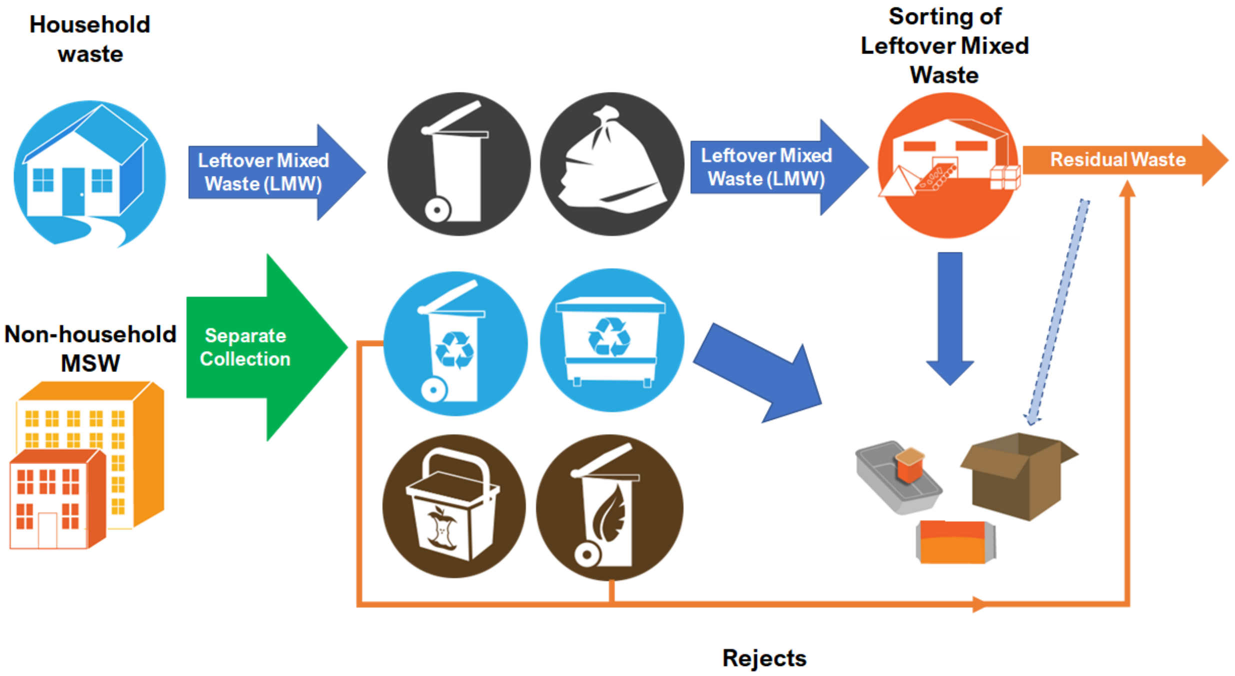
[3] Zero Waste Europe (2021) *Building a bridge strategy for residual waste: Material Recovery and Biological Treatment to manage residual waste within a circular economy.* Policy Briefing, January 2021.

[4] Dominic Hogg (2022) *The Case for Sorting Recyclables Prior to Landfill and Incineration*, Special Report prepared for Reloop, June 2022; see also Equanimator (2021) *Rethinking the EU Landfill Target*, Report for Zero Waste Europe, October 2021, zerowasteeurope.eu/library/rethinking-the-eu-landfill-target .

Figure 1: Schematic Showing Role of Facility and Convention for Naming Waste at Different Stages of Sorting



What has been missing thus far is an indication of the costs of the MRBT approach. There are, across the EU, a large number of mechanical biological treatment (MBT) facilities. These MBT facilities, especially those which have been in place for several years, did not always focus on extracting recyclables from mixed waste. Where they did so, they mainly focused on metals, and to a lesser extent, inert materials (possibly with a view to their being used as substitutes for aggregates). In addition, whilst some MBT facilities have sought to stabilise waste prior to landfilling, many were either partially or wholly focused on preparing a solid recovered fuel (SRF)/refuse derived fuel (RDF) through biodrying of waste. Finally, some of the best performing sorting systems for leftover mixed waste are currently to be found not as part of MRBT systems, but where the remaining residual waste is sent for incineration (this confirms, though, the possibility to recover materials from LMW). We see, therefore, all the elements of MRBT systems in place, but relatively few cases where all the relevant components are combined as part of a high-quality approach for dealing with LMW.

MRBT systems provide a means of dealing with LMW in a relatively flexible way, but with minimal contributions to global temperature increases from greenhouse gas emissions.[5] Also, as it was previously emphasised in the ZWE MRBT report, this approach ensures better scalability and operational flexibility than incineration (for it

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[5] The wording here is deliberate – the use of Global Warming Potential (GWP) as a means to assess the impact of greenhouse gases on climate change is widely considered to be flawed. See, for example, Smith, S.J., Wigley, M.L. (2000) Global Warming Potentials: 1. Climatic Implications of Emissions Reductions. Climatic Change 44, 445–457 (2000). doi.org/10.1023/A:1005584914078; Fuglestvedt, J.S., Berntsen, T.K., Godal, O. et al. (2003) Metrics of Climate Change: Assessing Radiative Forcing and Emission Indices. Climatic Change 58, 267–331 doi.org/10.1023/A:1023905326842; Shine, K.P.(2009) The global warming potential—the need for an interdisciplinary retrial. Climatic Change 96, 467–472 doi.org/10.1007/s10584-009-9647-6; Allen, M.R., Shine, K.P., Fuglestvedt, J.S. et al. (2018) A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. Clim Atmos Sci 1, 16 doi.org/10.1038/s41612-018-0026-8. What is more important is the impact which the emissions exert on radiative forcing (as well as the effects of aerosols in interacting with clouds) and on resulting global temperature increase. Where methane is concerned, the effect is relatively short-lived, but significant in time over which the gas exerts its effect. Using GWP as a metric of impact may be guiding us to inadequate action on methane emissions. For this reason, we have sought to minimize/eliminate methane, so that the emissions of GHGs of biogenic origin are limited as far as possible to CO_2 (to which the majority of any methane which would otherwise be emitted would likely be converted).

includes both material sorting equipment and technologies for biological treatment, both of which may be converted to dry recyclables and clean organics coming from newly introduced, or already existing but improved and maximised, kerbside schemes).[6] This aligns with a vision of ever-increasing material recovery rates and dwindling amounts of LMW and residual waste.

These MRBT systems are relevant to EU countries seeking to advance the case for a circular economy, but they also have global relevance because of their potential to reduce the extent to which waste management contributes to global temperature increase via emissions of methane. In principle, a well-operated process should allow waste to be treated with minimal (close-to-zero) methane emissions and close-to-zero nitrous oxide emissions, with the main process emissions being non-fossil CO2 emissions, as well as those linked to electricity to run the operation. There will also be emissions associated with transport of materials to and from the facility(ies), but these will vary according to specific circumstances.

This paper seeks to shed some light on the matter of the costs of MRBT systems. This should enable municipalities to consider the potential implications of adopting such approaches, and their affordability as compared with, for example, incineration (or a system based on mixed waste sorting coupled to incineration). The focus on a way of treating LMW should not be taken as evidence of a lack of attention to reducing the amount of LMW (or of residual waste remaining after the application of mixed waste sorting to LMW) being generated. On the contrary, the aim is to identify a form of treating LMW which is compatible with reducing residual waste as far as possible, and which offers a modern way of treating LMW in such a way as to eliminate, as far as possible, emissions of methane and of fossil-derived carbon dioxide. With materials being extracted for recycling, such an approach helps reduce the contribution of managing LMW to global temperature change.

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[6] Zero Waste Europe (2021) *Building a bridge strategy for residual waste: Material Recovery and Biological Treatment to manage residual waste within a circular economy.* Policy Briefing, January 2021. OR Equanimator (2021) *Rethinking the EU Landfill Target*, Report for Zero Waste Europe, October 2021, zerowasteeurope.eu/library/building-a-bridge-strategy-for-residual-waste and zerowasteeurope.eu/library/rethinking-the-eu-landfill-target .

Nature of Facility

The facility modelled in this costing exercise, with the support of different technology suppliers, has the following characteristics:

- The leftover mixed waste sorting (LMWS) facility achieves high levels of separation of targeted materials for recycling, including sorting of plastics into specific fractions. Key materials targeted are metals, plastics, some paper and card fractions, and polyester/cotton textiles. Although sorting facilities now have the potential to extract glass for recycling from LMW, this process is relatively expensive and quite challenging, technically, to achieve. In this model, no glass is sorted at the mechanical sorting facility. The operators of biological treatment facilities were asked to consider the extraction of 'inerts' in their process partly as a means of moving these into relatively low value recycling applications, but also, to avoid the costs of landfilling residues. These were the only materials the suppliers of biological treatment technology (as opposed to the suppliers of sorting technology) were asked to consider removing for recycling. We comment on their views vis-à-vis inerts below;

- Technology suppliers were asked to configure the biological treatment step so as to:

  a) Minimise methane (and nitrous oxide) generation from the biological treatment process itself, and

  b) Ensure stabilisation of materials to an extent that methane emissions from a landfill site operated with an active cover layer are largely avoided.

Regarding the first request; although facilities could have considered deploying high solids (dry) digestion processes prior to aerobic stabilisation, thereby enabling some biogas to be generated, we decided to focus only on aerobic systems for stabilisation. The essence of this technology is that it is well understood and presents fewer challenges to operators, whilst it should also reduce the extent to which the facility is susceptible to claims that methane emissions result from, for example, leakages or emissions as the material moves from an anaerobic step and into an aerobic step.

That being said, there have been studies indicating that successive steps of anaerobic and aerobic treatment can achieve more (in terms of reducing the tendency of waste to generate methane) than in systems where only one is deployed, whilst the production of biogas for use as a fuel, or as a source of electrical and/or heating energy would be an additional benefit (and source of revenue). As regards b), the technology suppliers were given a guide value of stability broadly equivalent to performance standards set in Austria/Italy. Whilst there is a great deal of information regarding various test methods for assessing stability of waste (which has been subject to biological treatment), the stability value was conceived of as the level likely to reduce fermentability of waste to such an extent that, when landfilled in a site with an active cover layer, the methane generation would be close to zero. The flux of methane would be so low that the cover layer would act to oxidise the majority of whatever methane is still generated by the landfilled waste.[7]

- It maintains flexibility within the overall system for managing LMW. This is reflected in i) the capability of the mechanical sorting plant, which is somewhat future-proofed, ii) the 'separate stages' into which the MRBT facility has been decomposed (to allow for spatial separation of the mechanical and biological steps), and also iii) the choice of aerobic biological treatment systems (which may have a lower unit capital cost than anaerobic systems). Aerobic systems also demonstrate flexibility to being 'switched' from treating residual waste to treating materials collected via separate collection (thereby, becoming 'double duty sites').

In the modelled facility, all LMW (see Table 1 below for assumed composition) goes through the LMWS step to extract materials for recycling. Materials such as plastic, metals, glass, and fibres are targeted for their value and resource potential (see Table 3 below for efficiency of separation).

Based on the central composition used in the modelling, then applying the efficiencies of sorting of each fraction to the composition, 220 kg per tonne of input LMW are removed by the sorting process. More generally, we would expect the type of future-proofed facility we have specified to achieve around 175-250 kg per tonne of input LMW, the exact figures being dependent on the composition of the waste received. Note that this includes some material that is likely to be rejected at subsequent steps in the processing of these materials.[8]

After mechanical sorting, the residual waste is then sent to the biological treatment facility. Variants on a housed windrow aerobic stabilisation facility have been specified such that the residual waste is subject to a composting-like process, reducing the fermentability and achieving stability of the organic materials. It is estimated that of the order 240 kg of mass will be lost due to the release of CO_2 and water vapour (and trace amounts of other gases such as ammonia) during the stabilisation process. More typically, we would expect that a total of around 25-30% of the mass that enters the biological treatment facility will be lost (Fig 1).[9] The stabilised output from the bio-stabilisation facility would be 540 kg for every tonne of LMW entering the modelled MRBT system. In the mass flow diagram below, we indicate our modelled figures as well as what might be 'typical' figures for such a facility where the waste composition is different to the one we have assumed.

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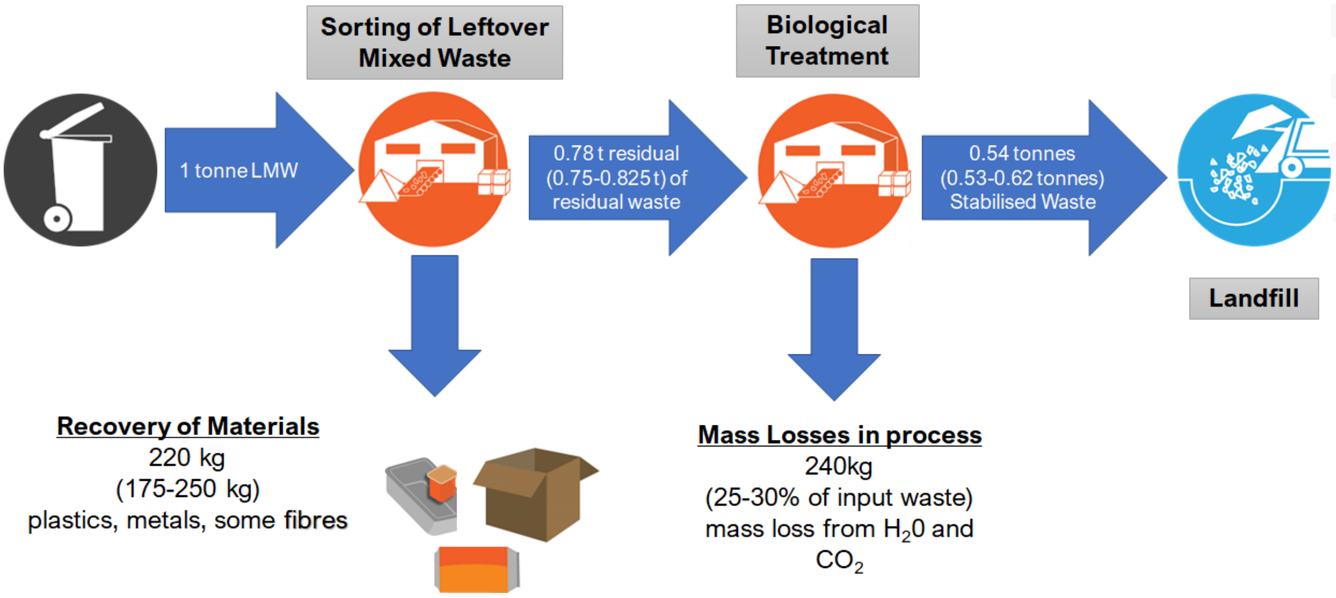
[7] See, for example, Wolfgang Müller (2009) Mechanical Biological Treatment and its role in Europe, Waste-to-Resources 2009 III International Symposium MBT & MRF, www.wasteconsult.net/files/downloads/2009_01E__Mueller_MBT_in_Europe.pdf
W Muller and H Bulson (2005) Stabilisation and Acceptance Criteria of Residual Wastes – Technologies and their Achievements in Europe, Conference "The Future of Residual Waste Management Treatment in Europe".

[8] See Eunomia (2023) *Mixed waste sorting to meet the EU's Circular Economy Objectives*, Report for Reloop and Zero Waste Europe, February 2023. In a previous report by Eunomia, a mixed waste sorting facility in Friesland delivered 36 kg to reprocessors from 254 kg of residual waste per inhabitant, whereas in Stavanger, the figure was 21kg for 151 kg of input per inhabitant. Thus, the mass removal due to mixed waste sorting was 14% in both Friesland and Stavanger (see Eunomia (2021) *Waste in the Net-Zero Century: Testing the Holistic Resources System via Three European Case Studies*, Report for TOMRA, July 2021). These figures represent choices to target specific fractions of LMW based on prevailing market conditions. Here, we have sought to future-proof the performance of the facility so that it extracts materials for which we have reason to believe there will be functional markets in place in future. Specifying the facility in this way ensures that those adaptations which might otherwise be desirable in future are already 'built in'. Material values, however, are not speculative in this regard (see below).

[9] In their 2015 report, Mueller and Bockreis model the mass-flow diagram of a common anaerobic MBT approach. They suggest a 20-30% mass loss from H_2O and CO_2. Mueller and Bockreis (2015) *Mechanical-Biological Waste Treatment and Utilization of Solid Recovered Fuels – State of the Art.*

Figure 2: Mass Flow for MRBT Process (figures outside parentheses are for modelled facility, figures within parentheses are estimated range of outcomes for this configuration under reasonable variations in composition)



Two different scales of operation were considered, 100,000 tonnes (100 kt) and 200,000 tonnes (200 kt). There are likely to be economies of scale above this level of throughput, especially for the LMWS step, and likely, some biological treatment configurations also (though to a lesser degree than is the case with incineration). The scales were chosen, though, with it in mind that the case for much larger scale facilities for treating LMW should be diminishing over time as the EU seeks to shift the management of waste up the hierarchy, and as it seeks to embed ways of dealing with products, parts, packaging, food and materials which are consistent with the principles of a circular economy and minimising its contribution to global temperature increases.

Comments on the Technology Specified

Discussions with the technology suppliers indicated a number of points worthy of note for each of the Steps.

Leftover Mixed Waste Sorting Facility

It would have been possible to specify facilities of relatively high, or relatively low, technical capability, notably in separating different plastic fractions. With a relatively low specification facility, a mixed plastics output could have been considered suitable for further sorting at a separate installation. We opted for a high specification, however, where plastics were sorted into constituent polymers, and to a degree, by colour. One reason for this was to derive greater value from the materials being sorted. Another was to ensure that the facility would not, in principle, be reliant on the presence nearby of suitably equipped facilities that could deal with mixed fractions. The one exception to this principle was, as we have already noted above, that although, technically, glass could have been sorted, we chose not to include sorting of glass.

It could have been interesting to include further processing, and hot-washing of plastic fractions, to upgrade the quality of the plastics. However, the scale of facilities we have specified would be delivering (in the case we have modelled) 9,000 tonnes and 18,000 tonnes of plastics for, respectively, the 100,000 tonne and 200,000 tonne facilities, and these are relatively small scales at which to include hot-washing processes. In cases where LMWS is fitted at the front of larger facilities, such investment may make sense as a means to reduce dependence on others, and to increase the value added by the process to the outputs, which are akin to commodities at that point.

Biological Treatment Facility

A key issue for the suppliers was the nature of the input composition to their facility. Some were also keen to understand the nature of the location (urban, peri-urban, rural) as they indicated that the attention required to be given to odour abatement, and the associated investment, would be influenced by that.

In most facilities that are used for biological treatment of residual waste, there is a screening phase prior to the biological treatment phase, which is typically used to sort out so-called over-size fractions from the under-size. Various studies carried out in respect of biological treatment facilities highlight how biodegradable fractions, especially food waste, are concentrated in the undersize fraction, whereas combustible fractions – such as plastics, card, larger pieces of wood, etc. tend to be concentrated in the oversize fraction. Over-size fractions are often sent (subject to some additional refining) to facilities such as cement kilns, and depending on local circumstances, this might be a source of revenue (or even if there is a payment made to have the material taken away, that payment may be lower than the cost of landfilling the same weight of material). We specifically asked operators to avoid separating off such a fraction for that purpose partly so as to explore the costs of a non-thermal route, and partly also to avoid the release of fossil-derived CO_2. In this respect, we were most likely (depending on the landfill gate fees available locally) increasing the cost of the facility. It should be noted that some Member States have set restrictions on landfilling in relation to calorific value; a ceiling value for landfilled waste is established. For reasons discussed below, we consider this largely counterproductive. Where these remain in place, however, then screening the oversize would be necessary to enable the output from the stabilisation process to be sent to landfill. The balance of costs (given the landfill gate fees we have used in modelling) of making this change is likely to be favourable, but we question its environmental rationale.

The level of stability required for the output from the facility is also critical in determining costs. Different measurements of stability exist and views differ as regards which is most appropriate to use. In our view, what matters is the ultimate objective of reducing the tendency of the waste to generate methane to such an extent that when it is landfilled in the facility to which it is sent, any residual emissions of methane are highly likely to be oxidised to CO_2 before they can be emitted into the atmosphere. As noted above, the degree of reduction in the gas generation potential that would have occurred in the process can be measured using one of the many respiration indices. The chosen level of performance was the level from a past Draft of a Biowaste Directive (Dynamic Respiration Index (DRI) less than 1,000 mg O_2/kg VS /hr or Respiration Activity after four days (AT4) below 10 mg 02/g dm).[10] Pursuing this standard of biodegradability would:

a) Significantly reduce the negative impacts of the biodegradable components (see Figure 3);

b) Achieve such benefits without incurring excessive costs. Since the potential to generate methane in landfills fall exponentially with time spent in a stabilisation site, there is an optimal stabilisation level, after which incremental reductions in biodegradability are unlikely to be justified by the increase in costs (environmental and economic) once the likely flux of methane through the landfill surface has fallen to low levels;

c) Lead to residual methane emissions which are manageable through suitably designed cover mechanisms at landfill sites (see Figure 4).

If a tighter level of stability is chosen, little is to be gained if the incremental benefits of setting a tighter standard have limited impact on the ultimate release of methane.

As noted above, we discussed with operators the potential for separation of inerts, partly to increase resource valorisation, and partly to reduce the costs of landfilling residues (the inert fractions become increasingly concentrated in the stabilised residual waste). Operators highlighted that there could be regulatory issues arising from attempts to make use of such materials, including when used for engineering within a landfill site. As a result, none clearly included this option. Had they done so, this might have reduced quantities landfilled by 50-75 kg per tonne of input. Note that some indicated also that this approach would be more likely where there was an option to make use of a fraction of the stabilised biowaste in some applications to land, subject to the materials achieving some relevant standards. Those would typically require some form of density refining of the output so as to 'clean up' the materials (and such an approach would likely be more consistent with an up front screening step designed to remove over-size fractions also).

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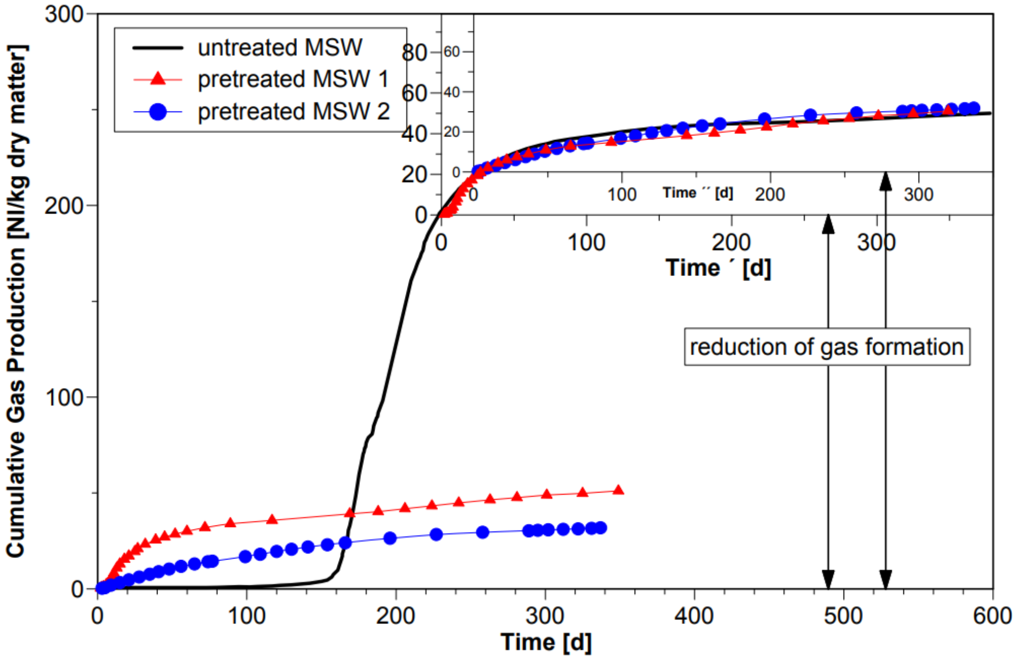
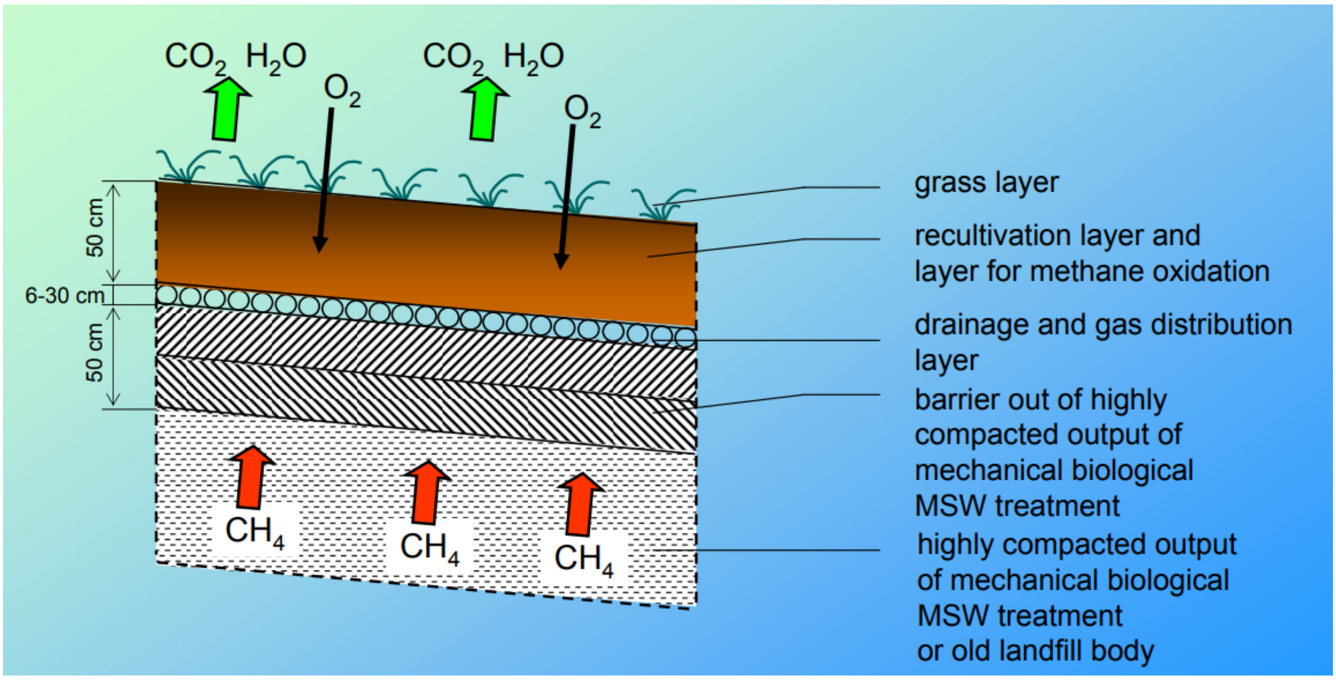
[10] Amongst other reasons, because the waste treated at, and the output of, the biological treatment facility are relatively heterogeneous, a test that observes a larger sample size, like DRI, might be preferred.

Figure 3: Graphic Showing Cumulative Gas Production in Landfill Simulation Reactor from Untreated and Biologically Pre-treated Waste



Source: Wolfgang Müller Mechanical biological treatment in Europe, Presentation to Cre Conference.

Figure 4: Landfill Design to Minimise Fugitive Methane Emissions



Source: Wolfgang Müller Mechanical biological treatment in Europe, Presentation to Cre Conference

Summary

In summary, and perhaps especially in the case of biological treatment, our requirement to avoid sending any material to thermal outlets may have been overly restrictive and may have made other process steps less likely. As such, and because the resulting quantity of landfilled waste is likely higher than would otherwise have been the case, the overall costs of managing waste that we have arrived at might (other things being equal) be higher than could be expected if we had given the biological treatment operators greater freedom to choose their preferred configuration, subject to the landfilled fraction having met the stability requirement we identified.

Also note that the composition of LMW is a relevant variable for both the LMWS sorting facility (being a determinant of mass removed, and the associated revenue generated) as well as the biological treatment facility (since proper operation of the facility is affected by composition, particle size, moisture content, C:N ratio and so forth). That having been said, optimisation around the concepts we have identified is unlikely to lead to major changes in costs of different proposals. Indeed, two operators provided costs for different configurations. When put through our financial modelling, the maximum difference across these options was around €10 per tonne (at both scales of facility).

Methodology and Key Assumptions

In this Section, the methodology and key assumptions underpinning the costings are highlighted.

Methodology

The modelling exercise seeks to uncover the economic costs associated with a MRBT facility, as described in the Introduction. The inputs to this assessment include:

- Data and costs from Mechanical Sorting technology suppliers,
- Data and advice from Biological Treatment technology suppliers, and
- Assumptions which underpin the financial modelling.

These are applied to the model of a MRBT facility to assess the costs per tonne of LMW processed.

Whilst the MRBT system might be located as one integrated facility, there may be circumstances where the mechanical sorting component of the MRBT system might be spatially separate from the biological treatment step. This could be for logistical reasons, or because it is deemed more appropriate (for example) to site a sorting facility in an urban/suburban location, and a biological treatment facility at the front of a landfill. So as to retain flexibility as regards this choice, costs were assessed separately for the LMWS facility of a given capacity and for the Biological Treatment facility of a scale able to manage the output from the LMWS facility.[11] In a greenfield scenario, it is reasonable to assume that building both facilities in the same location would result in capital and operational cost efficiencies, yielding a lower cost per tonne of waste processed than estimated in this exercise.

The study sought to obtain cost data for the MRBT configuration described above. Nonetheless, the study's aim was not to focus on costs of a specific configuration, but to inform the costs which might be expected from well-specified MRBT facilities. For reasons highlighted above, we may have narrowed the freedom of biological treatment operators to specify what they would ideally have done, though equally, we were seeking to understand how these costs might vary across a range of different countries, with different input costs, and under different underlying assumptions. In seeking to elicit costs for such facilities, however, starting with

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[11] In certain cases, a sorting facility would be better suited near the source of the municipal waste or near the point of sale for the recycled materials, while the bio-stabilisation facility would be better suited near the landfill. An arrangement of this nature would reduce the overall costs of transportation as the weight of the residual waste would be lower after sorting. It may also be advantageous, in some circumstances, to have multiple sorting facilities in different locations feeding one bio-stabilisation facility; the appropriate arrangement will depend on many factors including the population density in the region, the existing facilities available, the distances between the sources of waste and the landfill where stabilised residual waste will be deposited.

some specifics is far more desirable than starting with none. In this sense, we have tried to provide an analysis of the broader costs for the introduction and operation of MRBT facilities.

How Component Costs are Modelled

As mentioned earlier, the costs for LMWS and Biological Treatment facilities are modelled separately in this exercise to maintain flexibility in the orientation of the MRBT system. The costs modelled for the LMWS facility can be split into the following components:

- Capital expenditures such as land, infrastructure, technology, transport, etc.;
- Operational expenditures such as labour, electricity, insurance, etc.; and
- Revenues earned from the sale of recycled materials.

The costs modelled for a Biological Treatment facility can be divided into the following:

- Capital expenditures such as land, infrastructure, technology, transport, etc.
- Operational expenditures such as labour and electricity; and
- Cost of disposal of residues.

With regards to costs:

- For those that were likely to be relatively consistent across EU countries, mostly capital costs such as technology and infrastructure, a single figure was used across all Member States considered (see below).
- For those costs with significant variability across countries, such as labour, energy, and land, then depending on the country for which costs were provided, the relative costs of these were altered for the country concerned using various tables from Eurostat. These assumptions helped to indicate variations in cost across the EU, and were used to yield 'high' and 'low' cost estimates.

Member States Chosen as a Basis for Determining Cost Variations

At the outset, our client, Zero Waste Europe, selected a number of Member States where they felt that interest in MRBT systems might be particularly strong. These countries were: Italy, Latvia, Lithuania, Romania, Slovakia and Slovenia. The intention of this report is, ultimately, to inform the level of costs which might prevail in different situations. The selected Member States were used as a basis for understanding:

- The likely extent of variation in costs of the LMWS and biological treatment facilities, taking into account variation across these Member States in the costs of electricity, labour and land; and
- The extent to which the costs of landfilling residues is likely to vary across the EU. Note that in most countries, the (pre-tax) fees vary locally, whilst in Italy, taxes also vary by region.

Some base costs, from which these Member State models were derived, were for the German situation. As such, costs were also modelled for Germany. These Member State-specific variants have been used as a basis for indicating ranges of costs for different Member States. Perhaps as might be expected, before accounting for landfill costs, costs for Italy and Germany tended to be higher than for the other Member States (and were relatively closely aligned, based on our assessment).

Assumptions

Many key assumptions were made in the costing analysis for the MRBT process. Further detail is provided on these assumptions in this section of the report. Whilst the assumptions made are based on reliable data sourced from trusted databases (such as Eurostat) or from conversations with technology suppliers and operators within the industry, it should be recognised that the actual cost of an MRBT system will vary materially based on deviations in each of these factors.

Scale of Facility

For this exercise, two separate scenarios are modelled where the overall capacity of the system is 100,000 tonnes of waste per annum and 200,000 tonnes per annum. The two scales were chosen to offer flexibility in the analysis and to reflect existing sizes of waste management facilities across the EEA region. Generally, systems with more capacity will enjoy lower costs per tonne of waste processed, assuming the facility operates at capacity.

Waste Composition

Waste composition varies with a host of factors. The composition of LMW reflects not only those factors, but also, the degree to which systems of separate collection are successful in targeting materials for recycling. Waste compositions do affect, other things being equal, mass flows, material revenues, process optimisation at the biological treatment plants, and the output sent to landfill. However, compositions are ever-changing and very difficult to predict, and no one composition can be described as representative of all situations. Nevertheless, a singular composition of waste has been modelled in this analysis to be broadly representative of compositions one might find in the EU (see Table 1). Not only was this necessary to model mass flows and revenues from sorting facilities, but the output composition from the LMWS (derived from the composition in Table 1 and the assumed sorting efficiencies – see below) was provided to biological treatment technology suppliers (see Table 2). Note that even at very high rates of source separation, there remains material suitable for further sorting: citizens and businesses are not perfectly accurate sorters of materials they are instructed to divide (and the communication as to what to sort is also, on occasion, far from perfect).

Table 1: Waste Composition Assumed for LMW (may not sum to 100% due to rounding)

Material	Percentage
Food	22%
Garden	7.5%
Plastics	14%
Paper	7%
Cardboard	9%
Glass	6%
Ferrous Metals	3.5%
Non-ferrous Metals	1%
Textiles	7%
Sanitary	7%
Inert Material	8%
Wood	4%
Other	4%

Table 2: Output from LMWS into Biological Treatment (may not sum to 100% due to rounding)

Material	Percentage
Food	26%
Garden	9%

Plastics	7%
Paper	6%
Cardboard	7%
Glass	7%
Ferrous Metals	0%
Non-ferrous Metals	1%
Textiles	8%
Sanitary	8%
Inert Material	10%
Wood	5%
Other	5%

Materials Sorting Efficiencies

The LMWS facilities modelled in this study aim to sort a high percentage of the targeted recyclables. Generally, attempting to achieve higher sorting efficiencies results in greater complexity in the sorting process, thereby increasing the sorting cost per tonne of waste processed. However, in addition to increased revenues from the recycled material, any additional extraction of materials directly reduces the mass landfilled, lowering the overall landfill cost per tonne of waste processed. In the context of environmental benefits, which are not modelled in this analysis, there are considerable savings in energy use and greenhouse gas emissions associated with the increase in materials recovered for recycling.[12] The sorting efficiencies used in the model are displayed in Table 3.

Table 3: Assumptions Regarding Efficiency of Extraction of Key Materials

Plastics	Percentage
PET Bottles Clear	92%
PET Bottles Blue	92%
PET Bottles Coloured	90%

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[12] Eunomia (2023) *Mixed waste sorting to meet the EU's Circular Economy Objectives*, Report for Reloop and Zero Waste Europe, February 2023; Dominic Hogg (2022) *The Case for Sorting Recyclables Prior to Landfill and Incineration*, Special Report prepared for Reloop, June 2022.

PET Trays Clear	52%
PET Trays Black	0%
HDPE Bottles Clear	92%
HDPE Bottles Coloured	92%
LDPE Film	70%
PP Rigids	85%
PP Film	75%
PS	70%
Other	0%
Metals	**Percentage**
Ferrous Cans	90%
Ferrous Other	88%
Non-ferrous Cans	88%
Non-ferrous Other	75%
Fibres	**Percentage**
Cardboard Corrugated	45%
Other Cardboard Packaging	45%
Beverage Cartons	85%
Other Cardboard	20%
Paper (De-inking)	80%
Other Recyclable Paper	20%
Other Paper	20%
Textiles	**Percentage**
Poly/cotton	70%

Material Revenues

Understanding the likely revenue from sale of materials per tonne of input to the LMWS proves to be particularly challenging for fairly obvious reasons: these revenues are affected by composition, sorting accuracy, the state of the economy, demand for specific recycled materials, and other factors, some related to Member States policy considerations. These figures are significant in the overall analysis, however. We did consider looking at monthly figures over the past five years from sources such as letscrecyle.com, and then using mean figures and one standard deviation from these (either way) as the basis for central low and high figures, with material values discounted from these to reflect an adjustment for quality relative to the materials to which the letsrecycle.com figures apply. However, there is no consistent discount applicable, and some material fractions are not covered by letsrecycle.com (or other similar sources).

In the end, we adopted an iterative process: having agreed efficiencies of 'material extraction' by the LMWS, we discussed suitable revenue figures for the streams as they were extracted by the facility itself, partly informed, for some materials, by letsrecycle.com, applying percentage discounts to some figures whilst setting some others to low or negative values where markets are still in development. More time and effort was spent on deriving sensible figures for the plastics being sorted from LMW: in both the high and low revenue generation scenarios, these are responsible for around two-thirds of the total revenue generated from the materials that were sorted.

Whilst this type of analysis cannot be conducted in a cavalier manner, neither could it be ever said to be accurate: claims to such accuracy will likely be factitious. We believe, however, that the revenue per tonne figures – as shown in Table 4 - show a range which is likely to be applicable in a wide range of circumstances, other than where commodity prices swing to extremely high or low values, or in circumstances where either the use of plastic radically declines or the rate of separate collection for plastics is radically increased relative to other fractions being targeted for separate collection. Many would see both of these as highly desirable, but few would assume either (let alone both) to be imminent.

Table 4: Assumed Material Revenues Under Different Scenarios, €/tonne of LMW Input

Scenario (commodity values)	Revenue from Materials Recovered (€ per tonne of input LMW)
Low	€28.25
Central	€37.29
High	€46.33

Cost of Capital and Estimated Lifetimes

For this analysis, a 12% weighted average cost of capital has been assumed in the central case. The chosen level reflects a relatively conservative assessment of the cost of capital and might be representative of a project structure incorporating a blend of debt and equity investment.[13] In situations where municipalities are able to provide the finance for such investments, then a lower Weighted Average Cost of Capital (WACC) would be applicable, lowering the overall cost of the facility. Our 12% figure seems relatively prudent in the current context given that the technologies we are considering are not desperately high risk, so that even where no public sources of financing are available, much of the capital may be financed through debt (as opposed to equity).

In the costing model, one-off initial capital costs are annualised using reasonable estimates for useful lifetimes and the estimated cost of capital. The lifetime assumptions are made using data and advice from technology providers and are shown below in Table 5. Generally, the greater the useful lifetime of an investment, the lower the per year cost for that investment, yielding a lower cost per tonne of waste processed. Conversely, the greater the cost of capital, the higher the per year cost for that investment, yielding a higher cost per tonne of waste processed.

Table 5: Useful Lifetimes for Capital Expenditures

Capital Expenditure	Useful Lifetime
Property	20 years
Infrastructure	20 years
Technology	12 - 20 years
Vehicles	7 years
Other	7 - 20 years

Cost of Key Inputs

There are some costs associated with MRBT facilities that vary significantly across the member countries in the scope of this analysis. These costs include:

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[13] See Eunomia (2010) *Landfill Bans: Feasibility Research, Appendices to Final Report*, Report EVA130for WRAP, for a discussion.

- Labour;[14]
- Electricity;[15] and
- Land.[16]

For these inputs, publicly available sources were used to understand variations in costs and assumptions were made to model distinctions between a 'high' and a 'low' cost profile.

Costs of Landfilling

Residues from the biological treatment phase are assumed to be landfilled. Stabilised biowaste behaves, in principle, quite differently to 'untreated' leftover mixed municipal waste when landfilled. In principle, therefore, it could be managed at sites which are configured specifically to receive such wastes, where the aim is not to extract landfill gas for energy generation or flaring, but to increase the likelihood of residual fluxes of methane being oxidised as the methane passes through the landfill cap. Such landfills might not cost the same to operate as landfills designed to receive 'untreated' leftover mixed municipal waste. However, we have based costs on existing landfill sites in different countries.

EU Member States impose taxes on landfills, and some EU Member States have restrictions in place as regards what may or may not be landfilled. These data are relatively easy to acquire, and Cewep provides a summary which is periodically updated.[17] Data regarding the gate fees which are charged, prior to taxes being paid, are, however, not so readily available. Landfill gate fees were obtained for various Member States and we were supported by ZWE's network (to whom we are grateful) so as to inform the range of values that might prevail in different circumstances.

In the presentation of costs below, we have used high and low values for the costs of landfilling (including taxes) reflecting ranges across the EU. This has seemed the most sensible way to present these figures given the significance, as will become clear, of landfilling costs on the costs of the overall system. It should be noted that the upper end costs in the range we obtained sometimes appear to include the cost of pre-treatment so that where upper end landfilling costs are used in sensitivity, there may be some double counting of costs implied: in this respect, when using the upper end of the range of landfill costs, our cost calculations are likely to be very conservative.

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[14] Data from Eurostat were used (Labour Cost for LCI (compensation of employees plus taxes minus subsidies)) (ec.europa.eu/eurostat/databrowser/view/lc_lci_lev/default/table?lang=en)

[15] Data from Eurostat were used (electricity prices for non-household consumers with consumption band 20,000 MwH - 70,000 MwH) (ec.europa.eu/eurostat/databrowser/view/NRG_PC_205__custom_4378535/default/table?lang=en)

[16] Sourcing a sensible dataset upon which to base comparative values was more difficult for land. Not only did our desire to retain flexibility (as regards location) mean that the type (agricultural, industrial etc.) of land required could vary, but Eurostat provides comparative statistics only (as far as we could see) for agricultural land. Given that we had specific values for specific countries, and that we were seeking statistics giving 'relative values' for other countries, we opted to use the agricultural land values. The dataset from Eurostat has the data code, APRI_LPRC.

[17] See Cewep (2021) Overview of landfill taxes and restrictions, downloadable at www.cewep.eu/wp-content/uploads/2021/10/Landfill-taxes-and-restrictions-overview.pdf

Table 6: Assumed Costs of Landfilling Under Different Scenarios, €/tonne including taxes/levies

Scenario (landfill costs)	Costs of Landfilling (€ per tonne landfilled)
Low	€60.00
Central	€110.00
High	€160.00

Modelled Costs of MRBT Systems

In what follows, we present costs for the whole system, showing also the effects of changes in assumed levels of revenue generation (see Table 4) and the assumed costs of landfilling, inclusive of taxes and levies (see Table 6).

As previously noted, although we modelled costs for specific Member States, and for specific technological configurations, the figures we are providing are a synthesis of these modelled costs. We distinguish between "Lower" and "Higher cost" Member States according to costs of land, labour and electricity. The higher costs are representative of Italy and Germany, the lower costs are illustrative of Latvia, Lithuania and Romania. It should be noted, however, that some of the otherwise "lower cost" Member States can have relatively high landfill costs.

Summary Costs, Central Values for Landfilling and Received Revenue

Table 7 shows the costs of the MRBT system for both 100 kt and 200 kt systems. These use the central values for revenues generated from sale of materials from LMWS and for landfilling of residues from the Biological Treatment system (BT) step. There are significant economies of scale in moving from the 100 kt to 200 kt configuration, notably for the LMWS component, with the Biological Treatment system (BT) also showing declining costs with scale, though the smaller drop indicates that remaining economies of scale are limited above the 200 kt level.

The total costs – of €119-€145 per tonne at the 100 kt scale, and €98-€118 per tonne at the 200 kt scale – are comparable not only with landfill costs, but also, with the costs of alternatives such as incineration, especially where these generate electricity only, and taking into account also the reduced availability of EU funding for incineration and the likely inclusion of incineration in the EU Emissions Trading Scheme from 2028.

Table 7: Summary Figures Using Central Values for Revenue and Landfill Costs (€/tonne)

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt MRBT		
Leftover Mixed Waste Sorting (excl Revenue)	55	71
Biological Treatment (excl Revenue)	42	52
Revenue (central value)	-37	-37
Landfill Costs (central value = €110/tonne)	59	59
TOTAL	**119**	**145**

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
200 kt MRBT		
Leftover Mixed Waste Sorting (excl Revenue)	39	50
Biological Treatment (excl Revenue)	37	46
Revenue (central value)	-37	-37
Landfill Costs (central value = €110/tonne)	59	59
TOTAL	**98**	**118**

Note: The cost of landfilling only applies to the percentage of LMW that will be landfilled after biological stabilisation and recovery of recyclables

The way the net costs are 'built up' is also of interest. The costs for the LMWS and BT facilities are €97-€123 per tonne for the 100 kt system, and €76-€96 per tonne for the 200 kt system. The role played by the revenues, and the landfill costs in determining the final 'net total' costs is very important. It is evident that higher gate fees or lower revenues will increase the net total costs, and vice-versa. It should be considered also, as indicated previously, that the upper end of our range for landfill costs may already imply a degree of double counting.

Changes in Costs After Flexing Received Revenues and Landfill Costs

Table 8 highlights the effects of changing assumptions of 100 kt and 200 kt systems. Because the central values are chosen to be 'central', the swings are symmetrical, and because the scale of the system is assumed not to affect these values, the absolute magnitude of the swings around the central values are the same for both scales of system. Depending on revenues and landfill costs, the total net costs can move by +/- €36 per tonne. Landfill fees alone can lead to fees varying by +/- €27 per tonne. Typically, landfill fees might be better understood locally, and are less likely to vary than revenues (i.e. they are unlikely to show the same volatility as revenues). The revenue movements account for the remaining +/-€9 per tonne movement. Risks associated with the effect of any unanticipated changes in landfill fees are likely to be covered off effectively within a procurement process (if the operation of the MRBT system is 'contracted out' by a municipality) than the risks associated with commodity price swings, which might have to be dealt with via a form of 'gain share' (between the contracting parties), or other suitable mechanism.

Table 8: Effect of Changing Assumptions Regarding Revenue and Landfill Costs (€ per tonne)

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt MRBT		
Total Costs, central assumptions	119	145
With Low revenue	128	154
With High Revenue	110	136
With Low landfill costs	92	118
With High landfill costs	146	172
With High Revenue, Low Landfill Costs	83	109
With Low Revenue, High Landfill Costs	155	181

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
200 kt MRBT		
Total Costs, central assumptions	98	118
With Low revenue	107	127

With High Revenue	89	109
With Low landfill costs	71	91
With High landfill costs	125	145
With High Revenue, Low Landfill Costs	62	82
With Low Revenue, High Landfill Costs	134	154

Potential Adaptations to High Landfill Costs

As regards the relatively large impact on costs exerted by the costs of landfilling, it is also important to consider the comments made above regarding our somewhat restrictive approach to specifying the biological treatment step. It should be recalled that we specified the MRBT facility to avoid thermal treatment (to keep fossil-derived CO_2 to a minimum), and that as a result, the screening step that would typically be deployed to screen out over-size fractions was not included in the facilities put forward by suppliers. It was also the case that no supplier took up the option of removal of inerts, partly because of uncertainties around the regulatory regime that might apply.

Where landfill costs are high, it seems far more likely that attention would be given to seeking alternative outlets, such as cement kilns, for oversize fractions. This would reduce the quantity sent to landfill, and in situations where landfill fees are high, it would be highly likely that a saving – perhaps a considerable one – would be made as a result (the likelihood that receiving facilities would be charging fees anywhere close to €160 per tonne is low, and in some conditions, there may even be scope for revenue generation from sale of the over-size).

Similarly, as regards inert materials, local conditions and regulations may be more or less favourable to the use of materials removed through density refining. The quantity that could be removed seems likely to be relatively significant, not least given that the LMWS facility is not scoped to remove glass (another option, of course, is that in high landfill cost areas, this task could be specified for the LMWS facility).[18]

The exact outcome would likely be determined according to local conditions. However, in the high landfill cost situations, adaptations of the system (especially the biological treatment step) can reduce exposure of the system to the costs of landfilling by reducing the tonnage ultimately consigned to the landfill. These adaptations are, obviously, more likely to pay for themselves where the avoided costs of landfilling are higher.

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[18] See, for example, Połomka J, Jędrczak A, Myszograj S. (2020) Recovery of Stabilizer Glass in Innovative MBT Installation—An Analysis of New Technological Procedure, Materials (Basel). 2020 Mar 17;13(6):1356.

Split of Facility Costs According to Capex and Opex

The relative contributions to the total cost made by capital and operating expenditure are shown in Table 9. Because most of the capital costs were assumed to be invariant across Member States, these relative contributions to capital and operating costs are different in the Lower Cost and Higher Cost countries. In Lower Cost countries, the split is roughly equal between capital and operating costs. In the Higher Cost countries, the capital costs are responsible for a smaller share of costs (the 'Higher Costs' are more strongly reflected in (annualised) operational costs than capital costs).

Table 9: Contributions by Opex and Capex to Annualised Costs of Operating Facilities (excludes revenues and costs of landfilling)

System Throughput	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt MRBT		
Capex Contribution to Annualised Costs	48	54
Opex Contribution to Annualised Costs	49	69
200 kt MBT		
Capex Contribution to Annualised Costs	39	41
Opex Contribution to Annualised Costs	37	55

Capital Costs

One of the features of the MRBT system is that it requires – relative to incineration – a fairly low capital commitment. Capital costs are not expected to be highly variable across Member States. In Table 10, therefore, we show variation across the configurations for which we had data. These show that for 100 kt and 200 kt scales, even at the High end, capital costs are well below half that of an incineration facility. Note that no allowance is made for capital costs of landfills receiving stabilised residual waste.

Table 10: Variation in System Capital Costs (expressed per tonne of throughput)

System Throughput	Low (€ per tonne of System Throughput)	High (€ per tonne of System Throughput)
100 kt	296	377
200 kt	242	304

Effect of Lowering the Weighted Average Cost of Capital

We noted above that we took a relatively prudent approach to the cost of financing the facilities. If lower cost finance were available, for example, for public authorities, then the cost of capital would be likely to fall. In Table 11, we explore the impact of dropping the cost of capital from 12% to 8%. This has the impact of reducing the costs of the 100 kt facility by around €10.5 per tonne, and the 200 kt facility by around €8 per tonne. The effect is very similar across the 'Lower' and 'Higher Cost' Member States (because other than land, the capital costs are not modelled to vary across Member States).

Table 11: Varying the Weighted Average Cost of Capital

100 kt MRBT	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
Total Costs, central assumptions, WACC = 12%	119	145
With WACC=8%	109	135
200 kt MRBT	**"Lower Cost" Member State (€/tonne)**	**"Higher Cost" Member State (€/tonne)**
Total Costs, central assumptions, WACC = 12%	98	118
With WACC=8%	90	110

A Closer Look at the LMWS Facility

The costs associated with the LMWS facility itself are of interest in their own right.

LMWS as a Plastics Recycling Facility

It is interesting to consider these in the context of fees paid by producers under extended producer responsibility schemes (EPR), especially where these already respect the principles set out under Article 8a of the Waste Framework Directive.

What we show below is the costs of the LMWS, the revenues, and the Net Cost of the LMWS. We have then assumed that of the plastics sorted by the LMWS, 70% actually make their way into a recycling process (that is, we estimate a 30% loss in moving from the sorting output to the point where the material can replace virgin flake/pellets). The results are shown in Table 12 and Table 13 for the 100 kt and 200 kt situation, respectively. At the 100 kt level, the costs per tonne of plastics recycled are €226 per tonne for the Lower Cost MS, rising to €550 per tonne for the Higher Cost MS. At this scale, the LMWS is likely very competitive in Lower Cost MS, but the situation is more balanced in the Higher Cost MS (i.e. existing EPR fees for plastics are likely to be similar). At the 200 kt level, things appear very different: in both Lower and Higher cost Member States, LMWS becomes one of the lower-cost means of accessing plastics for recycling. It is worth noting that not all the plastics sorted will necessarily be 'packaging', but the EPR fees provide a reasonable benchmark for the costs of plastics recycling.

Table 12: Costs of LMWS When Considered from the Perspective of Plastic Recycling, 100 kt Facility

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt Leftover Mixed Waste Sorting		
Leftover Mixed Waste Sorting (excl Revenue)	55	71
Revenue (central value)	-37	-37
TOTAL	**14**	**34**

TOTAL (per tonne plastic*)	**226**	**550**

** Assumes 70% of Plastic Extracted from Leftover Mixed Waste is recycled*

Table 13: Costs of LMWS When Considered from the Perspective of Plastic Recycling, 200 kt Facility

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
200 kt Leftover Mixed Waste Sorting		
Leftover Mixed Waste Sorting (excl Revenue)	39	50
Revenue (central value)	-37	-37
TOTAL	**2**	**13**
TOTAL (per tonne plastic*)	**32**	**210**

** Assumes 70% of Plastic Extracted from LMW is Recycled*

LMWS as a Facility for Treating LMW

Another way of considering the value of the LMWS facility is to consider the costs in terms of the amount of waste that no longer has to be treated as 'residual waste'. In principle, this could be calculated as the cost per tonne of material extracted by the LMWS. However, so as to demonstrate a conservative approach, we have based the calculations on the assumption that 80% of what is extracted no longer has to be treated as residual waste. Note that the prices received for the sorted material are intended to reflect what would be received where the buyer anticipates having to pay for some disposal, so we are, to some extent, double counting the cost of managing waste which is not actually recycled.

As with plastics, we show the costs of the LMWS, the revenues, and the Net Cost of the LMWS. We then express these costs in terms of the amount of LMW removed, and hence, residual waste reduction (assumed to be 80% of the total quantity sorted). The results are as shown in Table 14 and Table 15 for the 100 kt and 200 kt situation, respectively. At the 100 kt level, the costs per tonne of LMW removed are €81 per tonne for the Lower Cost MS, rising to €196 per tonne for the Higher Cost MS. At this scale, in Lower Cost Member States, the

LMWS is likely very competitive with all LMW/residual waste treatment other than, in some Member States, landfilling (recall that our low and high landfill gate fees are €60 per tonne and €160 per tonne respectively). Again, the situation is more balanced in the Higher Cost MS;existing fees for treating LMW/ residual waste are likely to be below €196 per tonne in most, though by no means all, cases.

At the 200 kt scale, things again appear very different: in both Lower and Higher Cost Member States, with LMWS becoming a means to avoid cost in the management of LMW/residual waste. The figures of €12 per tonne and €75 per tonne justify use of LMWS simply as a way of reducing the cost of the management of LMW/residual waste.

Table 14: Costs of LMWS When Considered from the Perspective of Waste Treatment, 100k Facility

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
100 kt Leftover Mixed Waste Sorting		
Leftover Mixed Waste Sorting (excl Revenue)	55	71
Revenue (central value)	-37	-37
TOTAL	**14**	**34**
TOTAL (per tonne residual waste removed)	**81**	**196**

** Assumes 80% of Material Extracted is Not Residual Waste*

Table 15: Costs of LMWS When Considered from the Perspective of Waste Treatment, 200k Facility

Component costs/revenues	"Lower Cost" Member State (€/tonne)	"Higher Cost" Member State (€/tonne)
200 kt Leftover Mixed Waste Sorting		
Leftover Mixed Waste Sorting (excl Revenue)	39	50

Revenue (central value)	-37	-37
TOTAL	**2**	**13**
TOTAL (per tonne residual waste removed)	**12**	**75**

** Assumes 80% of Material Extracted is Not Residual Waste*

Facilitating Measures: Nature of Landfill Taxes and Restrictions

Landfill (and Incineration) Taxes

In most of the Member States for which we sought information on landfill gate fees and taxes, there are already taxes/fees in place. In some, there are also restrictions on landfilling (see Table 16). In the past, when Austria announced restrictions on landfilling through which landfilled waste would have to meet a stability criterion, it also adapted the ALSAG (the landfill tax) to incentivise the development of alternative treatment processes so that the necessary infrastructure to support the landfill restriction would be in place. A landfill tax differential was established between wastes that were not biologically stabilised and wastes that were, with a lower rate of tax applied to the biologically stabilised waste. The differential between tax rates for waste that had not been stabilised and waste that had, gave an incentive to companies to invest in stabilisation facilities. The high rate of tax for landfilling waste that had not been stabilised also encouraged investment in incineration (a tax was also implemented on incineration but at a relatively low rate).

In those Member States where MRBT systems are being appraised, it is sensible to consider, or re-consider, the way in which different approaches to managing waste should be addressed by taxation (and by restrictions – see below). In Member States where landfilling of waste that has not been subject to biological stabilisation is still prevalent, introducing the same type of differential as was introduced in Austria makes good sense. Schemes could, for example, ensure the existence of tax differentials between stabilised and unstabilised waste of the order €70 per tonne.

Alongside this, and with the tax scheme, the place of incineration also deserves careful consideration. A growing number of Member States have introduced taxes on incineration, partly reflecting the need to move waste up the hierarchy, and sometimes, reflecting the climate change impact of incinerating waste containing fossil-derived carbon. Use of LMWS facilities can reduce the fossil-carbon content of waste sent for incineration: in our analysis, the composition of plastics in LMW – assumed to be 14% - drops after LMWS to 7% of the residual waste. The non-fossil fractions experience the opposite effect, increasing their share in the overall composition from 53% of LMW to 58% of residual waste. The ratio of fossil carbon: non-fossil carbon content is likely to have moved from close to 50:50 to something of the order 33:67. Including, as Denmark has done, a component of an incineration tax to the fossil-carbon content makes sense, and would drive the use of LMWS prior to incineration in the same way as a tax differential could drive the stabilisation of waste prior to landfilling. Given that the inclusion of incineration in the EU-ETS is now a distinct possibility, and that some countries have already elected to include it voluntarily, then this option might also achieve the same objective through a different route.

Landfill Restrictions

As well as varying rates of landfill tax, across the EU, a range of different restrictions, or bans, have been implemented on wastes that might otherwise have been landfilled. A summary of these is given in Table 16 below.

Table 16: Landfill Restrictions in Place in EU Member States

Member State	Restriction
Austria	No waste with TOC > 5% with exceptions for: - mechanical-biological treatment waste with a calorific value < 6600 kJ/kg dry substance - mechanically treated waste with a calorific value < 6600 kJ/kg dry substance and TOC < 8%
Belgium	Flanders - Since 1998, no separately collected waste. - Since 2000, no combustible waste (TOC > 6% and LOI > 10%). - Since 2007, no biodegradable waste. Wallonia - Since 2004, no combustible waste (TOC > 6%) - Since 2007, no biodegradable waste.
Denmark	Since 1997, no recycling and combustible waste (3% TOC in 2011).
Estonia	No untreated waste since 2004 and unsorted MSW since 2008
Finland	No organic waste (TOC > 15 %) in application since 1st January 2016. The restriction was altered to TOC > 10% as of 1st January 2020.
France	No untreated waste since 2002 No source separated waste collected for recycling. No waste from municipalities which do not have source separation schemes.
Germany	Administrative regulation (TASi) introduced in 1993 on untreated waste with TOC > 3 %, full implementation since 1.6.2005. There are exceptions for: - mechanical-biological treated waste with a calorific value < 6600 kJ/kg - mechanically treated waste with a calorific value < 6600 kJ/kg and TOC < 8%

Member State	Restriction
Hungary	Since 2002 no untreated waste.
Ireland	Exemption from levy for waste which displays a proven respiration activity after four days (AT4) of (A) less than 10mgO_2/g dry matter, or equivalent until 1 January 2016; and (B) less than 7 mg O_2/g dry matter thereafter.
Lithuania	Since 1.1.2013, no untreated municipal waste.
Luxembourg	No untreated MSW and organic waste (TOC > 5%).
Netherlands	Restriction since 1995 on 35 waste streams, including combustible and biodegradable waste (TOC > 5%). As of 2018, it covers over 60 streams.
Poland	Since 1.1.2016, no combustible waste with > 5 % TOC, >8% LOI, Calorific value > 6MJ/kg
Slovenia	Since 2011, no waste with a calorific value > 6 MJ/kg of dry matter, TOC > 5% (18% by weight), AT4 > 10mg O_2/g dry matter. This restriction also includes mixed municipal waste and separately collected waste.
Spain	No national restriction, but some regions have implemented restrictions on biodegradable or non-treated waste
Sweden	Since 2002, no sorted combustible waste. Since 2005, no organic waste.

Source: adapted from Cewep (2021): note we have removed those which follow directly from transposition of the Landfill Directive, or which are applicable to e.g. separately collected waste streams, or which apply to wastes which are not of a 'municipal-type' of waste.

More than 20 years ago, some of the first restrictions were introduced in Austria and Denmark.[19] Both Germany and Austria included, alongside requirements for waste to be biologically stabilised prior to landfilling, restrictions in relation to the calorific value of what could be landfilled. This effectively guaranteed the splitting of a light, over-size, high calorific fraction at MBT facilities wherever any of the output was destined for landfill. For plastics in particular, it became important to landfill as little as possible, the result being that they would be sent either to incineration facilities or to cement kilns. The effect of this is to channel fossil carbon, as far as possible, to combustion, rather than allowing the fossil carbon to be sequestered in a landfill (or better still, separated for recycling). That line of thinking, whatever its merits may have been at the time, now seems outdated.

In Italy, a similar restriction was adopted in past years, though its entry into force was repeatedly postponed at the end of each of a number of successive years. The restriction was subsequently cancelled before it ever entered into force. Its withdrawal was included in the "Ancillary Environmental Provisions" – Collegato

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[19] See Eunomia (2010) *Landfill Bans: Feasibility Research, Appendices to Final Report*, Report EVA130for WRAP, for a brief review.

Ambientale - annexed to the yearly Economic/financial Act – Legge di Stabilità).[20] It is somewhat surprising that as a review of Table 16 shows, a number of Member States, such as Poland and Slovenia, have introduced such restrictions more recently. It might be easier to understand these restrictions on calorific value if the intention was to channel plastics towards recycling, but this has not been the effect: a requirement for all LMW from municipal waste to be sent to suitably equipped LMWS facilities prior to any further recovery or disposal operation would be more effective in achieving this. Some other restrictions (for example, those based on LOI (loss on ignition) tests) may be viewed critically for similar reasons.

Jurisdictions that have understood the climate change impacts of incineration know that if they are to minimise their contribution to global temperature increase, then they need to reduce fossil-derived CO_2 emissions, and do so urgently. The fact that so many of these restrictions were introduced in response to a well-intended, but poorly drafted, Directive on Landfill is a matter of some regret. It was partly (though not only) for these reasons that we indicated, in a previous report for Zero Waste Europe, to cease the argument regarding the supposed superiority of incineration over landfilling by:[21]

- Removing the R1 criterion;
- Ensuring that the practice of sending waste to landfill that has not been (biologically) stabilised is eliminated;
- Removing the landfill restriction in Article 5(5) of the Landfill Directive; and
- Requiring implementation of LMWS prior to landfilling or incineration.

These are not necessary for the removal of counterproductive restrictions, based on calorific value, on what can or cannot be landfilled: they would, however, remove the impetus for all such restrictions that comes, or is perceived to come (there is no requirement in EU legislation to restrict landfilling on the basis of calorific value) from the EU level (even if they are not actually then repealed by Member States). This would allow facilities to be sensibly specified to optimise performance with regard to cost and environmental performance, taking into account the prevailing market situations for various outputs, as well as the cost of landfilling.

Inert Materials

At various points above, we have discussed the matter of removing inert materials (or not) from the amount of waste destined for landfilling. The inclination to do this will be linked to the ability of the operator to find suitable uses for the material concerned, and the way those are regulated. The climate change benefits of such 'beneficial uses' as might be available are likely to be small, but the potential savings on the costs of landfilling may be significant.

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[20] LEGGE 28 dicembre 2015, n. 221: *Disposizioni in materia ambientale per promuovere misure di green economy e per il contenimento dell'usoeccessivo di risorse naturali* (G.U. n. 13 del 18 gennaio 2016).

[21] Equanimator (2021) *Rethinking the EU Landfill Target*, Report for Zero Waste Europe, October 2021, zerowasteeurope.eu/library/rethinking-the-eu-landfill-target.

In principle, subject to meeting relevant standards and reflecting a proportionately precautionary approach, there may be potential for making use of inert materials:

- Where sufficiently well-treated, for recycling, such as is possible for glass;[22]
- Where sufficiently well-treated, for beneficial use/recovery in construction applications;
- Where appropriate, and where their use replaces the use of other materials, in (landfill) site engineering, or in activities in relation to landfill cover.

A further option might be landfilling at sites permitted to receive inert wastes only, subject to acceptance criteria being met.

These applications will require different treatments to achieve the necessary quality standards, and for those uses linked to landfills, liability for fees and taxes would need to be considered.

Stabilised Residual Waste

The EU Directive on Waste seeks to ensure that the waste hierarchy is applied, and to that end, Article 2291) requires 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' (subject to Articles 10(2) and (3)).

Article 22(3) states

> *By 31 December 2018, the Commission shall request the European standardisation organisations to develop European standards for bio-waste entering organic recycling processes, for compost and for digestate, based on best available practices.*

We are not aware of this having taken place (or being underway).

In some circumstances in the EU, the shortage of organic matter in soils is posing problems. There are circumstances where the treated organic fraction of residual waste is being spread on land, including on agricultural land (often, for example, in viticulture, or wine growing). There might be reasons to be concerned about such developments should repeated applications lead to a build up of potentially toxic elements in soil, and should agricultural crops take up some of those elements and enter the food chain (different crops are known to take up different elements to varying degrees). It is for that reason that precautionary standards for high-quality compost are typically set with due attention paid to the potential for such build up, and by establishing limit values for potentially problematic elements in materials to be applied to land.

Notwithstanding these issues – which are of primary concern in the context of agricultural crops intended for human (or animal) consumption – there may be good reasons to allow restricted, periodic application of

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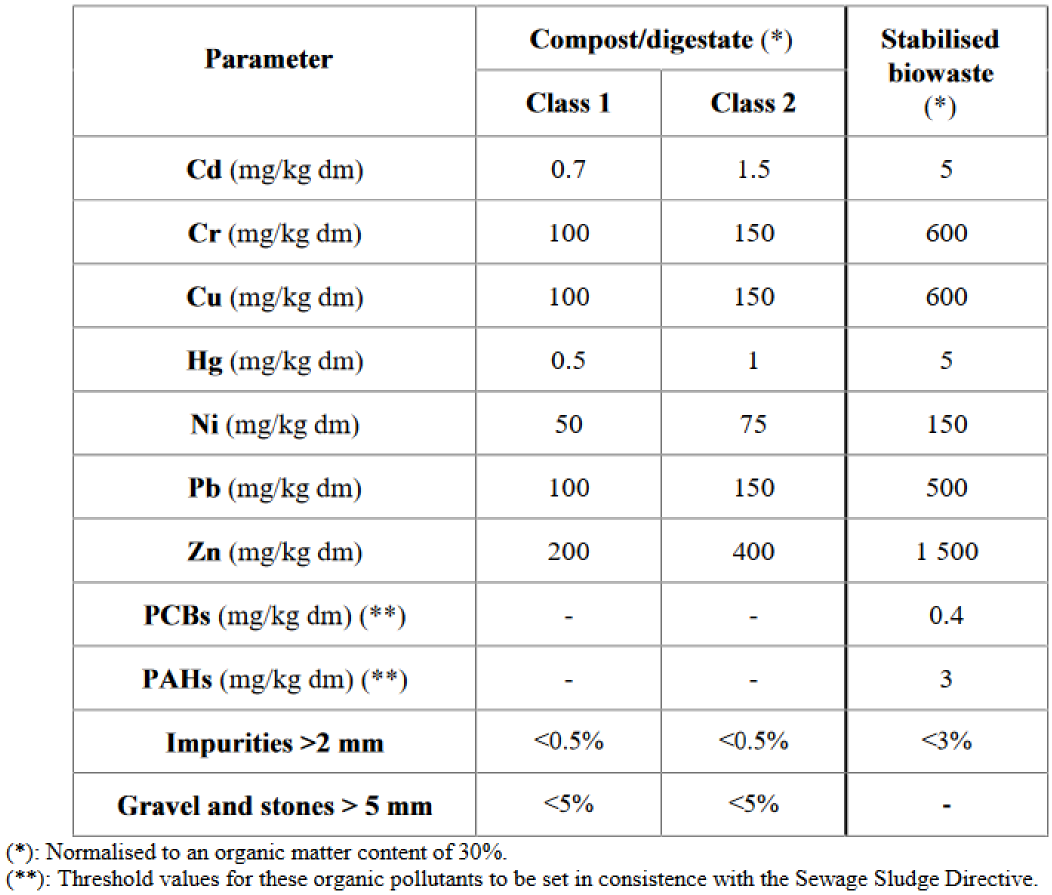
[22] See, for example, Połomka J, Jędrczak A, Myszograj S. (2020) Recovery of Stabilizer Glass in Innovative MBT Installation—An Analysis of New Technological Procedure, Materials (Basel). 2020 Mar 17;13(6):1356.

material to land, notably where addition of further organic matter would be desirable, and always subject to some precautionary limits still being applied.

Perhaps with this in mind, the 2nd Draft Working Document of the Biological Treatment of Waste, as it had been prepared up until its withdrawal (partly because, at the time, the requirement for separate collection of biowaste was deemed to be 'a step too far'), envisaged 2 Classes of compost/digestate (Class 1 and 2), and a separate standard for 'Stabilised Biowaste' (see Table 17). According to the Working Document:

> *Compost or digestate of class 1 shall be used according to best agronomic practice without any specific restriction. Compost or digestate of class 2 shall be used in a quantity not exceeding 30 tonnes dry matter per hectare on a three-year average.*

Table 17: Limit values set out in 2nd Draft Working Document on the Biological Treatment of Biowaste (12 February 2001)



Parameter	**Compost/digestate** (*)		**Stabilised biowaste** (*)
	Class 1	**Class 2**	
Cd (mg/kg dm)	0.7	1.5	5
Cr (mg/kg dm)	100	150	600
Cu (mg/kg dm)	100	150	600
Hg (mg/kg dm)	0.5	1	5
Ni (mg/kg dm)	50	75	150
Pb (mg/kg dm)	100	150	500
Zn (mg/kg dm)	200	400	1 500
PCBs (mg/kg dm) (**)	-	-	0.4
PAHs (mg/kg dm) (**)	-	-	3
Impurities >2 mm	<0.5%	<0.5%	<3%
Gravel and stones > 5 mm	<5%	<5%	-

(*): Normalised to an organic matter content of 30%.
(**): Threshold values for these organic pollutants to be set in consistence with the Sewage Sludge Directive.

Source: European Commission (2001) 2nd Draft Working Document on the Biological Treatment of Biowaste, 12 February 2001.

Stabilised Biowaste, on the other hand, could only be used:

> *'as a component in artificial soils or in those land applications that are not destined to food and fodder crop production [such as final landfill cover with a view to restoring the landscape, landscape restoration in old and disused quarries and mines, anti-noise barriers, road construction, golf courses, ski slopes, football pitches and the likes].*
>
> *For spreading on land or in areas likely to be in direct contact with the general public, stabilised biowaste shall also fulfil the sanitation requirements laid down in Annex II.*
>
> *The use of stabilised biowaste shall be allowed on condition of not being repeated on the same areas for at least 10 years and for a total quantity not exceeding 200 tonnes of dry matter per hectare.'*

There are arguments for implementing a similar regime today. Such material could not be counted towards recycling and composting targets: to do so would not be aligned with Article 11a (Rules on the calculation of the attainment of the targets), and especially 11a(4), which states:

> *As from 1 January 2027, Member States may count municipal bio-waste entering aerobic or anaerobic treatment as recycled only if, in accordance with Article 22, it has been separately collected or separated at source.*

Implementing the above approach would have the merit of establishing a clear delineation between what could, and could not count towards recycling and composting targets, whilst also recognising that there may be value in making use of organic matter derived from MRBT processes, subject to the precautionary limits in Table 17 (and others which might be deemed relevant) being met, and only in clearly delineated circumstances (and not in others), and with restrictions on application rates in place.

To the extent that this was deemed of interest, it would be a complement to the interest in extracting inert materials for recycling: the standard for Stabilised Biowaste could not be met without mechanically sorting out impurities, and refining the output from the process to achieve the agreed standards.

Zero Waste Europe is the European network of communities, local leaders, experts, and change agents working towards the elimination of waste in our society. We advocate for sustainable systems and the redesign of our relationship with resources, to accelerate a just transition towards zero waste for the benefit of people and the planet.

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ZERO WASTE EUROPE

Authors: Dominic Hogg (Equanimator Ltd) and Dinkar Suri
Editors: Janek Vahk, Enzo Favoino, Ana Oliveira (Zero Waste Europe)
Date: April 2023

General information: hello@zerowasteeurope.eu
Media: news@zerowasteeurope.eu
Cities-related topics: cities@zerowasteeurope.eu

zerowasteeurope.eu
www.zerowastecities.eu
www.missionzeroacademy.eu