Nothing left behind:

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

Executive Summary
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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:

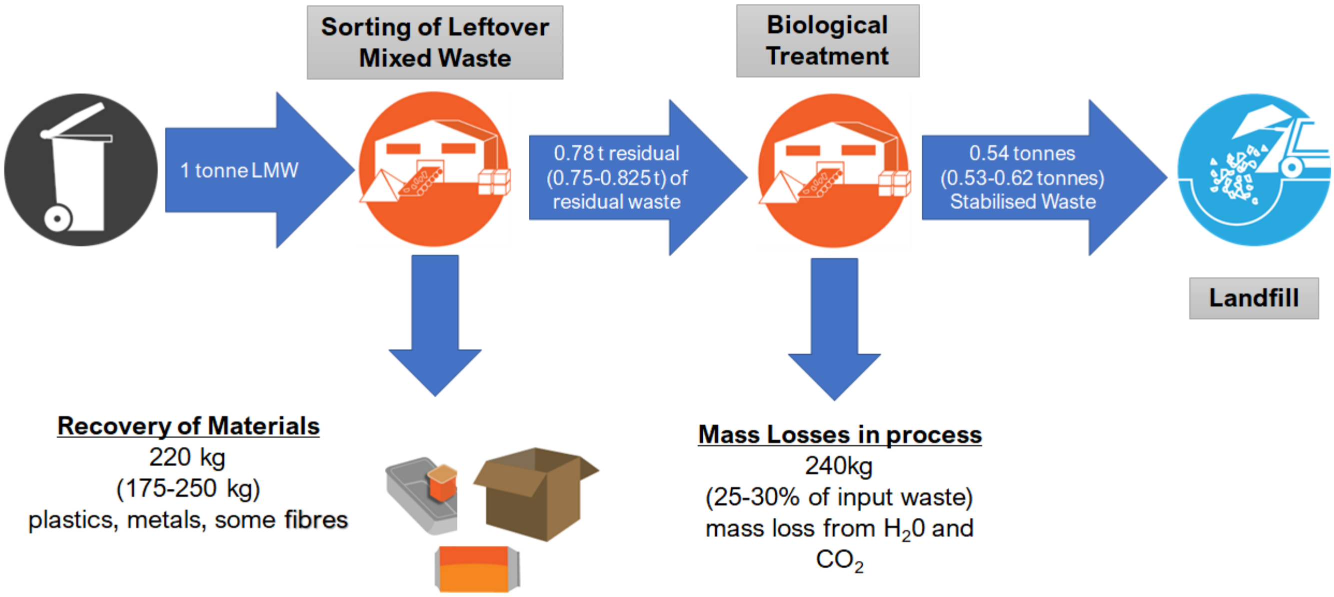
- Sort, from LMW, materials for which there are functioning recycling markets today, and some for which markets are in development;
- Incorporate an aerobic biological treatment step aimed at biologically stabilising the output from the sorting plant such that when landfilled at suitably operated sites, 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;

[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.

[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.

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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