Medworth Energy from Waste
Combined Heat and Power Facility

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1. Introduction

1.1 Overview of the Proposed Development

1.1.1 Medworth CHP Limited (the Applicant) is applying to the Secretary of State (SoS) for a Development Consent Order (DCO) to construct operate and maintain an Energy from Waste (EfW) Combined Heat and Power (CHP) Facility on the industrial estate, Algores Way, Wisbech, Cambridgeshire. Together with associated Grid Connection, CHP Connection, Access Improvements, Water Connections, and Temporary Construction Compound (TCC), these works are the Proposed Development.

1.1.2 The Proposed Development will recover useful energy in the form of electricity and steam from 625,600 tonnes of non-recyclable (residual), non-hazardous Municipal and Commercial and Industrial waste each year. Generating over 50 megawatts, the electricity will be exported to the grid. The EfW CHP Facility will have the capability to export steam and electricity to users on the surrounding industrial estate.

1.1.3 The Proposed Development is a Nationally Significant Infrastructure Project (NSIP) under Part 3 Section 14 of the Planning Act 2008 (hereafter referred to as the '2008 Act') by virtue of the fact that the generating station is located in England and has a generating capacity of over 50 megawatts (see section 15(2) of the 2008 Act). It, therefore, requires an application to be submitted for a DCO.

1.2 The Applicant

Background

1.2.1 The Applicant is a wholly owned subsidiary of MVV Environment Limited (MVV). MVV is part of the MVV Energie AG group of companies. MVV Energie AG is one of Germany's leading energy companies, employing approx. 6,500 people with assets of around €5 billion and annual sales of around €4.1 billion. The Proposed Development represents an investment of approximately £450m.

1.2.2 The company has over 50-years' experience in constructing, operating, and maintaining EfW CHP facilities in Germany and the UK. MVV Energie's portfolio includes a 700,000 tonnes per annum residual EfW CHP facility in Mannheim, Germany.

1.2.3 MVV Energie has a growth strategy to be carbon neutral by 2040 and thereafter carbon negative, i.e., climate positive. Specifically, MVV Energie intends to:

- reduce its direct carbon dioxide (CO_2) emissions by over 80% by 2030 compared to 2018;

- reduce its indirect CO_2 emissions by 82% compared to 2018;
- be climate neutral by 2040; and
- be climate positive from 2040.

1.2.4 MVV's UK business retains the overall group ethos of 'belonging' to the communities it serves whilst benefitting from over 50 years' experience gained by its German sister companies.

UK Facilities

1.2.5 MVV's largest project in the UK is the Devonport EfW CHP Facility in Plymouth. Since 2015, this modern and efficient facility has been using around 265,000 tonnes of municipal, commercial and industrial residual waste per year to generate electricity and heat, notably for Her Majesty's Naval Base Devonport in Plymouth, and exporting electricity to the grid.

1.2.6 In Dundee, MVV has taken over the existing Baldovie EfW Facility and has developed a new, modern facility alongside the existing facility. Operating from 2021, it uses up to 220,000 tonnes of municipal, commercial and industrial waste each year as fuel for the generation of usable energy.

1.2.7 Biomass is another key focus of MVV's activities in the UK market. The biomass power plant at Ridham Dock, Kent, uses up to 195,000 tonnes of waste and non-recyclable wood per year to generate green electricity and is capable of exporting heat.

Research and Development

1.2.8 MVV research the waste treatment market, and as new technologies emerge, review these to understand their suitability. MVV's research includes developments in Germany and the UK, and alternatives to combustion, such as gasification and pyrolysis, collectively referred to as Advanced Thermal Treatment (ATT). MVV's research, as demonstrated by third party experience, confirms that ATT of residual waste at the scale of, and with mixed residual wastes of the type envisaged by the Proposed Development, are not deliverable solutions.

1.2.9 Other technologies not involving thermal treatment, such as anaerobic digestion, and Mechanical and Biological Treatment (MBT), have also been researched by MVV. Most recently, MVV examined a system using enzymes to treat residual waste, but on assessment and following a site visit, it was concluded this system would not work on a commercial basis.

1.2.10 In reality, most technologies evolve slowly and take many years to scale up from pilot to commercial scale plants. Where full scale plants using new technologies have been built in the UK, the majority fail to be an effective residual waste treatment process, are unreliable and consequently not commercially viable, therefore close down.

Conventional EfW

1.2.11 Used in Europe for over 60 years, conventional EfW is a proven, reliable and a commercially scalable technology for the treatment of residual waste. Conventional EfW continues to be MVV's selected technology.

1.2.12 Conventional EfW is waste combustion of residual waste in a grate furnace chamber with heat recovery in the subsequent steam boiler. The recovered heat in the form of steam is used for power generation and/or replacing fossil fuel for heat supply in industrial processes or to commercial and residential properties.

1.2.13 In conventional EfW facilities, residual waste is used as a fuel, but does not have defined fuel specification in terms of composition, water content, ash content, size and contaminations. Therefore, a robust and flexible technology is needed to cope with any changes of the waste characteristics either short term, seasonal or long term over a facility's lifetime.

1.2.14 The furnaces in conventional EfW facilities have a robust design to cope with physical and chemical impacts of waste and potential contamination including, inter alia, gas and aerosol cylinders explosions or residues of bleach and acids.

1.2.15 The control systems in conventional EfW facilities are also designed to quickly respond to the combustion conditions (combustion time and oxygen supply) required by changing waste characteristics to allow for a complete combustion process, thus converting the residual waste into an inert ash which can be used as a secondary aggregate; the Incinerator Bottom Ash (IBA).

1.2.16 Whilst much older EfW facilities released the flue gas without very effective flue gas cleaning, with the introduction of abatement systems in the early 1990s, nowadays a comprehensive, monitored and controlled multi-stage flue gas cleaning system forms a major part of all conventional state-of-the-art EfW facilities.

1.2.17 Today, the flue gas released through the chimneys of conventional EfW facilities mainly comprises, in addition to naturally occurring nitrogen and oxygen, non-toxic carbon dioxide and water vapour. The thresholds for solid particles and gases such as carbon monoxide, nitrogen oxide, acid gases, heavy metals, dioxins and furans are set (the Emission Limit Values (ELV)) and monitored by the Environment Agency through the Environmental Permit system.

1.2.18 For many decades there have been several hundred conventional EfW facilities in operation in Europe and in the UK (approximately 60[1]), all having shown that conventional EfW facilities are a proven and robust technology with high availability for reducing landfilling (with its associated long term environmental impact) and for generating electricity and heat out of the waste.

1.2.19 These facilities are run by competent operators according to their environmental permits. Conventional EfW facilities are readily financed by a

[1] Tolvik UK Energy from Waste Statistics - 2022

variety of methods. In accordance with the waste hierarchy[2] conventional EfWs have displaced landfill as the end solution for residual waste and added to the energy security of their host countries, but not impacted on recycling levels.

1.3 Purpose of this document

1.3.1 This document summarises the development status of alternative waste treatment technologies in the UK, demonstrates why these are not suitable for residual waste, and affirms why the Applicant continues to select conventional EfW technology as the best form of treatment.

1.4 Structure of this document

- Section 1 – Introduction
- Section 2 – Alternative Technologies
- Section 3 – Conclusion

[2] Guidance on applying the Waste Hierarchy, Defra (June 2011)

2. Alternative technologies

2.1 Introduction

2.1.1 Residual Waste cannot be classified as fuel with a defined specification since the composition changes over the seasons and years depending on consumer behaviour and the implemented waste collection system.

2.1.2 Residual Waste mainly consist of the elements carbon and hydrogen and has a calorific value similar to lignite coal. The idea of using waste as a fuel or converting waste into a synthetic fuel (syngas) is not new and has been investigated over many decades.

2.2 Pyrolysis and gasification

2.2.1 Pyrolysis and gasification processes are, in the context of the UK's waste management industry, labelled as ATT.

2.2.2 Pyrolysis is a thermal treatment process similar to smouldering whereby the waste is heated without the addition of oxygen. It is used, for example, to manufacture charcoal from wood. The temperature increase results in cracking of the combustible waste solid hydro-carbon fractions into the volatile hydrocarbon gases H_2 and C_xH_y, liquid hydrocarbon oils and solid char, all of which can be used as fuel.

2.2.3 Gasification is a thermal treatment process whereby a limited amount of oxygen is added to the process but not sufficient to allow for complete combustion. As a result, the combustible waste fraction is converted into the volatile gases CO, H_2 and CH_4. For example, gasification was used to produce town gas out of coal before it was replaced with natural gas in the 1960s and 1970s.

2.2.4 In combustion, sufficient (excess) oxygen is added to the process to allow complete oxidation of all combustible hydrocarbon elements to CO_2 and H_2O.

2.2.5 Pyrolysis and gasification are considered as more efficient technologies but are complex and sensitive compared to combustion and, therefore, require defined conditions (notably a consistent fuel specification) to work properly.

2.2.6 Pyrolysis and gasification often require a specified temperature and pressure range to work efficiently.

2.3 Mechanical and Biological Treatment

2.3.1 Mechanical and Biological Treatment (MBT) of residual waste is considered as a non-thermal alternative to thermal treatment processes. The aim of MBT is to separate the waste into several fractions to further recover some of recyclable fractions, such as metals, glass and organic matter.

2.3.2 The organic fraction can be used for composting (with no energy recovery) or anaerobic digestion (with some energy recovery). Non-recyclable fractions can replace fossil fuel for combustion processes, e.g., in cement factories or require further thermal treatment e.g., at an EfW facility.

2.3.3 However, the so-called recyclable fractions from MBT facilities are often contaminated which makes it difficult or unsuitable to find a market for further use, and therefore sometimes end up being landfilled or treated in conventional EfW facilities. An example of this is the Waterbeach MBT Facility in Cambridgeshire, see **Section 2.6**.

2.4 ATT Development Status

2.4.1 Several European process and combustion manufacturing companies set up pilot facilities to generate a synthetic fuel from residual waste by means of gasification, pyrolysis or a combination of thermal treatment technologies in the 1990s and 2000s.

2.4.2 A comprehensive report about the technology and development status of ATTs has been carried out for the German Government by the RWTH University Aachen in 2015[3].

2.4.3 The report points out that ATTs do not work without pre-treatment *and "in conclusion, it can be stated that alternative thermal processes are only operable and economically viable when the following requirements or conditions apply:*

- *Compliance with legal requirements (e.g. melting processes Japan)*
- *Attainment of special product properties (e.g. vitrified slag, low pollutant content)*
- *Treatment of special fractions (e.g. highly toxic or chloride containing materials, fractions with low calorific value)*
- *Operation of pre-treatment facilities to substitute fossil fuels (e.g. in power generation, cement and lime plants)*

Hence, waste incineration is still state of the art to treat mixed municipal waste. None of the alternative processes has proved to be comparable in performance and flexibility. There are no alternative thermal processes available which are capable to compete with waste incineration considering both economic and ecological aspects. Because of their higher complexity, it is currently not to be expected that alternative methods can bridge this gap. In principle, treatment of mixed municipal solid waste should be reserved to established incineration processes, de-signed [sic] *and well-tried for this purpose."*

[3] RWTH University Aachen, Project No. Z 6 –30 345/18 Report No. 29217, Status of Alternative Techniques for Thermal Waste Treatment (2015)

2.4.4 Another comprehensive report about the technology and development status of ATTs has been carried out for the former Department of Business Energy and Industrial Strategy (now the Department for Energy Security and Net Zero) by the technical consultants AECOM and Fichtner Consulting Engineers in 2021[4].

2.4.5 This report (Advanced Gasification Technologies - Review and Benchmarking Summary report) has similar conclusions:

"The term advanced gasification technologies (AGTs) is used to refer to thermal conversion technologies (gasification or pyrolysis) for conversion of biomass or waste into aviation fuel, diesel, hydrogen, methane and other hydrocarbons.

As outlined in the Task 2 report, none of the AGT technologies reviewed are in commercial operation. For most of the systems investigated, parts of the process have been tested but the complete system has not been integrated and demonstrated at commercial scale. Where all components have been integrated, these plants are being operated as demonstrators with the aim of validating predicted plant performance.

Several pyrolysis systems are in commercial operation, but these are small modular plants which do not have the capacity for large scale production.

In the last 20 years, more than 30 gasification projects using waste or biomass have been developed in the UK, with assistance from a variety of government support mechanisms. All these projects were intended to produce electricity. However, many of these projects have never been successfully commissioned, did not perform in line with initial expectations, or only operated for a limited period of time.

While the specific circumstances of individual projects differ, a number of common themes have been identified that led to the difficulties experienced, including:

- *Delivery of projects by contractors with limited experience in complex process plant*
- *Commercial pressures on projects leading to a lack of robustness in plant design and auxiliary systems*
- *Underestimating the impact of feedstock variability on reliable plants operation*
- *Underestimating the complexities of significant scale-up of existing technologies*
- *Development of projects based on support mechanisms that incentivised projects that may otherwise have not had a favourable business case*

[4] Advanced Gasification Technologies - Review and Benchmarking Summary report BEIS Research Paper Number 2021/038 (2021)

Many of the barriers to deployment faced by AGTs could be overcome with further time and financial investment. However, due to the number, nature and magnitude of barriers identified there is considerable uncertainty in relation to the achievability of successfully deploying multiple large scale AGTs in the UK by 2035, as discussed with BEIS during this assignment. Furthermore, some of the barriers identified have potentially fundamental implications to the long-term viability of some, or all, of the AGT configurations considered.

Ultimately, the development pathway for AGTs will depend on several factors including the cost of products, CO2 savings achievable, technology risk of AGTs, competition from other technologies and support mechanisms available".

2.4.6 The Tolvik report[1] identifies the availability of ATT facilities is much lower than conventional EfW facilities, which results in increased landfilling as the waste continues to be generated but cannot treated at the ATT facilities; a reliable and continuous waste treatment facility is required.

"For those EfWs which were operational for the whole of 2022, the weighted average availability based on waste combustion hours was 87.7% (2021: 88.6%). The simple average turbine availability was identical at 87.7% (2021: 84.0%) – the first time turbine availability has been at least as great as waste combustion availability. This enhanced turbine availability helped contribute to the higher average net power export.

For the six reporting ACT facilities, the average availability during 2022 was 58.3% (2021: 48.5%) with a high of 81.6%. Excluding these ACT facilities, the weighted average availability for waste combustion at "conventional" EfWs during the year was 89.4% (2021: 90.6%)."

2.4.7 Based on the failing experience of ATT operation, several residual waste treatment projects in the UK originally consented with ATT technologies have changed their planning consents and Environmental Permits to accommodate conventional EfW.

2.5 Failed ATT facilities in the UK

2.5.1 **Table 2.1** lists ATT facilities in the UK which have failed or have been commercially substandard. **Table 2.2** list projects that were initially consented as gasification but were subsequently re-consented to conventional EfW in order to be able to secure finance.

Table 2.1 Failed ATT facilities in the UK

Site*	Technology	Status/comment
Sinfin Gasification, Derby	Residual waste gasification	Mothballed, facility failed to meet contractual performance tests and was taken over by the local

Site*	Technology	Status/comment
		authorities. The facility is mothballed pending a potential sale to a commercial partner, see **Annex A**.
Swindon waste wood, Park Grounds landfill	Waste wood pyrolysis	Shut down, failed to meet contractual performance tests. The facility is due to be demolished following termination of lease.
Swindon SRF	Residual waste solid recovered fuel conversion	Closed by local authority due to lack of commercial competitiveness. Decommissioned and demolished, see **Annex B**.
Hoddesdon ATT	Residual waste gasification	Mothballed, failed to meet contractual performance tests. The facility is now mothballed pending the owner considering options, see **Annex C**.
Air Products, Billingham, Teesside	Residual waste gasification	Failed to work; shut down, see **Annex D**.
Avonmouth ATT	Residual waste gasification	The facility failed to meet contractual performance tests therefore shut down; currently mothballed, see **Annex E**.
Canford Syngas	Residual waste gasification	The facility was designed to treat 100,000tpa of RDF as multi-line facility. The construction was stopped after the first line (20,000tpa) could not meet the performance targets; decommissioned.

*Does not include energy from waste facilities that were initially consented to be gasification or pyrolysis that were subsequently approved to be changed to conventional combustion energy from waste.

Table 2.2 ATT projects converted to conventional EfW

Site	Status/comment
Corby, 260,000tpa residual waste EfW	Facility planned as ATT, planning application modified to conventional EfW in 2020

Site	Status/comment
Baddeslay, 130,000tpa RDF EfW	Facility planned as ATT, permit application modified to conventional EfW in 2018
Northacre, Westbury, 243,000tpa residual waste EfW	Facility planned as ATT, planning application modified to conventional EfW in 2019
Doncaster, 300,000tpa C&I waste	Facility planned as ATT in 2018, planning application modified to conventional EfW in 2022
Binn ECO Park, Glenfarg	Facility planned as ATT in 2006, planning application modified to conventional EfW in 2021
Walsall, 478,300tpa waste	Facility planned as ATT in 2016, planning application modified to conventional EfW in 2020

2.6 Failed Mechanical Biological Treatment facilities in the UK

2.6.1 Tolvik published a report on Mechanical Biological Treatment – 15 Years of UK Experience[5]. This report provides a good overview of MBT facilities in the UK and is attached as **Annex F**. The report states:

"In 2007, DEFRA identified five potential outcomes for a local authority in procuring an MBT based treatment solution. They were to increase recycling, reduce the tonnage of waste to landfill, prepare a "compost like output" ("CLO") suitable for land remediation, generate biogas and/or to prepare a Refuse Derived Fuel ("RDF") to a specification. MBT was seen by many as an alternative to energy from waste ("EfW").

DEFRA's 2007 Technology Brief specifically noted:

"Recyclables derived from the various MBT processes are typically of a lower quality than those derived from a separate household recyclate collection system and therefore have a lower potential for high value markets. The types of materials recovered from MBT processes almost always include metals (ferrous and non-ferrous) and for many systems this is the only recyclate extracted."

The Technology Brief then went on to identify the issues associated with extracting recyclables from the input Residual Waste stream specifically:

- *Glass – the opportunity to recycle glass into high value products was discounted and the Technology Brief instead identified that, subject to achieving a suitable quality material, recovered glass could find application for use as a low grade aggregate;*

[5] Briefing Report: Mechanical Biological Treatment – 15 Years of UK Experience (2017)

- *Plastics – the Technology Brief identified that the use of optical sorting technology offered the potential to recover plastic by polymer type but noted that capital costs associated with installing such technologies were high, and cost/benefits of adopting them would be significantly influenced by the effectiveness of any recycling achieved upstream through kerbside collection systems;*
- *Textiles, Paper/Card – the Technology Brief noted, if extracted, these materials extracted via MBT were unlikely to receive an income as a recyclate.*
- *"CLO or digestate from mixed waste processing will not qualify for British Standards Institute (BSI) Publicly Available Specification PAS100 and PAS110 respectively, and is unlikely to be applicable for inclusion in recycling rates/targets….. Trials on mixed waste derived materials have reported large amounts of physical contaminants (e.g. glass) and levels of potentially toxic elements above limits for the standard PAS 100…. The use of CLO produced from mixed MSW on agricultural land is currently not permitted by the EA. If an outlet cannot be found for the CLO then it may have to be disposed to landfill. This will incur a disposal cost and any remaining measured biodegradable content will affect local authority landfill diversion targets"*

In practice, other than for very specialist land remediation schemes … there is no significant markets for CLO in the UK and so MBT facilities are increasingly configured solely for RDF production.

In the mid 2000s the potential outlets for RDF produced by MBT facilities were identified as being:

Industrial intensive users for power, heat or both (Combined Heat and Power, CHP);

- *Cement kilns;*
- *Co-firing with coal at power stations;*
- *Co-firing with biomass fuels in conventional technologies;*
- *Purpose built incinerators with power or power and heat (CHP);*
- *Advanced Conversion Technologies, such as pyrolysis and gasification.*

The expectation then was that the focus would be upon UK co-incineration facilities – particularly cement kilns – and there were concerns that this was a relatively limited market in which RDF would need to compete with other fuels.

Early experience of MBT operators identified that the fuel specification requirements for cement kilns and co-firing facilities were constantly evolving and that, in practice, for an MBT to consistently produce a suitable fuel from an ever-changing local authority feedstock was challenging.

On the basis of the available evidence it is difficult not to conclude that in general for local authorities (the main customers for MBT), MBT led Residual

Waste solutions have proved to be more expensive than EfW based alternatives."

2.6.2 In Scotland, A ban to landfill biodegradable municipal waste comes into force on the 31 December 2025, consequently Zero Waste Scotland commissioned Ricardo to produce a report on the alternative residual waste treatment options[6], see **Annex G**. The Ricardo report concludes:

"The experience of MBT in Britain and in mainland Europe has been heavily focussed on processes that generate RDF. Some projects have failed, and some have had issues associated with accommodating the waste composition and changes to it.

The performance of an MBT facility contract will also be greatly influenced by available markets for outputs and the UK experience has shown that securing outlets for CLO is particularly problematic, and it is often landfilled until other opportunities arise. Furthermore, the quality of recyclable materials separated at MBT facilities can be poor and market prices highly variable."

2.6.3 The Ricardo report collected data on 20 stand-alone MBT facilities in England. The data demonstrates that the recycling rate of these facilities is low and the majority of the output streams, in some cases 90%, is sent either to landfill, incineration or both. As an example, 90% of the outputs of the Waterbeach MBT facility in Cambridgeshire are sent to landfill as quoted in Appendix A2 (page 76 to 77) of **Annex G**.

[6] Alternative Residual Waste Treatment – Biostabilisation, Report for Zero Waste Scotland, Ricardo (2022)

Graphic 2.1: Extract from the Ricardo report (page 76 to 77) – MBT facility, Waterbeach, Cambridgeshire

Alternative Residual Waste Treatment - Biostabilisation
Ref: ED 15174 | Issue number 3 | 29 October 2022

MBT facility/ fate of outputs (2019 waste return)	Type of biological process/ fate of outputs (2019 waste return)
Waterbeach MBT (Cambridgeshire)	IVC The main destination of the output from the IVC process is landfill. However, the operator (Amey) is keen to construct an energy from waste plant to prevent the landfill of the output. A planning appeal was rejected in June 2020.
Total tonnes	101,723
Incinerator	0%
Landfill	90%
Recovery	2%
Transfer	8%
Treatment	0%

2.6.4 **Table 2.3** lists MBT facilities in the UK which have failed or have been commercially substandard.

Table 2.3 Failed MBT facilities in the UK

Site*	Technology	Status/comment
Cambridgeshire MBT, Waterbeach	Residual waste mechanical biological treatment	Not working to design specification and currently at an extended outage, majority of input is landfilled, see **Annex G** and **Annex H**.
Essex MBT, Basildon, TOVI Eco Park	Residual waste mechanical biological treatment	The Facility failed to meet contractual performance tests therefore the contract was terminated by local authority. Decommissioned and due to be demolished. The local authority's waste is currently being landfilled or sent to EfW facilities, see **Annex I**.
Greater Manchester MBT, Four MBT facilities within the	Residual waste mechanical biological treatment	The facility failed to meet performance tests, therefore, the contract was terminated by the local authority; mothballed, see **Annex J**.

Site*	Technology	Status/comment
Greater Manchester area		
Merseyside MBT, Huyton	Residual waste mechanical heat treatment	The facility shut down after the end of a 3-year DEFRA support programme; mothballed. see **Annex K**.
Rotherham MBT	Residual waste mechanical biological treatment with autoclave	The operator went into administration after several technical problems including an explosion. The local authority Council terminated the contract; mothballed, see **Annex L**.
Lancashire MBT, two facilities in Thornton and Leyland	Residual waste mechanical biological treatment	The facility failed to meet contractual performance tests and was taken over by the local authorities and closed; mothballed, see **Annex M**.
Renescience, Northwich	Residual Waste treatment with enzymes, anaerobic digestion and mechanical treatment	Complex process which is not commercially viable. Company decided to sell the facility, see **Annex N.** MVV carried out a site visit in February 2023, a short report is attached, see **Annex O**.
Derwenthaugh EcoParc, Gateshead	Residual waste mechanical biological treatment with autoclave	The facility failed to meet contractual performance tests and was closed down; mothballed, see **Annex P**.

3. Conclusion

3.1.1 Key conclusions are as follows:

- Conventional EfW with grate combustion is an established proven and reliable technology to treat inhomogeneous (changing characteristics in size and composition) residual waste; MVV and consequently the Applicant’s selected technology;
- The long-term experience of EfW operations and changes to regulations led to continuous improvements of the process efficiency and the air pollution control system;
- Whilst ATTs are more complex and efficient technologies compared to combustion, they require pre-treatment of the heterogeneous residual waste;
- In the last 20-years, more than 30 gasification projects using waste or biomass have been developed in the UK, with assistance from a variety of government support mechanisms. All these projects were intended to produce electricity. However, many of these projects failed to be successfully commissioned, did not perform in line with initial expectations, or operated for a limited period of time;
- MBTs have been introduced to increase the recycling rate. In practice the heterogeneous and changing characteristics in size and composition of residual waste made it difficult to reach the intended performance targets; and
- The MBT output fractions are often contaminated and do not meet their intended performance targets. Consequently, the majority of the MBT outputs require further treatment or landfilling.

Annex A: Sinfin Letsrecycle.com press article 3 February 2023

letsrecycle.com

February 3, 2023
by James Langley

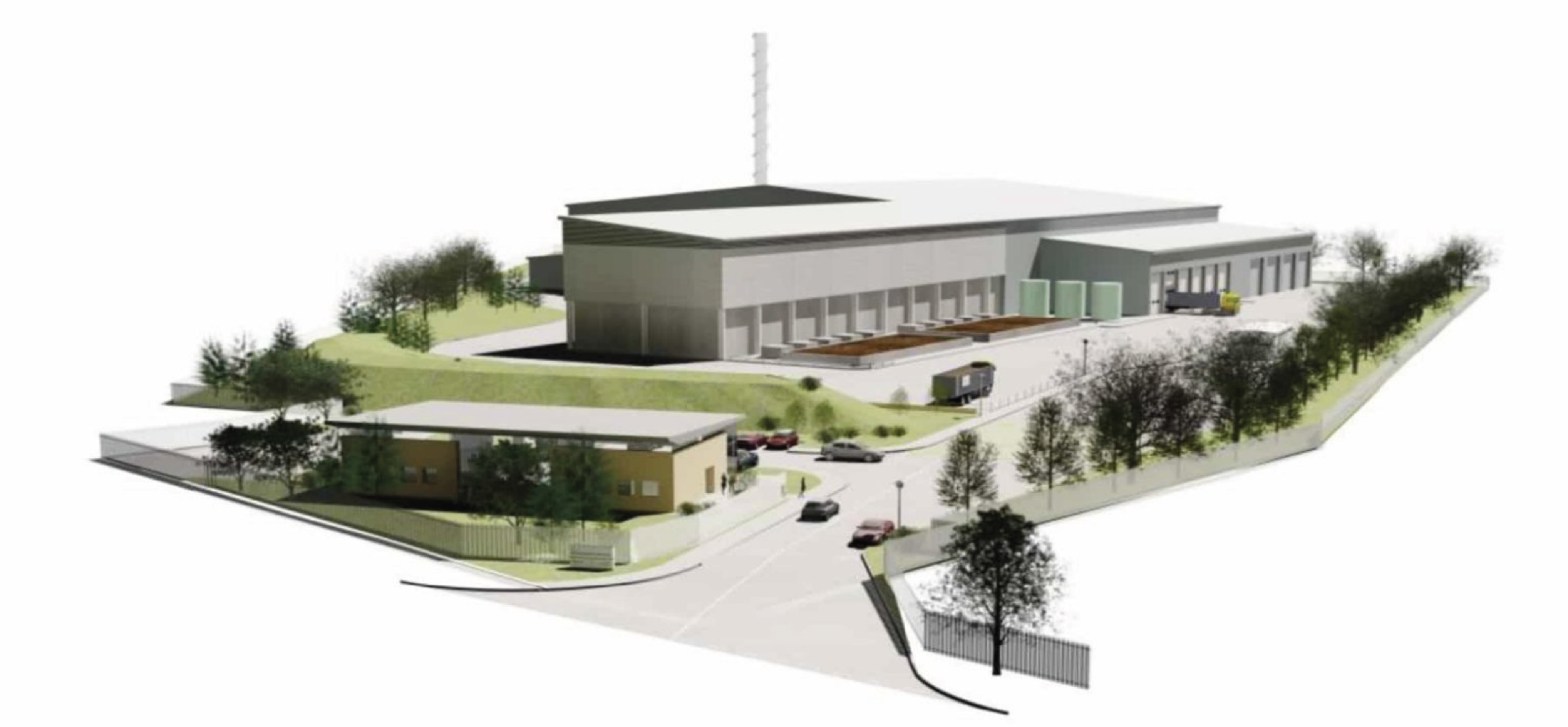
Councils

Energy

Vehicles & Plant

Derbyshire councils to repair and reopen Sinfin EfW plant

Derbyshire county and Derby city councils voted on 2 February to repair the failed Sinfin gasification plant and use it to treat residents' residual waste.



An artist's impression of the Sinfin facility, which was due to open in 2017

In 2009, Resource Recovery Solutions (RRS), a partnership between infrastructure firm Interserve and waste management company Renewi, signed a 27-year, £900 million waste treatment contract with the councils, which included running the 190,000-tonne capacity plant in Sinfin, Derby.

However, the councils brought the contract to an early end in August 2019 after problems with the plant, which included excessive odours and technical issues (see *letsrecycle.com* story).

The councils met Thursday to discuss whether they could "rectify" the plant's "defects" or whether they would have to close it and dispose of their waste using a third party.

Each decided respectively that it was "more cost-effective for Derby and Derbyshire council taxpayers" to use the plant to deal with household waste during the next two decades, according to a joint statement published on 3 February.

The councils say they will now go to the market to appoint specialist contractors to carry out the rectification work and operate the facility.

The councils also gave approval to set up a joint project board to "coordinate decision-making to help drive the project forward".

'Informed decision'

Cllr Chris Poulter, Derby city council's leader, said: "It was vital that we took the time to th could make an informed decision on the facility's future.

> The recommendation to rectify and use the facility offered the most viable,
> – Cllr Chris Poulter, leader of Derby city council

"The recommendation to rectify and use the facility offered the most viable, economic and cost-effective option and the best deal for council taxpayers in Derby and Derbyshire to provide a sustainable and long-term solution for dealing with household waste."

The councils' joint statement said rectifying the facility would give them more certainty about the future cost of dealing with household waste that residents either cannot or choose not to recycle.

Cllr Simon Spencer, Derbyshire county council's deputy leader, added: "There will always be some waste that residents either cannot or choose not to recycle and the business case shows that the waste treatment centre is still the best long-term solution – not just in terms of the cost to council tax-payers and protecting them against rising costs of dealing with waste by other means in the future, but also for the benefit to the environment and our ongoing commitment to cut carbon emissions to help tackle climate change."

Derby

Derbyshire county council had a household waste recycling rate of 45.1% in 2020/21, the latest financial year for which verified data is available, while Derby city council's rate was 36.7%.

Following the end of RRS's contract, the Sinfin plant stopped accepting waste, which the councils sent instead to energy from plants, refuse derived fuel facilities and landfills in the UK.

Renewi UK Services was then appointed to carry out a deep clean and undertake a series of condition surveys on the state of the facility to inform an appraisal into its future viability. The councils also gave Renewi a two-year 'continuity services' contract to ensure the city and county's waste continued to be disposed of.

RRS entered administration following the termination of its contract and the administrators subsequently sued the councils (see *letsrecycle.com* story).

Annex B: Swindon SRF Letsrecycle.com press article 31 January 2022

January 31, 2022
by Joshua Doherty

Councils

Vehicles & Plant

Waste Management

Viridor win will see Swindon SRF plant decommissioned

The Solid Recovered Fuel (SRF) plant run by Swindon borough council-owned Public Power Solutions (PPS) will be decommissioned, after Viridor bagged a £58 million contract to treat the council's residual waste.

The PPS plant treats 48,000 tonnes of Swindon's household, commercial and industrial waste per annum

The SRF contract was due to expire this year but the borough council had previously signalled its intention to sign a long-term residual waste treatment contract until 2045 with Public Power Solutions. Now, after putting a residual waste contract out to tender, it has been awarded to Viridor.

On Friday (28 January), *letsrecycle.com* reported Viridor's success which lead to question marks over the PPS facility, with PPS also having bid for the contract (see *letsrecycle.com* story).

A spokesperson for PPS has now said that the plant will now be decommissioned and instead the site operate as a waste transfer station. It is situated next to Swindon's household waste recycling centre.

"Whilst PPS is obviously disappointed not to have been awarded the waste disposal contract, we will work with Viridor to ensure that the transition is as smooth as possible," the PPS spokesperson said.

They added: “The SRF plant will be decommissioned and become a waste transfer station which will continue to receive Swindon’s household waste. As we are still in the contract handover stage, it would be inappropriate to comment further at this time.”

Contract

The plant was opened in 2014 by Defra minister George Eustice, who is now the environment secretary (see letsrecycle.com story).

It was constructed by Machinex, which successfully tendered for a £6 million contract to supply the custom-made sorting technology in May 2013 (see *letsrecycle.com* story).

Guests at the opening of the plant in 2014

At the time of opening, PPS said the plant — which treats 48,000 tonnes of Swindon’s household, commercial and industrial waste per annum — was estimated to bring savings of £16 million over its eight-year lifespan, with the possibility of an extension.

With the contract due to expire, PPS had said in its annual results for the 2020/21 financial year that it was “confident” it would win the new tender, and also said it was investing in a pelletisation plant.

The results explained that the company had been working with its shareholder, Swindon council, to invest in a pelletisation plant to “significantly reduce disposal costs, open up the UK market, and take the company one-step further towards energy from waste”.

However, the results said after the company had undertaken initial procurement for the pellet solution, the council “made the decision to test the market as part of their end-to-end review of the waste service….The company will be required to respond to this opportunity”.

Council

Viridor’s contract with Swindon will run for an initial eight years, with no breaks or extensions being included.

This will see the company process 55,000 tonnes of its own non-recyclable residual waste collected from the kerbside, and from its single household waste recycling centre.

A spokesperson for Swindon borough council said: “We are looking forward to working with Viridor as we continue our drive to secure value for money from our waste disposal operations. We are supporting both Viridor and PPS through the contract handover stage so it would be inappropriate to comment further at this time”.

Below is a video from PPS showing how the 2014 plant works. The council explains that waste is shredded, sorted and dried before being compacted into bales which then goes to the UK or Europe for fuel.

The council says a “significant amount” of recyclable materials such as tins, cans and glass bottles, that are put in “black wheelie bins instead of being recycled”, also get sent to the plant. The council said the plant “can remove some of this material but it cannot recycle it properly using this process”.

Annex C: Hodderdon ATT Letsrecycle.com press article 28 January 2022

Hoddesdon to shut as another waste-gasification plant fails

Luke Walsh 28 Jan 2022

UK: Facility became operational last year, but EWB understands it was never able to process the volume or variety of feedstock expected

The EfW plant, image copyright BIG

Infrastructure investor Bioenergy Infrastructure Group (BIG) is to mothball its Hoddesdon-based energy-from-waste plant in another blow for the UK's beleaguered waste-gasification sector.

EWB understands that while the plant and another EfW facility owned by BIG, Energy Works (Hull), were declared operational last May, Hoddesdon underperformed on both the quantity and quality of waste it was able to process.

When it was originally developed the plant was due to have a capacity of 10MWe and process up to 90,000 tonnes a year of refuse-derived fuel, however, EWB understands the "operational" plant did not get near to either of these.

A spokesperson for BIG confirmed to EWB: “Hoddesdon Energy Limited (HEL) has reached agreement with its contractor bringing to an end both the engineering, procurement, and construction, and operation & maintenance contracts of the EfW plant at Hoddesdon.”

The spokesperson confirmed HEL was also “evaluating several options” for the future of the facility, which will be “placed in preservation from March 2022”.

A source with knowledge of the project, who asked to not be named, said staff were told the plant will close in the next few weeks and will not reopen.

EWB further understands the cost of repairs and changes needed to get the facility up to full capacity were too great.

BIG told EWB in the summer of 2020 that the facility was back on track, with builders France-based Bouygues Energy & Services at that point “tuning the plant and working through snags” with its gasification technology.

However, since then EWB understands that the problems have persisted with the equipment not working to the expected standard and the cost of correcting the issues considered too high given there was no guarantee the problems would be fixed.

The plant started construction in 2015, with Bouygues Energies & Services winning the build contract, and was due to be operational in the first half of 2017. However, in the end it was quietly confirmed as operational four years later in 2021, when EWB checked on its progress.

The facility was initially developed by developer AssetGen Partners, before being taken over by BIG. AssetGen Partners was dissolved last year.

Back in 2015, investment fund Foresight and the then-called Green Investment Bank (GIB) backed half of the £60m (€82m) development in Hoddesdon, which was at that point set to be the UK’s first waste-gasification facility.

While facilities such as Amey’s Milton Keynes-based 93,600t/yr plant and Viridor’s Glasgow-based gasification plant have become operational, many others have struggled to do so.

Hoddesdon has sadly joined the increasing list of failures alongside Air Products, which failed to complete two waste-gasification projects in Billingham, to the north of Middlesbrough, in 2016.

And Resource Recovery Solutions (RRS), a joint venture between construction firm Interserve and waste business Renewi, has so far failed to commission a waste-gasification facility. However, plans to get the Derby EfW plant operational are continuing.

Many other projects initially developed with the intention of using gasification technology have switched to traditional grate-based systems.

One is the Northacre EfW plant, which is also part-owned by BIG. EWB first reported in March 2020 that it would not be developed with the gasification-technology it had been consented with.

Annex D: Air Products, Teesside Chronicle Live press article 27 April 2016

Teesside being revived are fading

The collapse of the Air Products' scheme at Billingham was a blow, but other firms in the sector will survive

Locator of Air Products' Tees Valley Renewable Energy Facilities

One North East firm has sidestepped a potentially damaging fallout from the collapse of a £600m energy scheme - but hopes the Teesside development will be revived are receding. Peter McCusker reports.

There was widespread joy when US industrial gases giant Air Products announced it would be investing £300m on a revolutionary way of producing electricity from waste on Teesside.

The following year, 2012, it unveiled plans to invest the same amount in a second plant, also in Billingham, with the combined operations able to produce 100MW of electricity; enough to power 50,000 homes as well as creating hundreds of jobs.

Billingham Reach.

Billingham-based Impetus, arguably one of the North's largest waste management companies, invested over £10m in a new waste transfer station on land adjoining the Air Products development site. This new facility now employs 100 people and has the capability of handling 640,000 tonnes of waste a year.

As Impetus completed its facility - the largest of its kind in Europe - it became apparent that, over the fence, the Air Products development was not progressing as planned.

And earlier this month, almost a year since it was due to open, Air Products threw in the towel saying it was withdrawing totally from the Energy from Waste (EfW) business.

Seifi Ghasemi, Air Products' chairman, president and chief executive, said: "We pushed very hard to make this new EfW technology work and I would like to thank the team who worked so diligently.

"We appreciate the hard work of our employees and contractors at the site, and certainly understand their disappointment in this decision. We are also disappointed with the outcome."

However concerns that Air Products' retreat would have a knock on impacts for Impetus have receded after it said it had secured new markets for its RDF.

Impetus, which employs almost 160 people and has annual revenues of £44m, released the following statement to Journal Energy: "The decision by Air Products is regrettable, but the decision will not have any negative impact on Impetus.

"Impetus owns the largest commercial waste transfer station in Europe, which was originally the intended manufacturer of RDF for TV1 and TV2.

"Last year, Impetus took the difficult decision to reorient its business strategy and operations away from Air Products to alternative RDF off-takers in anticipation of Air Products' decision.

"Whilst this has been a challenging transition Impetus has now fully replaced the anticipated Air Products RDF volumes and has emerged stronger from this process."

On announcing its withdrawal from the market Air Products said it would be looking for a buyer, but this now seems unlikely, at least in the short to medium term.

Last week it emerged that proposals for similar plant - using the same plasma gasification technology - have been put on hold as the Government assesses the fallout from Air Products' decision.

This is being run in conjunction with EfW firm Waste2Tricity, which also had a small role in the Air Products' Teesside project.

John Hall, managing director at Waste2tricity, told Journal Energy: "We remain committed to delivering the Bilsthorpe Energy Centre. Our partner Peel has received a letter from the Secretary of State Greg Clark, requesting comments on a recent decision by a third party organisation to exit the waste sector and plan to respond within the time frame provided."

While plasma gasification technology is proven for plants producing up to 10MW of electricity the Teesside facility was the first attempt to build at an 'industrial scale', which would have involved handling thousand of tonnes of waste every day.

A plasma gasification process deploys high-temperature electric arc furnaces to heat waste in presence of oxygen creating a syngas which can be used for generating electricity, or as a chemical feedstock.

The first sign things were not going to plan for Air Products was in November last year when 700 workers were pulled off construction of the partially-built TV2 project after a serious, but undisclosed engineering problem was found to affect TV1. The firm warned at the time that both would need a redesign.

However Air Products' board has decided that this would take too much time and money and it will now concentrate on its core industrial gases business.

The technology deployed by Air Products came from Canadian Firm AlterNRG and has been used successfully on a number of projects in Asia.

AlterNRG has not responded to a request for a statement on the situation, however an Air Products spokesperson told Journal Energy this week: "Right now our focus remains on working to optimize the cash value of our investments; We won't speculate on the future."

Annex E: Avonmouth ATT Chronicle Live press article 05 January 2017

An Avonmouth advanced thermal treatment (ATT) plant is to stay closed until 2018 as it plans a 'major redevelopment' to solve issues regarding feedstock supply.

Activity at the Avonmouth Bio Power Energy (ABPE) plant, which, in theory, is capable of producing electricity from up to 120,000 tonnes of refuse-derived fuel (RDF) a year using pyrolysis and gasification technology, has been suspended since June 2016 as its owners seek a long-term solution to under-performance.

The ACT plant (right) was designed to treat RDF created at New Earth's MBT facility (left)

Photo: New Earth Solutions

The plant was [redacted] to process RDF from its neighbouring mechanical and biological treatment (MBT) facility, with the site benefitting from 'grandfathered' double Renewable

Obligation Certificates for processing organic waste until 2033.

However, a summary in the ABPE annual report (https://beta.companieshouse.gov.uk/company/07932861/filing-history), filed in December and written by Director Nayjot Singh Dhillon, states: 'Since the initial plant implementation, the inability of New Earth Solutions MBT to constrain the supplied RDF within specification has driven development of the plant's capability to accept a wider than intended and continually variable RDF specification.' Consequently, the report says that 'whilst a number of improvements' were achieved, 'the plant has… always operated at below its targeted design point'.

These issues have led to a reduced thermal output of the plant, and therefore the plant has not met the company's expectations for the export of electricity. Attempts to increase the facility's capability, meanwhile, have resulted in increased equipment, operation and maintenance costs.

Acquisition

In an attempt to resolve the problems, the waste and energy recovery arms of New Earth were broken up, with the ownership and financing of the plant being transferred in July 2015 to Aurium Capital Markets and Macquarie Bank, alongside Syngas Products Group Ltd, which provided the technology for the plant.

This move was designed to allow the energy-from-waste facility to develop its own business strategy by keeping the supply agreement with the adjacent New Earth Solutions plant, but also source in-specification RDF from other suppliers. It also provided an injection of financing to revise the business's debt structure.

The change in ownership saw the three acquired companies (New Earth Energy West (Operations) ltd, New Earth Energy West Ltd and NEAT Contracting Ltd) and a newly incorporated entity, Avonmouth Bio Power (Operations) Ltd, change their names to Avonmouth Bio Power to reflect the new corporate branding.

'Sporadic and short-lived' improvements

While the report, which notes a total loss for the company of £13.6 million in the financial year ending March 2016, following an even greater loss of £37.8 million reported in 2015, states that following initial improvements in reducing reliance on New Earth Solutions by taking waste from other sources, a fire at the neighbouring MBT facility disrupted feedstock supply and the ‘plant’s ability to operate even close to full capacity’.

Improvements in operational performance after January 2016 were ‘sporadic and short-lived’ and so in June 2016 the board decided to suspend activity at the plant to enable a ‘major redevelopment programme’ to be undertaken. This programme, the company says, is designed to address operational problems including the potential switch of fuel supply from RDF, with the consistent supply of feedstock a key requirement.

It is anticipated that these works, plans for which are currently being implemented, will commence early this year, with operations not resuming until 2018.

New Earth’s turbulent 2016

Following the split between the waste and energy arms of the company, New Earth Solutions continued to experience troubles, and entered administration last June after a long takeover negotiation with a combined heat and power plant developer broke down.

After entering administration, New Earth Solutions went through several sales last year, first to DM Opco and then [redacted] in October.

While over 100 jobs at the company’s five UK MBT and in-vessel composting sites were saved by the initial acquisition out of administration, New Earth’s administrators, Duff & Phelps, later told investors that they were ‘unlikely’ to recover any funds and then published a report revealing that creditors were [redacted] after the sale, with ‘no hope of repayment’.

Under its new Irish ownership the company will continue to trade under the New Earth name, and Managing Director Peter Mills told *Resource* that it will be honouring all of its contracts signed before the company entered administration. New Earth manages around 450,000 tonnes of waste from both local authority and commercial customers at its sites every year.

The Avonmouth Bio Power Energy annual report is available to view on [the Companies House website. (https://beta.companieshouse.gov.uk/company/07932861/filing-history)](https://beta.companieshouse.gov.uk/company/07932861/filing-history)

An in-depth look on the state of advanced thermal technologies can be found in [redacted]

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[redacted]

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By Annie Reece | 19 June 2013 | Add a Comment

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[redacted]

New Earth partially refinances its Avonmouth ERF with Macquarie Bank (/article/new-earth-partially-refinances-its-avonmouth-erf-macquarie-bank-6639)

By [redacted] | 7 October 2014 | [redacted]

New Earth Solutions Group Ltd partially re-finances Avonmouth Energy Recovery Facility with a debt facility from Macquarie Bank.

[redacted]

New Earth bought by PandaGreen as Irish company eyes UK expansion (/article/new-earth-bought-pandagreen-irish-company-eyes-uk-expansion-11436)

By [redacted] | 18 October 2016 | [redacted]

All five of the waste treatment facilities operated by New Earth Solutions before its sale earlier this year have been acquired by PandaGreen Ltd, Ireland's largest waste management company, as it seeks to move into the UK market.

Annex F: 2017 Briefing Report: Mechanical Biological Treatment – 15 Years of UK Experience", Tolvik (2017)

2017 Briefing Report:

Mechanical Biological Treatment – 15 Years of UK Experience

September 2017

The Waste and Bioenergy Experts

Issue Number	1			
Date	07.09.17			
Author	APJ			

This report has been prepared by Tolvik Consulting Ltd on an independent basis using our knowledge of the current UK waste market and with reference inter alia to various published reports and studies and to our own in-house analysis. This knowledge has been built up over time and in the context of our prior work in the waste industry.

This report has been prepared by Tolvik Consulting Ltd with all reasonable skill, care and diligence as applicable. We do not warrant the accuracy of information provided. Whilst we have taken reasonable precautions to check the accuracy of information contained herein, the advice contained within the report is generic and we would strongly recommend that any assumptions be verified on a project specific basis. Tolvik Consulting Ltd shall not be responsible for the consequences (whether direct or indirect) of any such decisions.

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EXECUTIVE SUMMARY

- 15 years on from the signing of the first major MBT projects in the UK, and following the recent announcement of the termination of the Greater Manchester waste project, this report independently reviews the UK's experience in using Mechanical Biological Treatment ("MBT") in the treatment of Residual Waste.
- In 2007, DEFRA identified five potential outcomes for a local authority in procuring an MBT based treatment solution. They were to increase recycling, reduce the tonnage of waste to landfill, prepare a "compost like output" ("CLO") suitable for land remediation, generate biogas and/or to prepare a Refuse Derived Fuel ("RDF") to a specification. MBT was seen by many as an alternative to energy from waste ("EfW").
- A report prepared by Juniper as early as 2005 recognised that, for political reasons, MBT would have an important role to play in the UK waste management sector. Seen by many at the time as endorsing MBT as a solution, in fact the report clearly identified many of the challenges the MBT sector has since encountered.
- Based on available data, it is estimated that total Residual Waste inputs to MBT facilities in the UK in 2015/16 were circa **2.6Mt** – or around 9% of the total market. Almost all of this Residual Waste was delivered by local authorities under term contracts. The total capacity currently operational or in construction is estimated to be around **4.0Mt**.
- **Recycling** – reported recycling rates for MBT facilities currently range between 1% and 18% of all inputs, but in the majority of cases reviewed the recycling performance at MBT facilities has consistently fallen below contractual targets. This is for a number of reasons – including increasing pressure on recyclate quality (secondary materials extracted from Residual Waste are almost always more heavily contaminated than source segregated materials) and the changing composition of Residual Waste.
- **Reduced tonnage to landfill –** either by reducing mass or biodegradability. With the UK now expected to comfortably meet its 2020 Landfill Directive targets, using MBT to reduce the biodegradability of waste to landfill yields little or no commercial benefit. Using MBT to reduce the moisture content of Residual Waste prior to landfill yields some commercial benefit, but with the cost of landfill over £100/t, in this configuration MBT is costly compared with alternatives.
- **CLO for land remediation** – with tightening environmental legislation reducing potential land applications, opportunities for long term, sustainable markets for CLO have been found to be very limited and much of the CLO which is produced is now used solely for landfill restoration.
- **Biogas generation -** the average reported "load factor" (power generation divided by installed capacity) for larger MBT facilities producing biogas is just 21%. By way of reference a typical food waste Anaerobic Digestion ("AD") facility would have an average load factor of at least 70%. The low biogas yields are largely due to less food waste in the Residual Waste stream and technical issues relating to anaerobic digestion of Residual Waste.
- **RDF production** – the market for RDF (both domestic and export) has expanded rapidly in the last 5+ years. However the market for a high calorific value, refined RDF (as is generally produced by MBT facilities) is relatively limited and, as a result, for those MBTs without a contractually secure outlet, the delivered cost of RDF has risen from an expected £35-£40/t (to cement kilns) to as much as £85/t (RDF for export).
- The 2017 WRAP Gate Fee report suggested that for local authorities median MBT gate fees were £88/t – a little lower than the median gate fees for EfW. However, the WRAP report acknowledged that the integrated nature of such contracts means that it is very difficult to assess a per tonne gate fee for an MBT facility in isolation.
- This report has therefore considered the total cost of waste management for 29 Waste Disposal Authorities in England for which data was available. Whilst not necessarily the most robust

analysis, **it is unlikely to be a co-incidence that the five authorities with the most expensive total waste management cost per tonne of Residual Waste generated had primarily contracted an MBT based Residual Waste solution**. In context, only 7 of the 29 Waste Disposal Authorities were regarded as having primarily contracted an MBT based solution.

- Furthermore, using confidential data from a number of projects, a cost model was developed for a generic 120ktpa MBT facility producing RDF based on 2017 costs. This suggests a gate fee of around £125/t; with more prudent assumptions this rises to £138/t. By comparison, average gate fees for smaller new EfWs are more typically around £95/t.
- On the basis of the available evidence it is difficult not to conclude that in general for local authorities (the main customers for MBT), MBT led Residual Waste solutions have proved to be more expensive than EfW based alternatives.

1. INTRODUCTION AND CONTEXT

1.1. Background

The decision, 15 years ago, by East London Waste Authority ("ELWA") to award Shanks a long term waste contract based on the treatment of Residual Waste in a Mechanical Biological Treatment ("MBT") facility along with the signing of the 25 year MBT based contract between Biffa and Leicester City Council represented key moments in the development of MBT in the UK.

And 2017 sees the commissioning of DONG Energy's "first of a kind" 120ktpa REnescience facility in Cheshire which uses DONG's proprietary enzyme based MBT process.

Drawing from a wide range of information sources, this report independently reviews the track record of MBT in the UK since 2002, identifies some of the successes and failures and, most significantly, the key lessons learnt.

It is aimed both at those with an interest in MBT in the UK and international clients keen to learn from the UK's experience of the technology.

1.2. What is MBT?

In this report, MBT is defined as any waste treatment facility designed for the processing of untreated Residual Waste through mechanical and biological means.

It excludes Residual Waste treatment facilities which solely use mechanical processes ("Dirty MRFs") but includes facilities which incorporate autoclaves and associated treatment. It excludes In Vessel Composting and Anaerobic Digestion ("AD") facilities designed solely for the treatment of source segregated organic wastes – e.g. food waste, garden waste, industrial effluents etc.

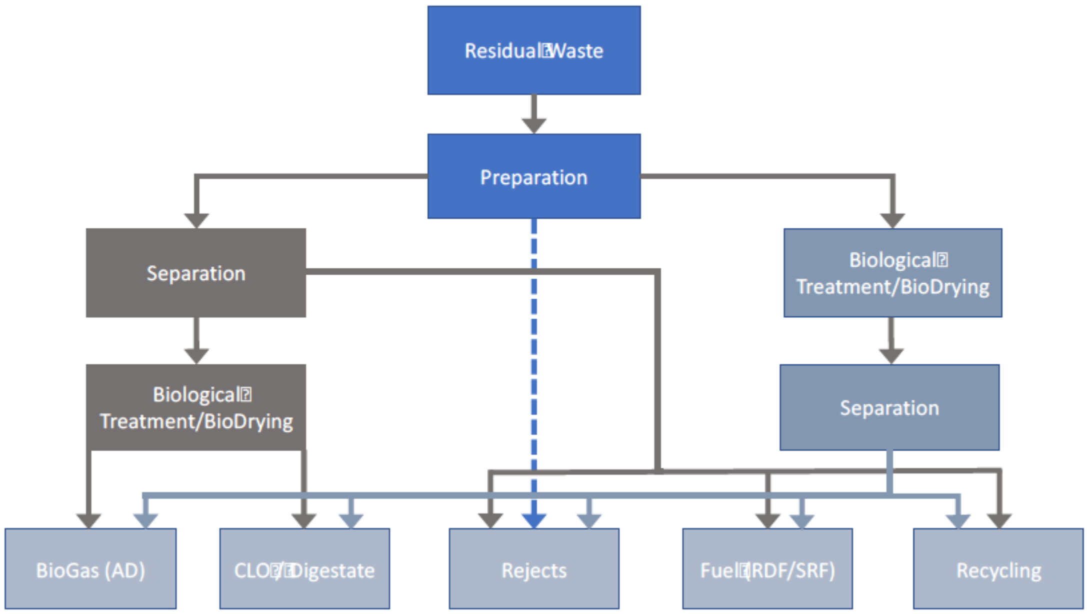

Figure 1: An Illustration of the potential MBT Options Source: DEFRA, with amends

It is generally accepted that MBT originated in Germany in response to restrictions on landfilling unprocessed Residual Waste. It was seen as an alternative to Energy from Waste ("EfW"), extracting recyclables from Residual Waste and reducing the greenhouse gas effects associated with the landfilling untreated waste.

1.3. DEFRA Waste Technology Briefs

To assist local authorities in making informed decisions to meet EU recycling and landfill diversion targets, DEFRA (UK Department for Environment, Food and Rural Affairs) produced a series of "Waste Management Technology Briefs". The first edition on MBT, issued in 2007 and subsequently updated in 2013[i] identified that "*a key advantage of MBT is that it can be configured to achieve several different aims*" with the potential to:

- **Increase Recycling** – by diverting a proportion of Residual Waste going to landfill through mechanical separation into materials for recycling;
- **Reduce Biodegradability** – (specific to EU landfill diversion targets) reduce the biodegradability and volume of Residual Waste to landfill;
- **Permit the application of waste to land** – by stabilising Residual Waste such that it could be used as compost like output ("CLO") for restoration purposes;
- **Generate Biogas** – converting the organic fraction of Residual Waste into a combustible biogas for energy recovery; and/or
- **Prepare RDF** - dry/mechanical separate Residual Waste, so producing a high calorific, fraction for use as refuse derived fuel ("RDF").

Using this as a framework, this report will review the performance of the UK MBT sector against these five target outcomes.

1.4. The Juniper Report

In 2005, prior to the DEFRA Brief, and in recognition an increasing interest in the technology, Juniper Consultancy Services released an independent, comprehensive 350+ page report entitled *"Mechanical Biological Treatment: A Guide for Decision Makers – Policies, Processes and Markets"*[ii]. The report, funded by SITA Environmental Trust, provided a comprehensive view of what then was a rapidly developing UK MBT market.

The Juniper Report covered 28 facilities in 8 countries as a snapshot of 27 technologies operating 80 operational MBT reference facilities and took over a year to compile. The report identified 12 of the 27 as "fully commercial".

Target Outcome	Selected Juniper Comments
Increase Recycling	*"With regards to recycling, MBT only provides a **modest increase** in the amount of dry recyclables"*
Reduce Biodegradability and volume to landfill	***"All of the generic process designs….will reduce the biodegradable content of the input waste**….. the extent to which is it reduced is inextricably linked to the type of output the process is designed to produce"*
Use as CLO and application to land	***"The policy framework affects the viability….of land remediation and landscaping applications**….and has significant uncertainties today at both the EU and UK level"*
Biogas generation	*"MBT configurations that focus on biogas production are often more attractive….Plastics have posed **technical challenges….which affect the performance of the digester and biogas yield…"***
Preparation of RDF	***"Cement companies will often prefer other types of waste derived fuel**…"*

Figure 2: Extracted Comments from Juniper Report – Executive Summary

As the Juniper Report noted the rationale behind the development of MBT in the UK was very clear:

"One of the prime motives for the development of MBT…….to find an alternative to incineration as a route to reducing the amount of biodegradable waste to landfill. The enthusiasm for MBT is predominantly due to a political desire to avoid the use of incineration – regardless of its merits as a proven, safe and economic approach to maximising resource recovery from waste when combined with appropriate levels of recycling."

The report also concluded *"MBT is an important option for the waste management sector."*

Figure 2 sets out the key observations within the Juniper Report with regards to the potential ability of MBT to deliver the five potential outcomes identified by DEFRA in their Technology Brief.

In reviewing the Juniper Report it is notable the extent to which the opportunities and challenges associated with MBT had been identified as early as 2005.

1.5. About Tolvik and the Author

Tolvik Consulting was set up in 2009 to provide independent market analysis and commercial due diligence to the waste and bioenergy sectors in the UK. Its customers include many of the UK's largest waste companies, project developers and a number of debt and equity investors.

Adrian Judge, the author of this report, started his career in the waste sector with Cory Environmental in 2000. One of his earliest projects in 2004 was to lead Cory's MBT based bid for a long term Residual Waste contract with Gloucestershire County Council; the procurement was subsequently abandoned.

More recently Adrian was Managing Director at the UK Green Investment Bank. There he led the bank team providing senior debt finance to the Wakefield MBT contract and in supporting a bidder in the North London Waste Authority Part A MBT based PFI contract.

This report has been subject to peer review by an individual with recent experience at developing and operating several MBT facilities in the UK.

2. THE UK MBT MARKET

2.1. MBT Capacity in the UK

With MBT being a term used to describe a wide range of different technologies and processes, MBT facilities are not restricted to a specific type of environmental permit or waste management licence. In order to identify MBT facilities, it is therefore necessary to use a range of information sources. Whilst Tolvik has taken all reasonable steps to identify all MBT facilities in the UK with a capacity greater than 25ktpa, the analysis is therefore not guaranteed to be fully comprehensive.

DEFRA maintains a list of waste infrastructure in England – its "Residual Waste Treatment Infrastructure Project List"[iii]. The December 2016 edition identifies 3.89Mt of MBT capacity in operation or construction. However, further analysis reveals that this includes 0.64Mt of "Dirty MRF" capacity – i.e. facilities which do not have a biological processing stage and which are excluded from this report.

Based on the available information, it is estimated that the UK MBT market comprises **2.86Mt** of MBT capacity of which is currently operational. There is a further **1.15Mt** currently in construction/commissioning - the much delayed Courtauld Road MBT in Essex, DONG Energy's Northwich facility and four MBT facilities being co-developed as pre-treatment processes alongside new EfWs. Summary details for all MBTs can be found in Appendix 1.

	Capacity (Mt)	# of Facilities
Operational	2.86	23
In Construction	1.15	6
Total	**4.01**	**29**
Ceased Operation	*1.02*	*6*

Figure 3: The current UK MBT Market Source: Tolvik analysis

Based on available data, it is estimated that total Residual Waste inputs to these MBT facilities in 2015/16 were circa 2.6Mt – or around 9% of the total Residual Waste market. Almost all of this Residual Waste was delivered by local authorities under long term contracts.

2.2. MBT - Desired Outcomes

Using a range of sources, it is also possible to identify which of the five target "outcomes" are relevant to the 29 MBTs which are currently in operation or construction. Most have more than one such target outcome. These results are summarised in Figure 4 showing a focus on recycling and RDF production.

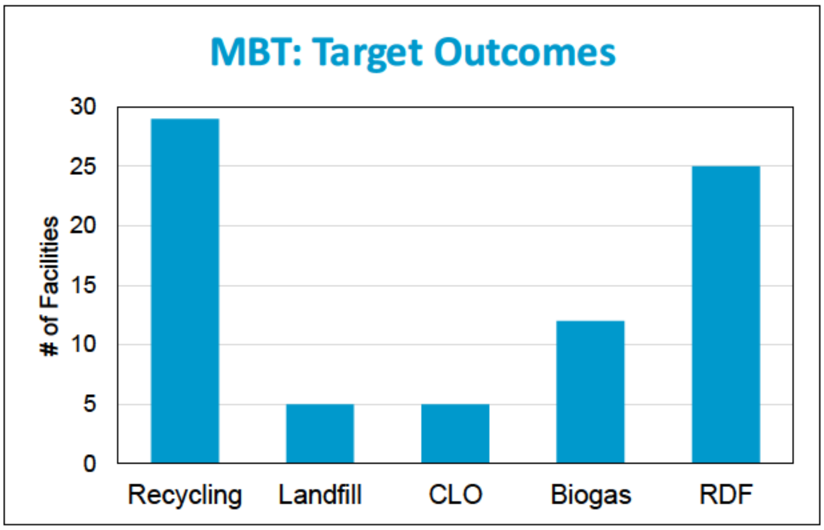

Figure 4: MBT: Target Outcomes Source: Tolvik analysis
NB "Landfill" = Reduced Biodegradability/Volume

3. OPERATIONAL PERFORMANCE REVIEW

3.1. Recycling

From the start one of the key attractions for local authorities procuring MBT based Residual Waste solutions was the potential for MBT to make a significant contribution to recycling rates. Figure 5 shows an early document released during MBT construction by one local authority which suggested that 25% of the incoming Residual Waste will be able to be recycled – including aggregates, glass, paper and card (into composting), metals and plastics.

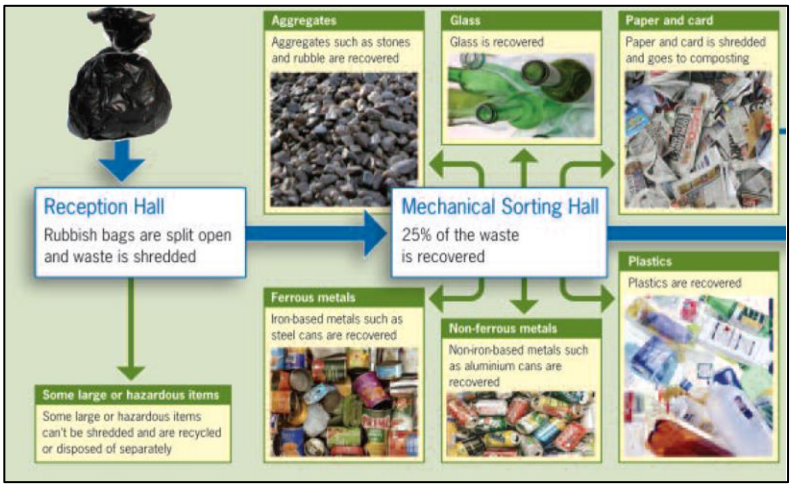

Figure 5: How an MBT plant works   Source: Anon

However, as DEFRA's 2007 Technology Brief specifically noted:

"Recyclables derived from the various MBT processes are typically of a lower quality than those derived from a separate household recyclate collection system and therefore have a lower potential for high value markets. The types of materials recovered from MBT processes almost always include metals (ferrous and non-ferrous) and for many systems this is the only recyclate extracted."

The Technology Brief then went on to identify the issues associated with extracting recyclables from the input Residual Waste stream specifically:

- **Glass** – the opportunity to recycle glass into high value products was discounted and the Technology Brief instead identified that, subject to achieving a suitable quality material, recovered glass could find application for use as a low grade aggregate;
- **Plastics** – the Technology Brief identified that the use of optical sorting technology offered the potential to recover plastic by polymer type but noted that capital costs associated with installing such technologies were high, and cost/benefits of adopting them would be significantly influenced by the effectiveness of any recycling achieved upstream through kerbside collection systems;
- **Textiles, Paper/Card** – the Technology Brief noted, if extracted, these materials extracted via MBT were unlikely to receive an income as a recyclate.

In terms of assessing the recycling performance of MBTs in the UK, it is worth noting that the definition of the "contracted" recycling performance (i.e. as required under contract with the local authority) may differ from the recycling performance used in official returns. A typical example would be the classification of organic "fines" used in land remediation/improvement projects which are not eligible for inclusion in official recycling statistics but which have been contractually accepted as "recycling".

This report has considered, where reported, the "contracted" recycling performance as arguably this better represents the expected outcome from the local authority client.

The highest (self-) reported recycling performance for an MBT in the UK which Tolvik has been able to identify is 18%.

Recycled Material	Range reported	Observations
Metals (Ferrous and Non Ferrous)	1 - 3%	All MBTs recover metals – may include metal recovery from IBA from resultant thermal treatment of outputs
Heavies (Glass and Stone)	0 – 8%	Generally need to pay (reduced) disposal cost
Plastics	0 – 6%	With low oil prices, poor quality and reduced demand from China, very limited available markets
Organic Fines	0 – 9%	Used to produce CLO for land remediation
Total	**1 – 18%**	

Figure 6: Reported Recycling Rates at UK MBTs

Where publicly reported, for the majority of MBTs reviewed the recycling performance has consistently fallen below contractual targets, largely due to difficulties in finding suitable markets for the "recyclates".

It is understood that some local authorities have written to DEFRA suggesting that leachate and evaporation from the MBT process should be treated as recycling. As yet there has been no definitive decision on this, however the challenge is to prove that these losses occur from recycling, rather than disposal, process.

Case Study – Barnsley, Doncaster and Rotherham ("BDR")

In 2012 Shanks, in a joint venture with SSE, signed a 25 year contract with the BDR Partnership for the treatment of Residual LACW from the three local authorities. The contract involved the construction of an MBT facility at Bolton Road, Manvers in Rotherham (which includes a dry anaerobic digestion system). The first waste was accepted at the MBT in February 2015 and full service commencement was achieved in July of the same year.

In a paper prepared for the partnership authorities in January 2017, the MBT recycling performance for the period April 2016 to December 2016 was reported to be 11.2% against a target of 19.0%.

	% of input Residual Waste	
Metals (Ferrous and Non Ferrous)	1.11%	
Glass and Stone	1.45%	
Plastic	3.37%	
Fines	3.42%	
Total on site		9.35%
Metals recovery from EfW	1.17%	
Third Party	0.66%	
Total Recycled		**11.18%**

Figure 7: BDR MBT Recycling performance Apr-Dec 2016

The report noted that, aside from various technical issues which limited the generation of recyclate, the market for plastics was poor and the contractor was having to pay to get plastics reprocessed.

It was subsequently reported that for the year as a whole the recycling rate had risen, following various improvements by the contractor, to 12.8%, but that remained significantly below the contractual target. However, it is understood that there is an expectation for this particular project that as the leachate from the MBT process is an input into the dry AD system (the outputs being biogas and CLO) DEFRA will accept moisture loss as "counting" towards recycling.

3.2. Reduce Biodegradability and Volume to Landfill

In the mid 2000s there were real concerns that the UK would be unable to meet the 2020 EU Landfill Directive target which set limits on the tonnage of biodegradable waste which could be sent to landfill. As a result, and in addition to rising landfill tax, in 2005/6 the government introduced Landfill Allowances Trading Scheme. This set local authorities with annual limits on the tonnages of waste they could send to landfill. The devolved regions set in place similar measures. Local authorities who landfilled in excess of their limit were subject to a potential fine of £150/t.

Since the targets were set with respect to the biodegradable element of Residual Waste, MBT processes which reduced the biodegradability of input waste as well as reducing its volume were an attractive option to local authorities which did not support EfW.

However, by 2011 the UK was sufficiently on track to meet the EU targets and the government abolished Landfill Allowances Trading Scheme; and whilst a reduced tonnage of waste to landfill continued to have a benefit to local authorities, a key driver in commissioning MBT had been removed.

Using a wide range of data sources of varying accuracy, an analysis of the average annual moisture loss at operational MBT facilities in the UK suggests performance ranging from between 1 – 34% with an input weighted average loss of 20.2%. Across all UK current MBTs this is the equivalent of a total mass reduction of 0.42Mt. This figure is used by Tolvik in its mass balance calculations for the UK Residual Waste market.

Those MBTs designed to maximise moisture loss through forced aerobic degradation of the waste are achieving a reduction in mass in excess of 22.5%, whilst those MBTs which focus upon biogas production are all achieving a mass reduction of below 10%. This highlights that in general an MBT can be configured to maximise the generation of biogas or maximise mass loss, but not both.

It is also worth noting that for plant operators there is a commercial balance to be struck between the retention time in the biological stage and the operational capacity of an MBT facility. A long retention time will increase mass loss but reduce capacity.

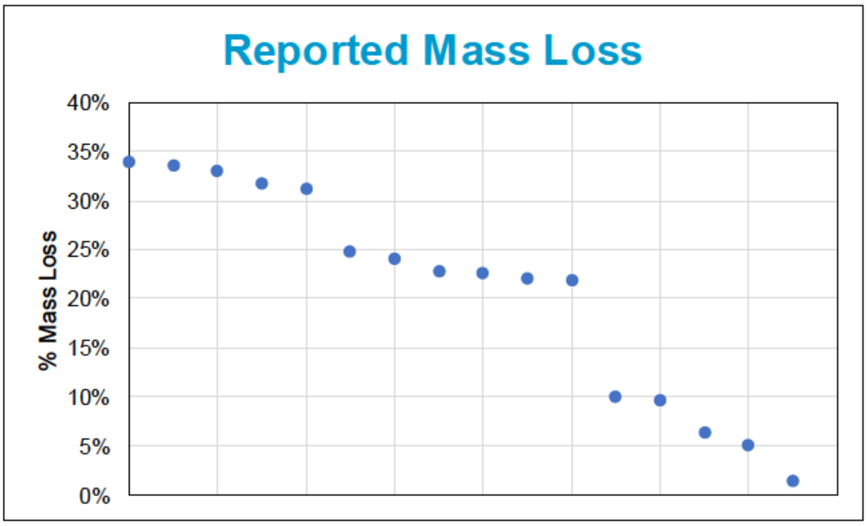

Figure 8: Reported Mass Loss as % of input Tonnage for UK MBTs

> **Case Study – Cambridgeshire**
>
> In 2008 Cambridgeshire County Council signed a £730m contract with Donarbon (who were later acquired by Amey) which included the construction of a large MBT at Waterbeach.
>
> The intention was that, as the local authority was not supportive of EfW, aside from making a significant contribution to recycling, the MBT plant would reduce both the tonnage and biodegradability of waste sent to landfill.

In 2012 it was announced that the MBT had already helped to save £3m of landfill costs. In 2015/16, uniquely for MBT in the UK none of the outputs from Waterbeach MBT were sent for thermal processing.

Figure 9: Waterbeach MBT

By September 2016 it was reported that the contract was being reviewed in order to identify cost savings as the overall cost of the solution was relatively expensive. Options to be considered included the removal of the MBT from the overall solution, refinancing the project and/or switching to RDF production.

In August 2017 Amey confirmed their plans to develop a large scale EfW on the same site.

3.3. Application to Land

By configuring an MBT to process the mechanically separated organic fraction it is possible for an MBT to produce a partially stabilised CLO/digestate material. The 2007 DEFRA Brief identified:

"The potential applications of these outputs are dependent upon their quality and legislative / market conditions. CLO and digestate has the potential to be used as a source of organic matter to improve certain low quality soils, e.g. in the restoration of brown field sites, or for landfill cap restoration."

The 2007 Brief also went on to identify the potential scale of the market for CLO/digestate in excess of 11 million tonnes. However, with developing UK legislation, an updated version of the Technology Brief issued in 2012 was significantly less bullish and pointed out that:

"CLO or digestate from mixed waste processing will not qualify for British Standards Institute (BSI) Publicly Available Specification PAS100 and PAS110 respectively, and is unlikely to be applicable for inclusion in recycling rates/targets….. Trials on mixed waste derived materials have reported large amounts of physical contaminants (e.g. glass) and levels of potentially toxic elements above limits for the standard PAS 100…. The use of CLO produced from mixed MSW on agricultural land is currently not permitted by the EA. If an outlet cannot be found for the CLO then it may have to be disposed to landfill. This will incur a disposal cost and any remaining measured biodegradable content will affect local authority landfill diversion targets"

In practice, other than for very specialist land remediation schemes (e.g. china clay workings in Cornwall) and landfill restoration (which is increasingly at risk that the CLO will in fact be subject to landfill tax), there is no significant markets for CLO in the UK and so MBT facilities are increasingly configured solely for RDF production.

Case Study – Lancashire and Blackpool

In 2007 Global Renewables was awarded a 25 year PFI contract by Lancashire and Blackpool to develop and operate two large MBT facilities at Thornton and Leyland.

The Global Renewables solution was based on the UR-3R MBT processes which they had developed in Australia and operated at Eastern Creek. Like many MBT processes it initially involved a mechanical separation process. This was followed by a system of large percolators, the purpose of the percolators being to separate and wash the organic waste which was then sent to a compost hall where it was to be transformed into a CLO. The plan was that this CLO would be used to plant 2.5 million trees over the course of the 25 year contract. The liquor from the percolators, rich in organic materials, was then drained off and sent to AD.

The local authorities were strongly against EfW and selected the technology as "*Global Renewables Limited had been the only company to offer a biological waste disposal solution that did not require an incineration process*". The 2005 Juniper Report had identified that the technology was "unproven."

Figure 10: Thornton MBT

In 2014 the local authorities terminated the contract and took control of the facilities. In 2016 the decision was taken to largely close the facilities.

In practice, the two MBT facilities faced a number of challenges:

1. No market for CLO - the expectation that, with time, the CLO would not have to be sent to landfill was over-optimistic. In practice regulations remained in place which meant that the opportunities to use CLO for tree planting were limited. The expectation that 75% of input waste could be diverted from landfill was undeliverable – in 2012 the figure was reported to be just 25% and so the local authorities ended up carrying the additional landfilling cost which meant that the overall solution was very expensive.
2. Changing waste composition - with the roll out of the separate collection of food waste across much of Lancashire, the organic content of the remaining waste sent to the MBT facilities was lower than expected.
3. Technical – there were a series of major mechanical failures and major odour issues, and Global Renewables was fined £150k for breaches of their environmental permit.

3.4. Biogas Generation

One of the key marketed advantages of MBT was the potential for it to be configured to generate renewable energy using the mechanically separated organic element of the Residual Waste stream in an AD process to generate biogas. The DEFRA Technology Brief suggested that biogas "*electricity production per tonne of waste input can range from 75 up to 225 kWh, varying according to the feedstock composition, biogas production rates and electrical generation equipment*".

As Figure 11 identifies, including the Lancashire MBT facilities, to date 8 MBTs in the UK have operated with an installed electrical generation capacity of greater than 1 MW. The average reported "load factor" (power generation divided by installed capacity) for these facilities since 2011 is just 21% - a figure distorted by one facility with an average load factor in excess of 60%. By way of reference, a typical food waste AD facility would have an average load factor of at least 70%.

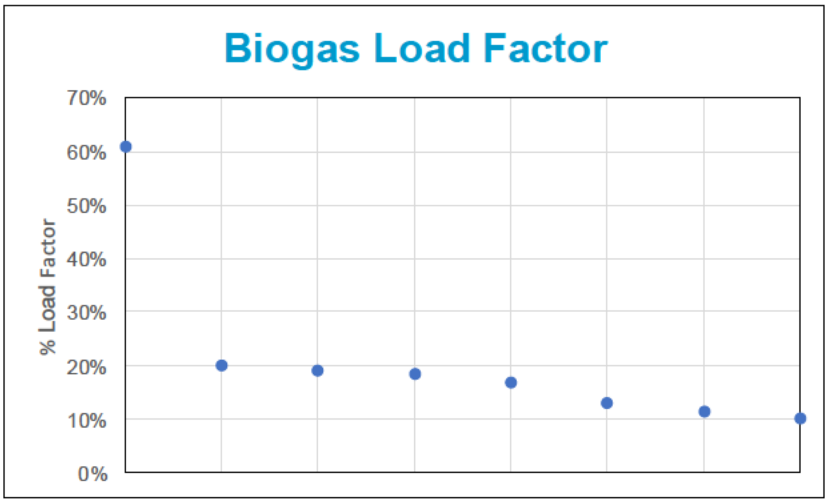

Figure 11: Average Biogas Load Factors Source: Variable Pitch[iv]

Whilst such a low load factor is not explicitly a metric of technical underperformance, it seems unlikely to be cost efficient for an MBT facility to be designed with a generation capacity significantly in excess of the expected output (i.e. with a low load factor).

There are a number of potential causes of this apparent underperformance, and most commonly it is reported that the changing composition of Residual Waste – and in particular the lower food waste content as a result of the increased separate collection of food waste – is adversely impacting biogas yields.

Case Study – Greater Manchester

In 2009 Greater Manchester Waste Disposal Authority entered a 25 year contract with Viridor Laing for the management of waste across the city. The solution included 4 MBT facilities with associated AD processing capability, with the AD element *"maximising the value of waste processed through the generation of green electricity and reducing the volume of fuel subsequently sent for energy recovery"*.

In August 2017 it was confirmed that the contract had been terminated. The operation of the MBT facilities will now revert to the Authority who plan "*modifications (which are yet to be fully determined) to the current suite of facilities*" in order to save money. The general expectation is that the MBT facilities will either, like Lancashire, be shut or their operations significantly scaled back.

Figure 12 is an extract from the report presented at the 2017 Annual General Meeting of the Authority where it was stated that *"in the period when all 4 plants were operational peak outputs were 25% of forecast and generation levels in 2016/17 were 15% of anticipated levels"*. The Authority went on to report that there was *"limited confidence in the long term reliability or performance of the plants compared to forecast."*

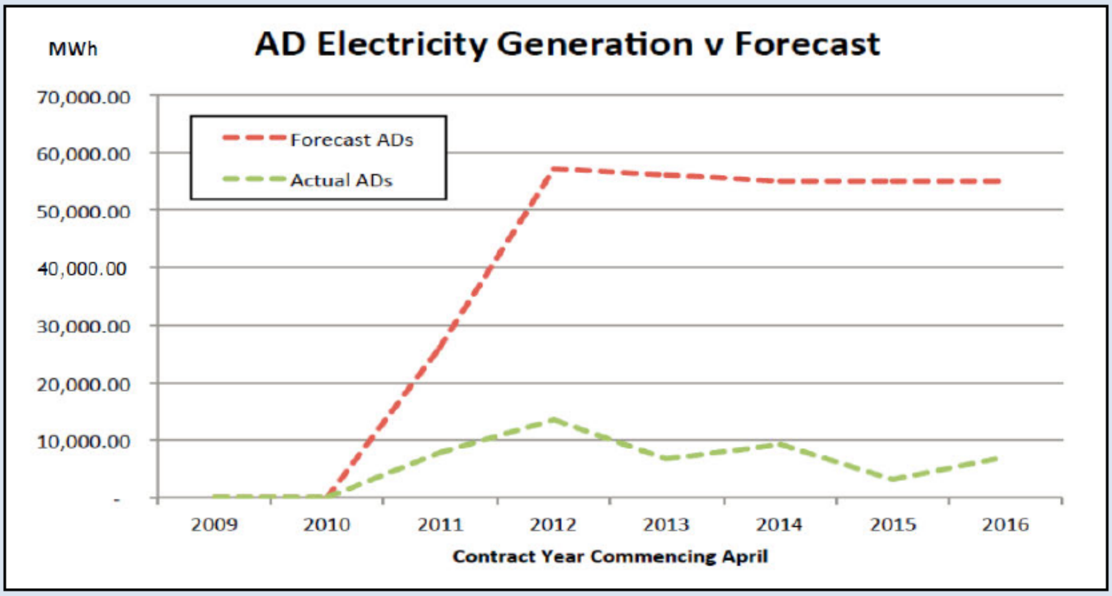

Figure 12: Biogas Generation Performance of MBT Facilities Source: GMWDA

The reasons for the termination of the contract are understood to have been primarily due to economics – the procuring authority has described it as "*expensive compared with current market rates*" and the underperformance of the MBT and AD facilities.

The key operation issues were:

1. Corrosion – there were significant delays in the final acceptance of a number of project facilities largely due to corrosion defects at the MBT and AD plants; Costain as construction contractor had been engaged in an extensive programme of rectification;
2. Lower than expected recycling – this was due to a number of factors, but the capture of grit and metals at the MBT in particular were poor which meant that the overall recycling performance was only half that expected – as illustrated by Figure 13.

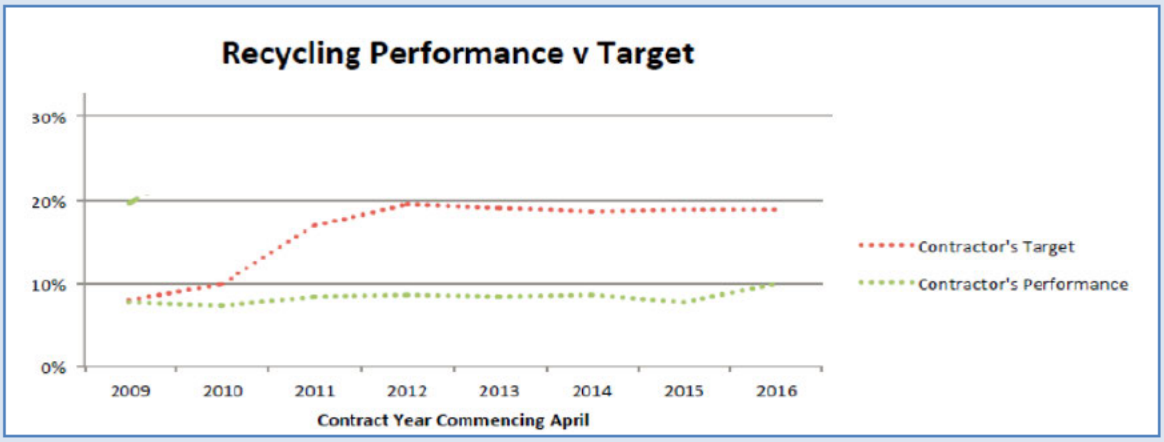

Figure 13: Contractual Recycling Performance Source: GMWDA

3.5. RDF Preparation

In the mid 2000s the potential outlets for RDF produced by MBT facilities were identified as being:

- Industrial intensive users for power, heat or both (Combined Heat and Power, CHP);
- Cement kilns;
- Co-firing with coal at power stations;
- Co-firing with biomass fuels in conventional technologies;
- Purpose built incinerators with power or power and heat (CHP);
- Advanced Conversion Technologies, such as pyrolysis and gasification.

The expectation then was that the focus would be upon UK co-incineration facilities – particularly cement kilns – and there were concerns that this was a relatively limited market in which RDF would need to compete with other fuels.

Early experience of MBT operators identified that the fuel specification requirements for cement kilns and co-firing facilities were constantly evolving and that, in practice, for an MBT to consistently produce a suitable fuel from an ever-changing local authority feedstock was challenging.

On the face of it, the development of the RDF export market since 2011 and the increase in the number of UK EfW facilities (both using conventional and Advanced Conversion Technologies) would appear to have significantly expanded the potential market for RDF. However the conundrum MBTs face is that, whilst the RDF they produce is "cleaner" and of higher calorific value than untreated Residual Waste, there remain relatively few outlets that truly "value" these attributes. The vast majority of EfW plants are designed to process high quantities of low calorific value fuel and their income model is principally based on the gate fee for their fuel rather than the energy produced.

As a result, whilst capacity has increased to meet demand, for those MBTs without a contractually secure outlet, the cost of RDF has risen from an expected £35-£40/t (to cement kilns) to as much as £85/t (for RDF export).

The recent 2017 WRAP Gate Fee report[v] provides the split for RDF outputs from UK MBT facilities as shown in Figure 14.

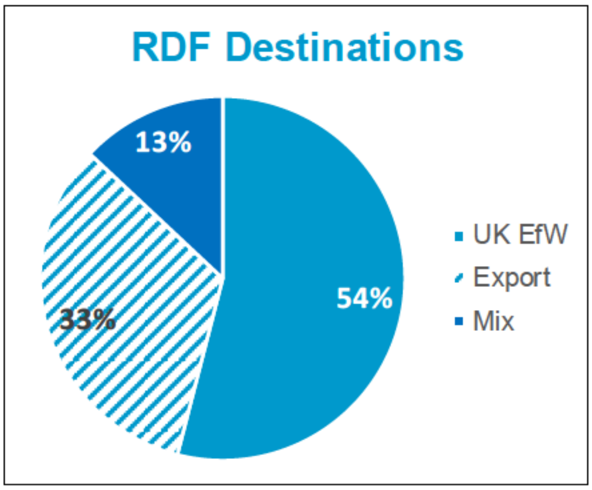

Figure 14: Destinations for RDF Produced by UK MBT Facilities Source: WRAP

Case Study – East London Waste Authority

The ELWA contract is one of the longest running MBT contracts in the UK, and over the period of its operation the configuration of the two MBT facilities have been developed to reflect changing market dynamics.

The original contract was structured to maximise recycling and, with the absence of alternative energy recovery markets, the production of Solid Recovered Fuel ("SRF") for co-incineration. The higher specification of the SRF meant that residence time in bio-drying stage was significant.

Figure 15: RDF produced at an ELWA MBT

As the thermal markets have developed, including the market for RDF exports (with Shanks the first to export from the UK in 2010), production of a lower grade RDF has increased which requires a shorter residence time, allowing the MBTs to "*maximise the diversion of waste from landfill*".

To support the production of in excess of 200ktpa of RDF, Shanks made an investment of £2m in new balers in 2016; it was also announced in the same year that Shanks had entered a 10 year contract for the export of 100ktpa to an EfW in the Netherlands.

4. COMMERCIAL CONSIDERATIONS

4.1. Background

The Juniper Report commented:

"Critics of MBT have said that because it is only an interim treatment, the overall costs of an MBT led-solution will always be higher than alternatives. Whilst this will often be the case, we do not think it has to be in every case"

This section of the report considers the relative cost of MBT when set against EfW.

4.2. WRAP Gate Fee Report

The 2017 WRAP Gate Fee report considered the gate fees reportedly paid by local authorities. The report's authors advised that they had 18 responses to their survey relating to MBT facilities, which suggested that the median gate fee for MBT was £88/t compared to £85/t last year, showing no significant market change. The most common (mode range) response was £80-£85/t and the range was £66/t - £170/t.

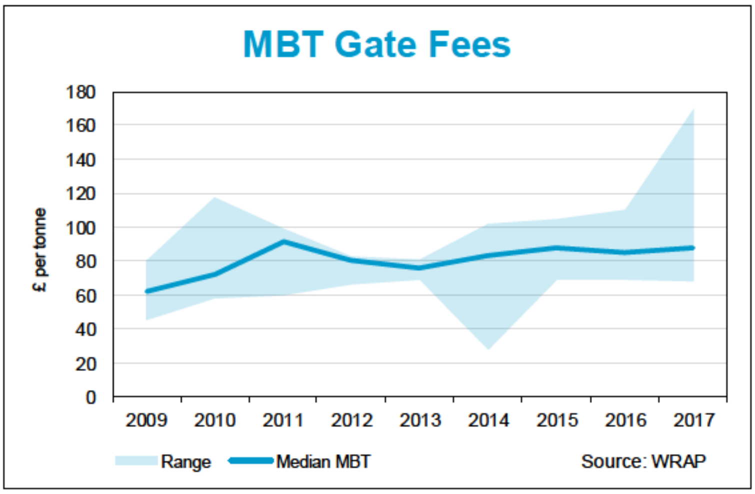

Figure 16: Local Authority MBT Gate Fees Source: WRAP

These reported gate fees are the "full" cost – i.e. include the disposal costs of all streams. However, the complex pricing structures of many long term local authority contracts means it is very difficult to assess a per tonne gate fee for an MBT facility in isolation; however if the analysis in the WRAP report is correct then the median MBT gate fee paid by local authorities is below the median gate fee for more recent EfW contracts.

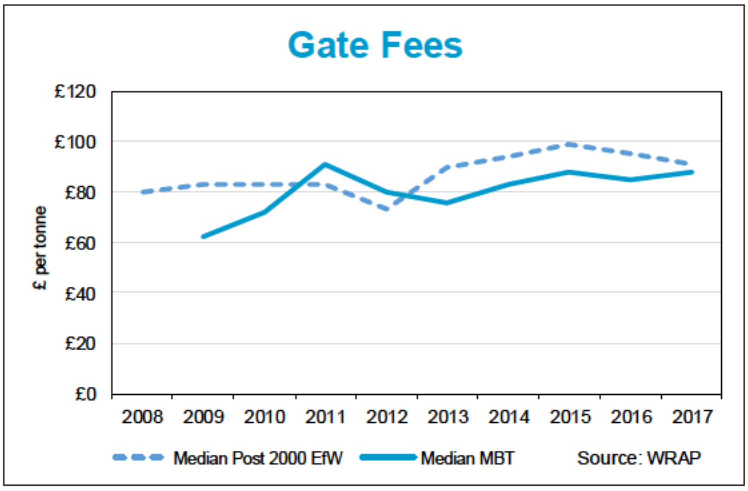

Figure 17: Local Authority Median MBT and EfW Gate Fees Source: WRAP

The difficulties in estimating a per tonne gate fee are such the WRAP report findings require further analysis. Two alternative approaches have therefore been taken:

- A review of local authority budgets;
- The creation of a "costed" model for a generic MBT solution.

4.3. Local Authority Budgets

Using publicly available data, a review has been made of the 2017/18 net revenue budgets of 29 Waste Disposal Authorities in England and excluding local authorities which are also Waste Collection Authorities (i.e. unitary authorities). The budgets for these (largely shire councils and specialist waste disposal authorities) do not include the cost of waste collection. The data for 4 Waste Disposal Authorities was not available in a format which could be analysed.

In addition to the total cost of Residual Waste treatment, these budgets also include the operation of waste transfer stations, treatment of other waste streams, civic amenity sites, recycling credits, closed landfills etc. In this sense they do not provide a "clean" data set – but the largest single item is almost certainly the cost of Residual Waste treatment. They may also be influenced by third party revenue sources, government credits (e.g. via the Private Finance Initiative) and the extent to which the local authorities own assets rather than procuring a service from a private sector contractor.

This total cost has been compared with the tonnage of Residual Waste generated in 2015/16 (the last year for which comprehensive data is available) to give a net cost per tonne. The data was then plotted in Figure 18.

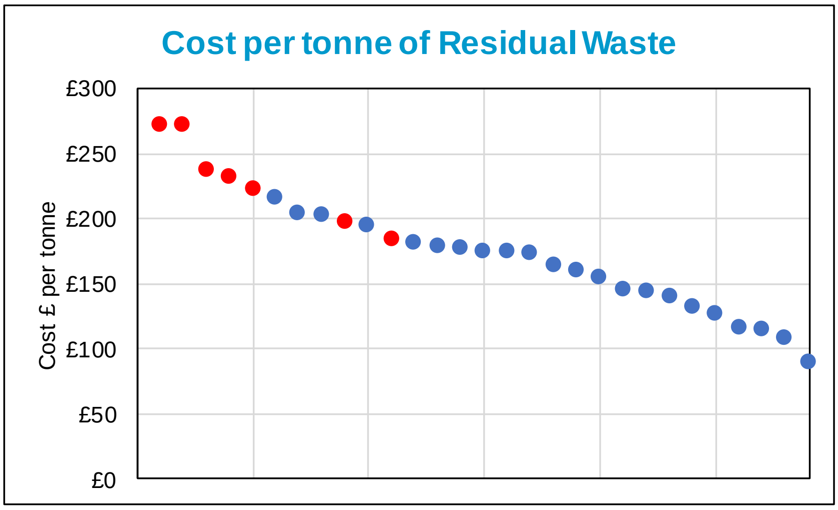

Figure 18: WDA Net Revenue Budget/Residual Waste tonnage Source: Tolv k analysis

It should not be inferred that the cost per tonne shown in Figure 18 is the average Residual Waste gate fee – as described the cost includes a number of other elements. However, the red dots represent those Waste Disposal Authorities whose principal form of Residual Waste treatment is MBT – Cambridgeshire, Cumbria, ELWA, Essex, Greater Manchester, Lancashire and West Sussex. Of the 29 analysed Waste Disposal Authorities, the 5 authorities with the most expensive total waste management cost per tonne of Residual Waste had primarily contracted an MBT based Residual Waste solution.

4.4. Cost Model

Using a range of data sources, a simplified financial model has been developed for a purpose built, subsidy free MBT processing 120ktpa on the basis of the mass balance set out in Figure 19. A 20% mass reduction is in line with the UK average albeit in practice the percentage will either be higher (for those systems using an aerobic biological stage) or lower (for those generating biogas).

Mass Balance		
%	Tonnes	Waste
100%	120,000	MBT Input
61%	73,200	RDF for Export
20%	24,000	Moisture Loss
4%	4,800	Plastics
2.5%	3,000	Metals Recovery
2.5%	3,000	Heavies
10%	12,000	Rejects to Landfill

Figure 19: Modelled MBT mass balance   Source: Tolvik analysis

Waste	Cost per Tonne			
	Baling	Transport	Gate Fee	Total
RDF for Export	£10	£15	£65[vi]	£90
Moisture Loss				£0
Plastics			£65	£65
Metals Recovery (Fe)			-£50	-£50
Metals Recovery (Non Fe)			-£300	-£300
Heavies		£10	£40	£50
Rejects to Landfill		£10	£106	£116

Figure 20: Modelled costs for waste outputs   Source: Tolvik analysis

Figure 20 provides indicative costs for the disposal of each of the outputs from an MBT process. The assumed cost of £65/t for RDF export represents the least cost ex-works price reported by Letsrecycle over the last 5 years, whilst the landfill cost is based on landfill tax of £84.40/t + £22.00/t median gate fee in the WRAP Gate Fee report. The price for metals, plastics and heavies is affected by the cleanliness of the recyclate stream. Recyclates from MBTs will inevitably be less clean than from source segregated dry recyclates collections or metals extracted from IBA and so will attract lower values.

Waste	Tonnes	£/tonne	Sub-Total £k	Total £k
MBT Input	120,000	**£125.08**		15,724
RDF for Export	73,200	-£90.00	-6,588	
Moisture Loss	24,000	£0.00	0	
Plastics	4,800	-£65.00	-312	
Metals Recovery (Fe)	2,400	£50.00	120	
Metals Recovery (Non Fe)	600	£300.00	180	
Heavies	3,000	-£50.00	-150	
Rejects to Landfill	12,000	-£116.40	-1,397	-8,147
Operating cost	120,000	-£17.50		-2,100
Overhead and Profit	120,000	-£10.00		-1,200
Capital Cost recovery – 20 years discounted basis, 2.5% inflation				-3,562
			Balance	**0**

Figure 21: Required Gate Fee   Source: Tolv k analysis

Based on confidential data from a number of waste management facilities, the operating cost for such an MBT has been modelled at £17.50/t and the overhead and profit element for the operator a further £10.00/t.

Using various benchmarks, the capital cost for such a facility is assumed to be £42 million.

Based on a minimum return on equity of 8% and excluding any tax, a gate fee of **£125.00/t** is generated. This represents a “floor” to the expected gate fee for such an MBT facility if built in 2017.

If more conservative assumptions of (£75.00/t for RDF and £20.00/t operating cost) are applied with regards to a need for an operator margin and expected market prices and the required % equity return modelled at 10%, then the gate fee increases to **£138.00/t.**

This compares with an average gate fee of c.£95.00/t for a recently closed local authority project based on EfW technology. Notably, this actual EfW gate fee is in line with the WRAP median gate fee for a post 2000 EfW.

4.5. MBT Operator Financial Performance

The nature of long term waste contracts is that the contractor accepts much if not all of the operating cost risk. If a local authority gate fee is low, it may well be because the operator under-bid the cost. This is evidenced by the poor financial performance by MBT operators. Publicly available examples include:

4.5.1. Shanks (now known as Renewi)

By any metric Shanks is the largest MBT operator in the UK, with its facilities accounting for around 27% of total UK MBT capacity. The UK operations of its municipal division accounted for some £175m of turnover – almost all of which was in the UK, but with an operating loss for the 12 months to March 2017 of £4.2m. As the most recent report noted:

“The cost of some RDF contracts has doubled from a lowest point of €40 per tonne to current rates of around €80 per tonne, at an exchange rate that has moved adversely by over 20% during the past 18 months”.

In 2017 Shanks provisioned for £28m (up from £5m) for onerous contracts.

4.5.2. PandaGreen (previously New Earth Solutions)

In October 2016, New Earth Solution was purchased by Ireland based PandaGreen. New Earth Solutions operated 3 MBT facilities in the UK and went into administration earlier in 2016 following the posting of a £29m loss.

This loss accrued in large part due to a failure to successfully develop an associated Advanced Conversion Technology EfW facility, necessary to make the MBT processes economically viable through delivering lower disposal costs than could be achieved by exporting the RDF.

4.6. Conclusion

The available evidence means it is difficult not to conclude that the identified criticisms of MBT referred to in the Juniper Report were correct and that MBT led Residual Waste solutions are generally more expensive than an EfW based alternative.

APPENDIX 1 – MBT LIST

Local Authority	Facility Name	Biogas	Year Ops	Operator	Capacity (ktpa)
Poole	Canford		2003	Panda	125
Newcastle	Byker		2006	Suez	120
Leicester City	Bursom	Yes	2006	Biffa	150
Dumfries & Galloway	Dumfries		2007	Shanks	65
Western Isles	Creed Park		2007	Council	15
ELWA	Frog Island		2007	Shanks	180
ELWA	Jenkins Lane		2007	Shanks	180
Darlington	Aycliffe Quarry		2009	John Wade	50
Cambridgeshire	Waterbeach		2009	Amey	200
Leicestershire	Cotesbach		2010	Panda	50
West of England	Avonmouth		2011	Panda	200
Cumbria	Hespin Wood		2011	Shanks	75
Cumbria	Sowerby Wood		2013	Shanks	75
Greater Manchester	Bredbury Pk	Yes	2013	Viridor	92
Greater Manchester	Longley Lane	Yes	2013	Viridor	110
Greater Manchester	Cobden St	Yes	2012	Viridor	73
Greater Manchester	Reliance St	Yes	2011	Viridor	65
Southwark	Old Kent Road		2012	Veolia	87
Wiltshire	Northacre		2013	Hills	90
BDR	Manvers	Yes	2015	Shanks	286
Wrexham	Wrexham		2015	FCC	75
Wakefield	South Kirkby	Yes	2016	Shanks	145
West Sussex	Brookhurst Wood	Yes	2016	Biffa	327
Essex	*Courtauld Road*		*2017*	*UBB*	*377*
Milton Keynes	*Milton Keynes*	*Yes*	*2017*	*Amey*	*120*
Cheshire	*Renescience*	*Yes*	*2017*	*DONG*	*120*
North Yorkshire	*Allerton Park*	*Yes*	*2018*	*Amey*	*260*
Derbyshire	*Sinfin Road*		*2018*	*Shanks*	*72*
Glasgow	*GRREC*	*Yes*	*2018*	*Viridor*	*200*
TOTAL					**3,984**

Ceased Operations:

Neath Port Talbot	Crymlyn Barrows		2002/2008	Council	170
Merseyside	Huyton		2008/2011	Orchid	80
Rotherham	Rotherham		2007/2012	Sterecycle	100
Gateshead	Derwenthaugh		2010/2013	Graphite	320
Lancashire	Leyland	Yes	2010/2016	Council	175
Lancashire	Thornton	Yes	2010/2016	Council	175
TOTAL					**1,020**

APPENDIX 1 continued – LOCATION MAP OF MBTs

APPENDIX 2 - GLOSSARY

ACT	Advanced Conversion Technology
AD	Anaerobic Digestion
C&I Waste	Commercial & Industrial Waste
CHP	Combined Heat and Power
CLO	Compost Like Output
DEFRA	Department for Environment, Food and Rural Affairs
EU	European Union
EfW	Energy from Waste
Ktpa	‘000s tonnes per annum
Mt	Million Tonnes
MBT	Mechanical Biological Treatment
MRF	Materials Recycling Facility
Residual Waste	Waste which remains after recycling
RDF	Refuse Derived Fuel
SRF	Solid Recovered Fuel

APPENDIX 3 - SOURCES

i http://webarchive.nationalarchives.gov.uk/20130403153720/http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/mbt.pdf

ii https://www.cti2000.it/Bionett/BioG-2005-004%20MBT_Annexe%20A_Final_Revised.pdf

iii data.defra.gov.uk/Waste/residual_waste_mar2016_05.xls

iv http://www.variablepitch.co.uk/

v http://www.wrap.org.uk/gatefees2017

vi http://www.letsrecycle.com/prices/efw-landfill-rdf-2/

Annex G: Alternative Residual Waste Treatment – Biostabilisation, Ricardo (2022)

Creating a world
fit for the future

Alternative Residual Waste Treatment

Biostabilisation

Report for Zero Waste Scotland

Zero Waste Scotland – Ref. 20-PR-181-RG

ED 15174 | Issue number 3 | 29 October 2022

Ricardo Confidential

Customer:

Zero Waste Scotland Limited

Customer reference:

20-PR-181-RG

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Date:

29 October 2022

Ref: ED 15174

Ricardo is certified to ISO9001, ISO14001, ISO27001 and ISO45001

Executive summary

Background

A ban on the landfill of biodegradable municipal waste (BMW) will come into force in Scotland on 31 December 2025. On that basis, local authorities in Scotland will need to review options for processing residual municipal solid waste (MSW) (residual waste[1]) to ensure future compliance with the ban.

The project documented in this report was commissioned to review the practice of biostabilising residual waste, principally with consideration to its subsequent disposal in landfill, rather than as part of a treatment process that produces refuse derived fuel (RDF) or solid recovered fuel (SRF) for energy recovery.

Residual waste can be biostabilised utilising mechanical biological treatment (MBT) technologies and the level of biostability necessary to allow the treated waste to be landfilled under the ban is detailed within Scottish legislation.

As the name suggests, MBT is the treatment of waste by both mechanical and biological means. Biological treatment of waste degrades complex organic compounds into simpler compounds. If the treated waste is then landfilled, it is more stable and will degrade less within the landfill and so will generate less landfill gas than it would without prior biological treatment. Landfill gas is a mixture that includes gases with global warming potential (GWP). The more organic material that is degraded in the MBT process, the more stable the waste becomes (biostabilisation).

The project scope did not include comparison to be made with any other form of residual waste treatment, nor any recommendation to be made on whether MBT should be employed in Scotland. There are advantages and disadvantages to all forms of residual waste treatment. This study set out to explain whether MBT is feasible for meeting the BMW landfill ban criteria and to explain the advantages and disadvantages of employing MBT, in the Scottish context, to help local authorities and policy makers make informed decisions.

The high-level project scope was to:

- Set out what biostabilisation of residual waste involves.
- Review how techniques have been implemented in Britain (high level summary) and, via case studies, in selected EU countries.
- Undertake a carbon lifecycle assessment (LCA) for the biostabilisation of residual waste.
- Consider the balance and interaction of technical, economic, policy and environmental factors that influence the implementation of biostabilisation techniques in practice.

The carbon LCA undertaken is bespoke to the MBT process, and the approach used shares some similarities to a carbon LCA, for energy from waste (EfW), previously undertaken by Zero Waste Scotland. Within the agreed scope of work, there are some limitations to the carbon LCA undertaken; for example, it does not consider future changes in waste composition and it utilises a single approach to allocating carbon emissions, in line with the prior Zero Waste Scotland EfW carbon LCA.

Types of MBT technology

Various MBT technologies are described below, and throughout this report, and specific MBT facilities in Great Britain (23 no.) and in the EU (6 no.) are discussed. None of the specific facilities discussed have been confirmed to meet all the modes of operation of most interest to this study, which are listed below.

- No RDF production.
- Main output is destined for landfill.
- Achieves a level of biostability that will comply with the Scottish ban criteria.

The mechanical processing that takes place at MBT facilities involves size reduction and sorting of the residual waste into different components. Typically, materials are separated into recyclable fractions, RDF, contaminants and an organic rich fraction. The organic rich fraction is then processed

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[1] Residual waste is the waste that has not been placed in containers provided to allow collection of recyclable materials.

utilising an aerobic composting or an anaerobic digestion (AD) process, which are both biological processes. The output of the biological process is generally either a compost like output (CLO) or, for AD processes, digestate and biogas. Biogas is used as a fuel for energy generation or vehicle propulsion.

Mechanical separation techniques can involve a wide array of technologies, most of which are well proven and commonplace in waste management processes. However, as waste is separated into different streams, each stream has different properties, such as moisture content, bulk density, particle size and particle shape. A change in input waste composition can have a notable affect upon facility performance, especially in terms of blockage and spillage at equipment in mechanical pre-treatment but also in terms of the residence time in the biological process and the throughput capacity of the whole facility. The more complex the mechanical process, the greater the potential for issues as the input waste composition changes.

The biological process can comprise:

- In-vessel composting (IVC).
- Biological drying (Biodrying).
- Anaerobic digestion (AD).

Of the above biological processes, IVC and dry-AD (a form of AD) followed by IVC can be designed and operated to allow various extents of biostability, including to meet the Scottish ban criteria. Biodrying will not achieve a high level of biostability and wet-AD (another form of AD) output is not practicably amenable to the necessary subsequent IVC process required to achieve a high level of biostability.

Ricardo has not established the level of biostabilisation achieved at British MBT facilities, nor for the six case study sites reviewed in other countries. In Britain, there is currently no legislative requirement to meet a specific threshold of biostability prior to landfill. The focus of most MBT facilities, in Britain and the EU, is not to biostabilise waste prior to landfill; to the contrary, the focus is often to divert as much waste as possible away from landfill. Nonetheless, it is Ricardo's conviction that IVC can, subject to design and mode of operation, achieve levels of biostability in residual waste that will comply with the Scottish ban criteria.

Organic materials present within residual waste are amenable to composting and composting can be managed, including duration and extent of maturation[2], to achieve a high level of biostability. Proposed biostability thresholds for EU Ecolabel (for growing media, soil improvers and mulch) and EU end of waste criteria include values that are more stringent than the Scottish ban criteria, demonstrating that composting can achieve high levels of biostability.

Furthermore, Ricardo has contacted technology providers that have confirmed that they can design facilities capable of achieving the Scottish ban criteria. Reference facilities were mentioned, although none that only process residual waste.

Biodrying involves aeration of waste to commence the composting process to raise the waste's temperature to drive off moisture. However, the composting process is cut-short once the waste has dried to the desired level and, unlike a full composting process, water is not added. A humus like composted output is not produced in biodrying. Biodrying will not stabilise residual waste to the level necessary to allow its landfill in Scotland.

Anaerobic digestion alone will not meet the Scottish biostabilisation criteria. Anaerobic digestion can be undertaken on a dry or wet basis. Unlike wet AD, dry AD digestate is more amenable to subsequent IVC processing. As such, dry AD and IVC combined can be used to meet the Scottish biostabilisation criteria.

Whilst wet AD cannot, in a practical manner, meet the Scottish biostabilisation criteria, it is a popular MBT option within Europe, including in Britain, where it typically accompanies processes to generate

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[2] Maturation is sometimes employed after the main composting process. During maturation, there is minimal active management of the process and the temperature and rate of degradation gradually reduce, and the compost becomes 'matured'. Matured compost has a greater level of biostability than un-matured compost.

RDF rather than outputs for landfill. As such, some case study examples of wet AD have been included in this study for information purposes.

A comparative summary of the main strengths and limitations of each biostabilisation technique employed at MBT facilities is detailed in the table below.

MBT option	Can be designed to meet BMW landfill ban criteria?	Technology complexity for biological process	Advantages (relative to other MBT options)	Disadvantages (relative to other MBT options)
IVC	Yes	Less complex than AD	IVC technology alone can achieve the ban criteria (if designed and operated to do so). Easier to control/more stable process than AD.	IVC does not allow for energy recovery from organic materials.
Wet AD	Not in a practical manner	Complex	Easier to control and optimise than dry AD- substrate can be mixed, heated and transferred with greater ease. AD allows for energy recovery- IVC does not.	AD will not biostabilise enough to meet the ban- needs to be followed by IVC. However, the liquid nature of wet AD digestate output is unsuitable for IVC without drying and mixing with material with structure- i.e. not a practical option even if technically possible (likely to require mixing non-source separated MSW with source separated material). Requires greater footprint area than dry AD.
Dry AD	Only when combined with IVC and must have prior RDF removal	Less complex than wet AD but less easy to mix and maintain steady operation	AD allows for energy recovery- IVC does not. Dry AD output can be suitable for IVC, whereas IVC is not practical for the output from wet AD.	AD will not biostabilise enough to meet the ban- needs to be followed by IVC. Batch processes are not practicable for high throughput facilities and semi-continuous flow processes require some 'contaminant' (RDF materials) removal prior to AD.
Biodrying	No	Least complex of all	Fast, easier to optimise than other options and relatively low footprint area compared to IVC.	Biodrying does not allow for energy recovery from organic materials. Will not allow enough biostabilisation to meet the ban criteria.

A change in the organic content of residual waste will have a significant impact upon the function and utilisation of the biological process. That is evident from some of the case study facilities reviewed, where facility modification or closure to residual MSW treatment has occurred. Introducing source segregated organics collection is likely to be significant and the impact is likely to be greatest at an

AD facility, whose design and anticipated performance involve electricity, heat or biomethane production.

MBT in Britain

In theory, if not always in practice, MBT offers several benefits over landfill and incineration. Benefits might include a reduction in material sent to landfill, or incineration, resulting from biological process losses and, potentially, the removal of higher quantities of recyclable materials. Nonetheless, energy from waste (EfW) by thermal treatment (generally combustion- incineration) is more popular, in terms of the number of facilities and tonnage treated, than MBT in Britain.

Twenty-three British MBT facilities have been identified in this study, comprising one in Wales, two in Scotland and 20 in England. MBT facilities that are integral to onsite EfW facilities (thermal treatment of waste) have not been included in the list, except for one facility because it is in Scotland.

All but one British MBT facility (an English IVC facility) generated RDF in 2019. The operators of the facility that did not generate RDF wish to construct an EfW facility at the site.

Of the 23 British MBT facilities, the biological processes undertaken include:

- 8 Biodrying (including the one Welsh facility and one of the two Scottish facilities)
- 9 Wet AD (including the one Scottish MBT/EfW facility)
- 1 Dry AD with IVC
- 5 IVC

There is currently no limit on the biostability of waste that can be landfilled in Britain and Ricardo is not aware of any British MBT facility that biostabilises waste to the level required by the forthcoming Scottish ban.

British MBT facilities are focussed upon landfill diversion by removal of recyclable materials, production of RDF and mass loss via biological treatment.

Based on the experiences of Ricardo staff, the quality of recyclable materials separated at MBT facilities can be poor and market prices highly variable.

The British experience has shown that securing outlets for CLO is particularly problematic, and it is often landfilled until other opportunities arise. However, if residual waste was subject to removal of recyclable materials, biostabilisation and landfill, without RDF production, there would be no need to find an outlet for CLO.

Scottish MBT facilities

Scotland has two MBT facilities, which are the Glasgow Recycling and Renewable Energy Centre (GRREC) and Lochar Moss in Dumfries and Galloway.

At GRREC, mechanical processing is followed by wet AD and a gasification[3] EfW process is integrated with the residual waste MBT process. English MBT facilities with on-site thermal EfW processes have not been included within this report; the exception was made for GRREC as it is in Scotland.

Irrespective of the production of RDF to be input into the gasification process, the GRREC facility utilises wet AD and, therefore, does not biostabilise waste such that it could be landfilled following the 2025 ban. However, the process will avoid the landfilling of BMW if the total organic carbon in the solid residue (char) from the thermal process is below the required limit such that it can be landfilled to comply with the requirements of the BMW landfill ban.

The Lochar Moss facility is a biodrying/RDF facility (Ecodeco technology) and in 2019 the single largest output fraction was RDF. Whilst the facility may potentially be able to meet the requirements of the ban, through EfW and landfill of ash, it will not do so by biostabilisation.

[3] Gasification is a thermal process that partially oxides waste in a low oxygen environment.

Case study countries and facilities

France, Germany, Italy and Spain were selected as countries known to have established experience of MBT. The main influences of legislation and policy, compost standards, biostabilisation criteria and landfill tax were reviewed and six MBT facilities, located in France (x1), Germany (x3) and Spain (x2) were researched and feature as case studies in this report.

The case study facilities broadly reflect the current variety of MBT processes typically employed in Europe.

Five of the case study facilities produce RDF, and the situation at the sixth is unclear. The prevalence of RDF production encountered when selecting the six case study facilities reflects the same situation that exists in Britain, where RDF production is the norm. The prevalence of RDF production is primarily the result of policies to divert waste from landfill and the waste hierarchy, which places energy recovery above landfill.

Two of the case study facilities no longer process residual waste, influenced by the introduction of source segregated biowaste collections and, in one instance, due to EfW being a cheaper option. A third facility will be significantly impacted by a change in legislation that will significantly impact the mode of operation, potentially threatening its future.

Although France, Germany, Italy, Spain and Scotland share the high-level desire to divert waste from landfill and to apply the waste hierarchy, the policies, legislation and regulation applied to achieve those ambitions vary considerably. In turn, there are different conditions in each country that can impact upon the development of MBT facilities. A summary of some of the main differences is provided in the table below.

Policy/ legislation/ regulation	Country	Impact on MBT viability	Applicability to Scotland
Allow CLO application to agricultural land	France and Spain (if compost standards met) (Does not apply to Germany and Italy)	Significant advantage to an MBT operator (no landfill or EfW gate fees)	No end of waste status for CLO (so not an option)
No specific biostabilisation criteria for the landfill of BMW	France and Spain (only some regions in Spain have banned BMW going to landfill) (Germany and Italy have criteria)	Advantage to an MBT operator as a high level of biostability is not necessary, and biostability does not need to be consistent. An operator may design a process with less retention time than it would if biostability criteria applies (reduced capital and operational costs and smaller facility footprint area)	Ban on BMW to landfill, with biostabilisation criteria, to apply from 2025
Minimum energy recovery mandated (70% of material unsuitable for material recovery must go to energy recovery)	France	Significant advantage to MBT with RDF production (and direct EfW also has an advantage over landfill) because landfill of such material is not possible	Scotland does not have a comparable policy

Policy/ legislation/ regulation	Country	Impact on MBT viability	Applicability to Scotland
Waste not recycled that has a calorific value over a certain threshold cannot be landfilled	Germany	Significant advantage to MBT with RDF production (and direct EfW also has an advantage over landfill) because landfill of such material is not possible	Scotland does not have a comparable policy
Mandatory separate collection of organic waste	Germany (widespread and a requirement) France (to apply from end of 2023) (Does not apply to Spain and Italy)	Disadvantage to an MBT operator because mass loss from the biological process is a central focus for most MBT facilities (particularly problematic if separate collection introduced during the operation of an existing facility)	Will apply to Scotland if there is an increase in separate collection
Polluter Pays principle (payment for specific amount of residual waste collected)	Germany	Disadvantage to an MBT operator if quantity of residual waste diminishes	Scotland does not have a comparable policy
Landfill tax and incineration tax but with discounts for most operators limiting tax effect	France	Unlikely to significantly impact an MBT operator in this instance due to discounts	Landfill tax but no incineration tax
High landfill tax rate	Spain (Catalonia)	Significant advantage to MBT (if RDF produced) and for EfW operators over direct landfill. MBT (biostabilisation and landfill) will fare better than direct landfill due to a reduction in material landfilled, but EfW will fare best	Applies in Scotland

The review of policy and case study facilities in other countries, and facilities in Britain, highlights several points of interest to the possible future landfill of biostabilised residual waste in Scotland, as listed below.

- The landfill of biostabilised waste, without prior RDF production, in Scotland would not reflect a typical MBT operation in Britain and the EU. The experiences, benefits and difficulties encountered elsewhere should be considered in that context.
- The prevalence of RDF production and minimisation of waste to landfill are common themes within Britain and the EU, informed by the waste hierarchy. If MBT with biostabilisation and landfill, without RDF production, is to be promoted in Scotland, it may be beneficial to review the provisions of the waste hierarchy from a carbon perspective.

- There are many differences in policy, legislation and regulation between France, Spain, Italy, Germany and Scotland. Some policies in other countries are not relevant to Scotland or are unlikely to apply in future; that includes the application of CLO to agricultural land, and restrictions on the landfill of some waste that could be utilised for energy recovery. Such policies will influence the economic viability of MBT.
- Fast moving changes in policy and the regulatory landscape increases uncertainty and investment risk. In Scotland, as is common elsewhere in Britain and the EU, waste policy and practices are being developed and refined on an ongoing basis. Policy changes, such as measures to increase the source segregation of waste, can lead to changes in waste composition. A change in waste composition, especially from an increase in the source segregation of food waste, can have a significant impact upon the continued viability of an MBT facility.

Carbon lifecycle assessment

All scenarios modelled in the carbon lifecycle assessment (LCA) showed a calculated carbon impact (not benefit), per tonne of residual waste treated, as shown below.

- IVC only, without RDF production: 12kg CO_2eq/t
- Dry-AD+IVC (must involve RDF production): 66kg CO_2eq/t
- IVC only, with RDF production: 115kg CO_2eq/t

The greatest influences on the carbon balance are whether RDF is produced, and subsequently combusted elsewhere for energy recovery, and whether materials are recycled. The former unfavourably impacts the carbon balance whereas the latter benefits it.

The combustion of RDF has a net impact (not benefit) of high significance to the overall carbon balance, as is evident from the difference between the two IVC only scenarios considered (see above). That is due to the combustion of fossil carbon, which is 'stored' if landfilled under an MBT scenario wherein RDF is not generated and the MBT output is landfilled.

Dry-AD+IVC has the benefit that biogas, of biogenic origin, is produced and combusted to generate electricity, but that advantage comes with a need to remove RDF and the impact associated with RDF combustion.

In future years, the mix of the supply of electricity to the grid in Britain is expected to decarbonise substantially to meet legally binding targets. A grid mix with lower carbon intensity will entail lower carbon emissions from the production of electricity consumed at MBT facilities, as well as lower carbon benefits associated with electricity generation at Dry AD facilities or generated from the combustion of RDF separated at MBT facilities. Overall, this is likely to make IVC without RDF production even more advantageous, from a carbon performance perspective, compared to Dry-AD with IVC and IVC with RDF production.

Carbon impacts are not the only aspect that needs to be considered. Any solution must be sustainable, in all senses of the word, for the anticipated lifetime of a waste facility.

Balance and interaction of factors affecting MBT viability

The balance and interaction of factors affecting MBT viability are complex, especially because MBT covers a range of possible equipment configurations and technologies, with a variety of output materials that can be utilised in different ways. MBT processes vary significantly in terms of technology, complexity, scale and cost.

As described above, MBT of residual waste, with landfill of biostabilised output material, is technically possible and there are potential environmental (carbon) benefits that could be realised if such an MBT operation can be sustained in the long-term. There are also various policy measures that could be implemented that may or may not benefit an organisation considering developing an MBT facility.

However, to be sustainable over the long-term, an MBT facility must be financially viable. Financial viability is influenced by how stable technical performance, policy and regulation and market conditions are. However, policy and regulation can change considerably and relatively quickly, and market conditions, such as recyclate markets and the presence of competing facilities, are variable and unpredictable.

A change in policy, or general economic conditions, can bring about a change in waste composition. A change in waste composition can cause technical issues at an MBT facility and can impact upon the quality of the facility outputs. In turn, that can affect the possible end use of facility outputs and the revenue from energy or material sales.

Local authority contracts are generally in place for several years, and many British MBT facilities have been developed under public-private partnerships (PPP) and private finance initiative (PFI) agreements, with complex contractual terms that often include wider waste management services. Determining a cost for MBT, and then making comparisons with other technology options is therefore problematic at the national scale. It is difficult to arrive at a typical gate fee for British MBT. However, there is no evidence to suggest that it is a cheaper option than EfW and, in some instances, it may prove to be the more expensive option per tonne of waste treated.

An important aspect of such complex long-term contracts is how risk is shared between the contracting parties.

Under a long-term contract, a local authority will sometimes be prepared to pay ‘a bit more’ to limit its exposure to fluctuations in market conditions. The contractor will assume the risk but is hopefully compensated by receiving a good payment per tonne of waste treated, as determined by the payment mechanism. Such contracts are typically in place for around 20 years, and a lot can change in a short space of time. Irrespective of cause, whether technical error in facility design, change in waste composition, or change in market conditions, there is plenty of scope for one or more parties to a contract to become dissatisfied.

The complex interaction between the influencing factors described above is a negative aspect of MBT facilities. Other residual waste management techniques, EfW for example, are typically less sensitive to the types of interactions described above.

Recommendations

Some MBT technologies can treat BMW to a level of biostability that will meet the Scottish ban criteria, and it performs well from a carbon emissions perspective. However, MBT can take many forms and its implementation can be problematic.

To employ MBT in Scotland, with landfill of most of the facility outputs, would require a step-change in attitude and approach by many involved, in whatever manner, in waste management. That approach is not currently practiced in Scotland, and only one English facility has been identified that does so.

If employed, the result would be unlikely to cause a decrease in waste landfilled, it would most likely increase, and this would not be in keeping with the waste hierarchy wherein energy recovery is deemed preferable to landfill.

If further consideration is to be given to MBT development in Scotland, Ricardo’s recommendations for future consideration are summarised below.

1. Priority should always be given to minimising waste generation, and to collection of source segregated waste wherever practicable. Recycling has carbon benefits but recovering and recycling components of residual waste is more difficult than for source segregated materials. Furthermore, unlike organic materials in residual waste, source segregated organics can be processed to gain end of waste status in Scotland. If successful source separation of recyclable materials and organic waste in Scotland limits opportunities for MBT in Scotland, then that must be considered a good outcome so long as residual waste generation is minimised as much as possible.
2. If MBT was to be promoted in Scotland, it is likely that policy or financial instruments would need to be developed to allow it to become the favoured option. If MBT aimed at landfill and not RDF production was to be promoted, then a review could be undertaken into how landfill tax might be applied to support such practice.
3. A review could be made of the waste hierarchy and whether it requires amendment, in a time when the carbon balance of waste management is becoming ever more prominent in decision making. The carbon LCA undertaken in this study demonstrates a marked difference in incinerating RDF versus its landfill, if that material is biostabilised prior to landfill.

4. A review could be made of the experience of MBT implementation in England. That might include liaison with UK waste management companies and local authorities that have experience of MBT implementation.
5. A review could be made of the remaining landfill capacity in Scotland and changes in the tonnage and volume inputs to Scottish landfills that might result from the landfilling of biostabilised residual waste in Scotland.
6. A review could be made of the practice of producing mixed polymer pellets from materials separated at MBT facilities. To begin with, that could involve liaison with Zero Waste Europe to understand the evidence base informing statements it made in a report it published[4].
7. Because most designers and operators of MBT facilities are familiar with RDF production, greater due diligence will be needed if selecting MBT-IVC technologies that do not involve RDF production. The suitability of MBT will have to be assessed on a case by case basis and with consideration to the local authority specific residual waste composition and any forecast future variation.

[4] Building a bridge strategy for residual waste- Material Recovery and Biological Treatment to manage residual waste within a circular economy- Policy Briefing, June 2020, Zero Waste Europe

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Glossary

Abbreviation	Definition
AD	Anaerobic digestion
BMW	Biodegradable municipal waste
CIC	Consorzio Italiano Compostatori The Italian composting and biogas association
CHP	Combined heat and power
CLO	Compost like output This term is used to describe the output from a residual waste composting process, in recognition that it cannot lose its waste status and simply become a compost product. Sometimes known as stabilised organic material (SOM) or 'stabilite'.
CV	Calorific value
DM	Dry matter Often expressed in terms of weight percentage, this describes what portion of the waste or product is not comprised of moisture.
EF	Emission factor
EfW	Energy from waste
EPC	Engineering, procurement and construction
EPR	Extended producer responsibility
EWC	European Waste Catalogue Also referred to as LoW (List of Waste).
GDP	Gross domestic product
GWP	Global warming potential
HDPE	High-density polyethylene
HWRC	Household waste recycling centre
IVC	In vessel composting
LAS	Landfill allowance scheme No longer in force, this was the name for schemes that applied in Scotland and Wales that were focussed on reducing the landfill of BMW.
LATS	Landfill allowance trading scheme No longer in force, this scheme applied in England and was focussed on reducing the landfill of BMW.
MBT	Mechanical biological treatment
MRF	Material recovery facility
MSW	Municipal solid waste

Abbreviation	Definition
PAS	Publicly available specification PAS100 applies to compost and PAS110 applies to digestate.
PET	Polyethylene terephthalate Also abbreviated to PETE, this is the chemical name for polyester.
PFI	Private finance initiative
PPP	Public-private partnership
RAL	Reichs-Ausschuß für Lieferbedingungen und Gütesicherung This is the committee for delivery and quality assurance in Germany.
RDF	Refuse derived fuel
SCM	Scottish carbon metric
SEPA	Scottish Environment Protection Agency
SOM	Stabilised organic material Sometimes known as compost like output (CLO) or 'stabilite' (see CLO above).
SRF	Solid recovered fuel The term SRF is sometimes used interchangeably with RDF, but SRF generally refers to a fuel that is more consistent in quality and that has been produced to stricter quality criteria.
TGAP	Taxe Générale sur les Activités Polluantes In France, landfilling and incineration activities are subject to this general tax on polluting activities.
WRATE	The Waste and Resources Assessment Tool for the Environment
WTS	Waste transfer station

1 Introduction

1.1 Background

A ban on the landfill of biodegradable municipal waste (BMW) (the ban) will come into force in Scotland on 31 December 2025. On that basis, local authorities in Scotland will need to review options for processing of residual municipal solid waste (MSW) (residual waste) to ensure future compliance with the ban.

A key objective of the ban is to help reduce Scotland's carbon emissions on a carbon dioxide (CO_2) equivalent basis.

In order to address the ban, there are two ways to treat residual waste prior to its landfill. These are energy from waste (EfW), with resultant landfill of any ash that is not recycled, and biostabilisation in mechanical biological treatment (MBT) facilities. The treatment of organic matter to increase its stability is known as 'biostabilisation' and requires the use of either an aerobic or anaerobic biological process.

The project documented in this report was commissioned to consider biostabilisation as a means of meeting the ban, principally with consideration to the subsequent disposal of treated waste in landfill.

MBT processes are also employed to produce compost like output (CLO) for application to land and as part of a treatment process that produces refuse derived fuel (RDF) or solid recovered fuel (SRF) for energy recovery. However, such processes are not the primary focus of this study. Where RDF/SRF is produced in MBT processes, it is sent for combustion and energy recovery rather than landfill and can typically comprise around 50%, sometimes much more if the output of the biological process is what forms the RDF/SRF, of the input residual MSW. As such, an MBT facility with RDF or SRF production is not predominantly aimed at 'biostabilisation', but largely on producing fuel for EfW.

Organic material present in residual waste will degrade under aerobic or anaerobic conditions, generating carbon dioxide and, in the case of anaerobic processes, methane. Both gases have a global warming potential (GWP), and that of methane is 28 times[5] greater than carbon dioxide over a 100-year period.

When waste is landfilled it is subjected to anaerobic conditions and generates landfill gas, which contains high levels of both methane and carbon dioxide. Paragraph 4 of Schedule 3 of The Landfill (Scotland) Regulations 2003 (as amended) (the 'Landfill Regulations') requires that landfill gas must be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and, to the extent possible, used. These regulations also require that landfill gas which cannot be used to produce energy must be flared. However, even in a well-designed and operated landfill, where landfill gas is generated it is not possible to fully capture it all and the emission of landfill gas to atmosphere is a significant source of global warming gases. In 2019, emissions of methane from waste management in Scotland amounted to 1.4Mt CO_2eq (Scotland's total emissions of greenhouse gases amounted to 47.8Mt CO_2eq in 2019, of which 9.2 Mt CO_2eq were methane emissions)[6].

The landfill of biostabilised residual waste will generate significantly less landfill gas, and global warming impact from methane, than the landfill of residual waste that has not first been biostabilised, thus meeting the main objective of the ban.

1.2 Aim and approach

The project aims were to understand the potential role of biostabilisation as an approach for meeting the ban in Scotland, and to establish the carbon balance associated with MBT in Scotland.

From project inception, the approach utilised in this study was refined and developed in collaborative discussion with Zero Waste Scotland.

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[5] IPCC Fifth Assessment Report
[6] https://www.gov.scot/publications/scottish-greenhouse-gas-statistics-1990-2019/pages/3/

The high-level approach to fulfilling the project aims was to set out what biostabilisation of residual waste involves, to review how techniques have been implemented in Britain and selected EU countries and to undertake a carbon lifecycle assessment for the biostabilisation of residual waste. This information allows a summary to be made of factors, such as technical, economic, policy and environmental, that might influence the success, or otherwise, of MBT facilities in the Scottish context.

The main activities that were undertaken for this study are listed below.

- Identification of the methods of biostabilising residual waste, which all involve mechanical biological treatment (MBT) technologies, and their respective benefits and limitation, including in the context of the Scottish BMW landfill ban.
- Identification, through desk-based study and Ricardo knowledge, of how many MBT facilities exist in Britain and what processes are employed at each facility.
- Desk study review of how and why MBT has been employed in France, Spain, Italy and Germany, as countries that have an established track record in MBT development. This includes six case studies that were selected from a list of 28, in collaboration with Zero Waste Scotland to ensure coverage of a range of technologies and facility configurations. The main area of interest for this project is removal of recyclable materials and biostabilisation of the remaining residual waste, without RDF production, and with subsequent landfill of the biostabilised output. That is not a typical approach employed by MBT facilities and so the case study sites instead present a range of facility and output scenarios, with elements that might be applicable in the Scottish context.
- Undertaking of a carbon life cycle assessment for biostabilisation processes that could be employed in Scotland to meet the biostabilisation criteria for the landfill of residual waste. This includes processes with and without RDF production.

Some of the discussion in this report has been informed by the experiences of Ricardo staff, whether gained at Ricardo or not, that have collectively worked on many MBT facility projects in the UK. For confidentiality reasons, it is not possible to elaborate on where and when that experience was gained.

2 Policy and legislation in Scotland

2.1 Making Things Last: A Circular Economy Strategy for Scotland 2016[7]

Scotland's strategy focuses on four main areas: food and drink, remanufacture, construction, and energy infrastructure. It seeks to encourage circular business models across Scotland though funding and investment, such as hire and leasing systems and performance-service systems. As with the other circular economy strategies, there is also discussion of the need to reform producer responsibility and incentivise reuse and repair services. The drive of this strategy is to move resources up the waste hierarchy as much as possible, limiting the amount of residual waste produced.

The strategy sets out Scotland's waste targets, which include:

- A ban on biodegradable municipal waste going to landfill from 1 January 2021 (revised to 31 December 2025[8]).
- No more than 5% of all waste sent to landfill by 2025 (following the BMW to landfill ban).
- Reduce all food waste arisings in Scotland by 33% by 2025 and work with industry to reduce on-farm losses of edible produce.
- Reduce waste arisings by 15% against the 2011 baseline of 13.2 million tonnes by 2025.
- 70% recycling, composting and preparing for reuse of all waste by 2025.

The BMW landfill ban was revised from 2021 to 2025 due to '….*concerns that Scottish residual waste would be sent across the border to be landfilled in England, as some local authorities and commercial operators had not made sufficient progress towards complying with the ban*[8]'.

The implication of these waste targets is that Scotland's residual waste will continue to change in quantity and composition. The quantity of waste arising should reduce and an increase in composting and recycling will most likely involve increased source segregation and, therefore, less recyclable and organic materials within the residual waste stream.

If residual waste is to be biostabilised and subsequently landfilled without production of RDF, there may be an implication to the achievement of the target of not landfilling more than 5% of all waste. Where RDF is removed, it can typically comprise around half of the input residual waste. If residual waste is to be sent direct to EfW, the resultant bottom ash, much of which can be recycled, and air pollution control residue, will represent a lower mass of waste to be landfilled than by the biostabilisation and landfill approach to residual waste management.

2.2 Landfill tax

Landfill tax is a tax paid by landfill operators on the disposal of material at a landfill site[9]. The tax was introduced in 1996 to incentivise the diversion of waste from landfill and to promote waste reduction and recycling.

From April 2015, the Scottish Landfill Tax is being administered by Revenue Scotland and receipts/declarations are no longer included in HMRC figures.

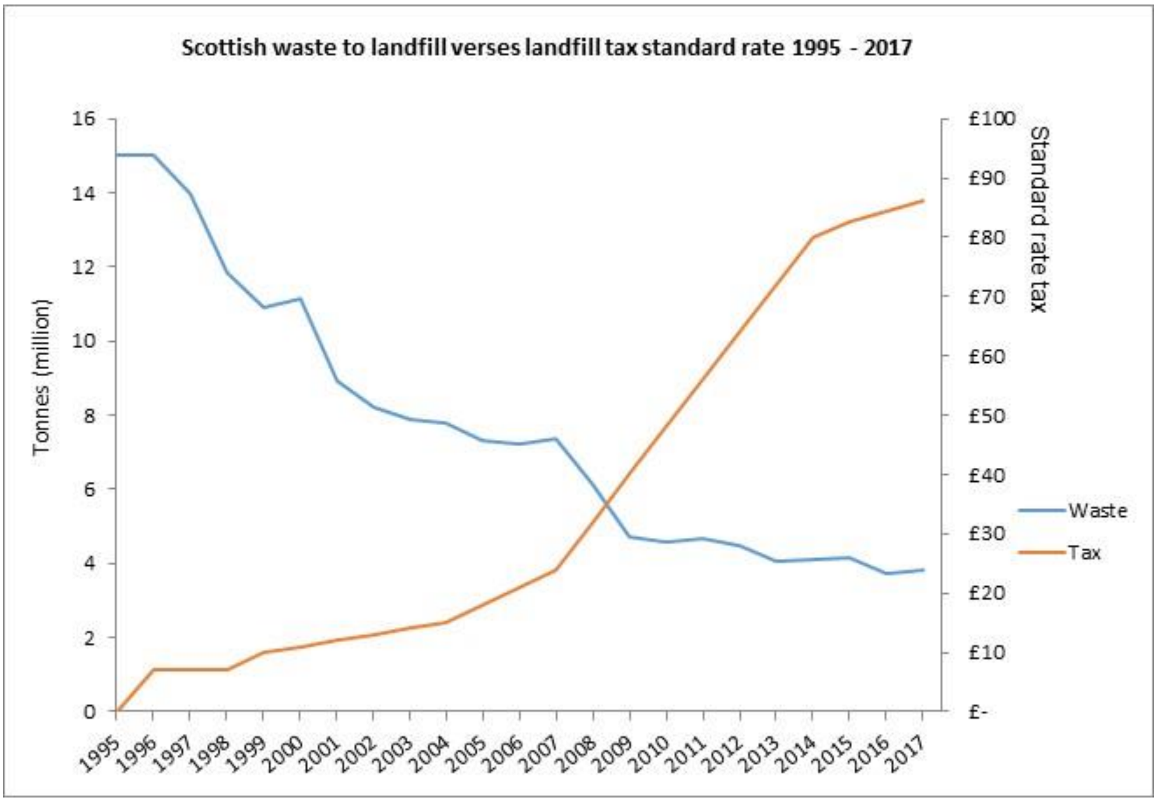
The tax is charged on a weight basis, but there are two rates depending on the type of waste. Non-hazardous and low-polluting waste, such as non-biodegradable wastes that have low organic content or do not break down under the anaerobic conditions that prevail in landfill sites to produce methane are charged at a lower rate, while all other taxable materials are charged with the standard rate. In 2021, the lower rate in Scotland was £3.10 per tonne and the standard rate was £96.70 per tonne[10].

[7] https://www.gov.scot/publications/making-things-last-circular-economy-strategy-scotland/pages/17/
[8] https://www.letsrecycle.com/news/latest-news/scotland-reluctantly-pushes-landfill-ban-to-2025/
[9] https://www.gov.uk/government/statistics/landfill-tax-bulletin/october-2020-commentary
[10] https://revenue.scot/taxes/scottish-landfill-tax/slft-rates-accounting-periods

Landfill tax has been a key factor in the changing of attitudes leading to the diversion of waste from landfill. As seen in Figure 1, the rate of landfill tax has been increasing since it was introduced, whilst the quantity of waste sent to landfill has reduced.

By diverting waste from landfill, the landfill tax has promoted other waste management routes, primarily incineration, and those other routes increased by 199% between 2011 and 2019[11].

Figure 1: The reduction of waste landfilled in Scotland against the rising landfill tax[12]



2.3 Compost and digestate standards

SEPA's 'Regulation of Outputs from Composting Processes'[13] specifies the requirements for the output from a composting process for it to cease to be waste.

In order for it to achieve product status and no longer be subject to waste regulatory controls, the treatment process and any compost produced must be certified to conform to the standards contained in BSI PAS100:2018 Specification for Composted Materials (Publicly Available Specification, PAS). In addition, there are 'Additional Scheme Rules for Scotland' that must be adhered to as well as limitations on plastic content that are more stringent than the PAS100 requirements.

Pertinently, the PAS100 Specification requires that input materials to the composting process shall be source segregated biowastes and/or source segregated biodegradable materials. This requirement means that outputs from the composting of residual waste cannot conform to PAS100 and must remain regulated as waste, which prevents opportunities for its use as a non-waste product. Other requirements preclude the use of sewage sludge or its derivatives and preclude the blending of outputs with other materials in order to meet the required quality criteria.

For similar reasons, the outputs of digestate from anaerobic digestion plants treating residual waste cannot conform to BSI PAS110:2014 (Specification for whole digestate, separated liquor and separated

[11] https://www.sepa.org.uk/media/527075/2019-waste-incinerated-commentary.pdf
[12] https://www.sepa.org.uk/regulations/waste/scottish-landfill-tax/
[13] https://www.sepa.org.uk/media/219843/wst-g-050-regulation-of-outputs-from-composting-processes.pdf

fibre derived from the anaerobic digestion of source-segregated biodegradable materials) and must remain regulated as waste.

2.4 Biostabilisation criteria

The forthcoming ban on the landfill of BMW is detailed within The Waste (Scotland) Regulations 2012 ('the Regulations'), which amends regulation 11 of The Landfill (Scotland) Regulations 2003 (the 'Landfill Regulations'). Regulation 11 is concerned with the prohibition of acceptance of certain wastes at landfill and the amendment adds biodegradable municipal waste to the wastes types to be prohibited. The date of prohibition is detailed as 1st January 2021, but that was subsequently amended to 31 December 2025. The amendment includes a definition of biodegradable municipal waste as follows:

> *For the purposes of this regulation, waste is–*
>
> *….*
>
> *""biodegradable municipal waste" if it consists of municipal waste that is also biodegradable waste, but does not include waste—*
>
> *(i) that is treated, and either—*
>
> > *(aa) respiration activity after a static respiration test is less than 10 milligrams of oxygen for each gram of dry material; or*
> >
> > *(bb) dynamic respiration over one hour is less than 1000 milligrams of oxygen for each kilogram of volatile solids;*
>
> *(ii) that is incinerated, and the total organic carbon content is less than 5%"*

As such, to landfill biodegradable municipal waste, it must either be incinerated and contain no more than the permissible level of organic carbon content, or it must be treated such that it meets the stability criteria under 'aa' or 'bb', i.e. through biostabilisation.

Biodegradable waste is defined in Regulation 2 (1) of the Landfill Regulations as follows:

> *"biodegradable waste" means any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food, garden waste, paper and cardboard.*

SEPA Guidance[14] (WST-G-55, version 1, April 2018) provides more detail relating to the requirements of the Regulations:

> *BMW includes biodegradable household waste together with biodegradable waste which is similar to household waste such as, for example, waste from the retail and hospitality sectors. It includes residual ('black bag') waste and other mixed municipal wastes collected from households and commercial businesses coded as 20 03 01. In 2016, 1,223,587 tonnes of waste coded as 20 03 01 was landfilled in Scotland.*
>
> *BMW also includes sorting residues from processing mixed municipal waste often coded as 19 12 12. In 2016, 779,521 tonnes of 19 12 12 waste was landfilled in Scotland although not all of this was from municipal sources. It is important to distinguish between sorting residues from different sources so that sorting residues from BMW are not landfilled. Mixed sorting residues derived from sources which include municipal waste will be assumed to be wholly municipal waste for the purpose of the ban.*
>
> *….*
>
> *The Regulations provide two ways to demonstrate that treated BMW is no longer biodegradable and can, therefore, be landfilled. The tests set out in the Regulations are linked to two types of treatment – Mechanical Biological Treatment (MBT) and Incineration (Energy from Waste (EfW)).*

[14] https://www.sepa.org.uk/media/352595/sepa_bmw_landfill_ban_guidance_note.pdf

> *If the waste undergoes a mechanical biological treatment, any residues destined for landfill must achieve either;*
>
> *• a Respiration Activity after four days (AT4) below 10 mg O_2/g dm; or*
>
> *• a Dynamic Respiration Index below 1,000 mg O_2/kg VS/h*
>
> *If the waste is incinerated, any residues destined for landfill must achieve a Total Organic Carbon value of less than 5%.*

The amended Landfill Regulations mean that when municipal waste that is biodegradable is treated to meet the required criteria it is not then, for the purposes of the regulations, '*biodegradable municipal waste*'. That means that the waste is not '*capable of undergoing anaerobic or aerobic decomposition*'.

From a technical perspective, that waste treated to such levels exhibits respiratory activity when tested in a laboratory implies that it is undergoing decomposition. However, such treated waste will be more stable compared to untreated BMW. Waste being subject to MBT processes, or if it is landfilled, degrades exponentially and so a substantial increase in stability can be achieved in a short period of time relative to the period required for full decomposition.

Although the landfill ban criteria relate to the landfill of treated waste and not to the application of material to land, it is useful to consider criteria for the application to land to provide context.

- In a 2014 EC Joint Research Centre (JRC) report[15], the following limits were proposed as potential end of waste stability criteria (numbers and units changed to equate to the Scottish ban units):
  - ≤ 800 mg O_2/kg VS/h (for compost)
  - ≤ 1,600 mg O_2/kg VS/h (for digestate)

  The proposed stability criteria are part of wider proposed end of waste criteria, and are proposed '*to protect the market against insufficiently treated materials which may cause adverse environmental impacts during storage, transportation and application….A minimum stability should avoid unwanted emissions during transport and storage and prevent materials from entering the market without proper treatment*'.
- A 2015 EC commission decision[16] is concerned with '*establishing the ecological criteria for the award of the EU Ecolabel for growing media, soil improvers and mulch*' and contains the following provisions for stability (numbers and units changed to equate to the Scottish ban units):
  - Stability requirements of soil improvers and mulch intended for non-professional applications and growing media intended for all applications: ≤ 480 mg O_2/kg VS/h
  - Stability requirements of soil improvers and mulch intended for professional applications: ≤ 800 mg O_2/kg VS/h

The EU Ecolabel criteria were proposed in a 2015 JRC report[17], which notes that the proposed limit for professional applications is based upon the 2014 JRC report on end of waste. The report also refers to the end of waste stability limit for digestate, albeit that does not feature in the Commission Decision. The report notes:

> *The minimum stability for professional uses proposed in the EU Ecolabel criterion is meant to ensure a sufficient level of stability, while preventing the introduction of materials that have hardly undergone any treatment (e.g. so-called "shred-and-spread" compost), despite the fact that these untreated materials might be used in agriculture. The figure proposed ensures that the materials were processed to get a reasonable level of stabilization by means of aerobic stabilization. In the case of digestates, a post-composting process would be needed, to overcome the market barriers identified and to improve the perception of the waste-derived products. This aims to avoiding methane and odour emissions, while it suffices to comply with*

[15] End-of-waste criteria for biodegradable waste subjected to biological treatment (compost & digestate): Technical proposals, JRC scientific and policy reports, European Commission, 2014

[16] Commission decision (EU) 2015/2099 of 18 November 2015

[17] Revision of the EU Ecolabel Criteria for Soil Improvers and Growing Media, Technical report and draft criteria proposal, JRC scientific and policy reports, European Commission, 2015

the market expectations for professional purposes, which often use active compost, for soil improvers or mulch, according to the feedback received from the stakeholder.

The 2015 JRC report quotes work undertaken by others[18] in which proposals are put forward for categorisation of compost product stability for biowaste and green waste compost. The categorisation is copied as Table 1.

Table 1. Proposals for categories of compost stabilisation (2015 JRC report)

Category of compost product	Oxygen uptake rate (mg O_2/kg VS/h)
Very unstable	> 960
Unstable	480 – 960
Stable	160 – 480
Very stable	< 160

Whilst some of the values discussed above are below the Scottish ban criteria, i.e. more stringent, the Scottish ban criteria is for treated BMW to be disposed to landfill and represents significant improvement in stability compared to untreated BMW. The EU Ecolabel and end of waste values illustrate that BMW treated to the Scottish ban limits will still generate some landfill gas when landfilled.

The generation of landfill gas from the landfill of biostabilised MSW has been considered in the carbon lifecycle assessment (carbon LCA) undertaken for this study.

[18] Veeken A.H.M., de Wilde V., Hamelers H.V.M., Moolenar S.W. and Postma R. (2003) OxiTop measuring system for standardised determination of the respiration rate and N-mineralisation rate of organic matter in waste material, compost and soil. Wageningen University, Netherlands.

3 Mechanical biological treatment and biostabilisation

3.1 Overview of MBT processes

As the name suggests, MBT is the treatment of waste by both mechanical and biological means. Biological treatment of waste degrades the organic compounds within it, meaning that if it is then landfilled it will generate less landfill gas than it would have without treatment. The more organic material that is degraded, the more stable the waste becomes, and the less landfill gas will be generated if the waste is subsequently landfilled. The biostabilisation of residual waste takes place in a controlled manner in an MBT facility.

Whilst treatment of source segregated food waste at an anaerobic digestion facility, or an in-vessel composting facility, involves both mechanical and biological processing, such a facility is not referred to as an 'MBT' facility. Instead, MBT processes typically refer to the treatment of whole 'black bag' or residual waste of domestic or commercial origin and there are typically several main material output streams (see section 3.5).

The biological process employed at an MBT facility most commonly involves one or more of the following:

- In-vessel composting (IVC).
- Biological drying (Biodrying).
- Anaerobic digestion (AD).

In some instances, such as at the Glasgow Recycling and Renewable Energy Centre, MBT facilities are integral to a thermal treatment processes, i.e. incineration or gasification (gasification is utilised in Glasgow).

In most instances, other than for biodrying, the biological process is preceded by a mechanical pre-treatment process.

3.2 Mechanical pre-treatment processes

An MBT process typically commences with the removal of contaminants, RDF and recyclable materials and size reduction. Contaminants may include items that might damage equipment, such as hazardous or oversize waste, grit, and materials unsuitable for recycling or energy recovery. Manual sorting by operatives sometimes accompanies the mechanical processing stages.

A greater degree of mechanical pre-treatment tends to take place at MBT wet-AD facilities (see section 3.3.3). However, metal recovery and size reduction, as a minimum, are found at the majority of MBT facilities.

Obtaining the best quality RDF, recyclable material or organic fraction for subsequent biological processing can require extensive mechanical processing, entailing high capital and operational expenditure. MBT facility pre-treatment processes can be relatively complex and can require a lot of effort to clean and maintain and a lot of power to operate. With knowledge of the composition and quality of the input waste, a decision must be made about what level of performance is desired and whether a high level of performance is worth the investment required. Potential future changes in waste composition must also be considered, although unless a planned change is known about, predicting future composition will produce uncertain results.

The impact of input waste composition not only influences the quality of outputs, but it can also influence facility throughput, and blockage and downtime events. As the input waste is separated by equipment into what can be numerous separate and interconnecting processing lines, the composition affects the amount of waste on each line and its bulk density. As waste composition changes over time, bottlenecks in the process may appear, subject to the equipment size margin employed at facility design.

The more waste is processed into different fractions, the greater the potential for loss of small fraction organic material to the other output streams, i.e. to RDF, recyclable materials and 'rejects' sent to landfill. However, the more the residual waste is processed, the better the quality of the different output material streams.

Municipal residual waste is, by definition, what remains when materials of greatest value are separated at source and, therefore, it is a relatively poor-quality waste stream. Whilst some recyclable materials and organic waste will be present, it will be of lower quality than would be expected if it was source separated. Food and liquids present will soak into paper, card and textiles and adhere to them and all wastes will be intermixed and require separation, which cannot be realistically achieved with absolute success.

Whatever form of residual waste treatment is employed, wherever practicable, source segregation of materials and waste minimisation should be the priority.

A large proportion, often around half, of residual waste can comprise materials suitable for use as RDF. This is likely to include a lot of materials, such as mixed plastic film, which has a low potential to be recycled. Therefore, RDF production is common at many MBT facilities.

Metals are relatively easy to remove and generally attract a revenue.

Size reduction aids material handling and homogeneity.

Where input waste, or output digestate, requires pasteurising, or other heat treatment such as pressure sterilisation, prior size reduction is also necessary to comply with animal by-product legislation. Whether such heat treatment is necessary, depends upon the intended use of the facility's organic stream output material. If the intention is for it to be landfilled or incinerated, heat treatment is not normally required. Owing to different temperatures achieved in the biological process, the particle size requirements are different for IVC than for AD.

Residual waste that is processed in an MBT facility, prior to being landfilled, should not require pasteurising or pressure sterilisation, because it will not become exposed to the food chain when landfilled.

The design of an MBT facility can vary significantly subject to the nature of the waste being processed, the desired facility outputs and simply because there are many ways of achieving the same result.

A wide range of equipment and configurations are available. Mechanical pre-treatment equipment commonly found at residual waste MBT facilities is described in Appendix A1.

3.3 Biological processes

3.3.1 IVC

Composting is where aerobic microorganisms in the environment, and present on the organic matter, utilise oxygen present in air to oxidise organic matter, and in so doing generate carbon dioxide, water, heat and compost. The process degrades and stabilises the waste.

Where organic materials from residual waste are processed, the composted material is often called 'compost like output' (CLO), in recognition of its poorer quality compared to compost from source segregated organics. The term CLO is generally only used when the stabilised waste is refined to remove physical contaminants prior to land application, e.g. for land restoration.

In industrial composting processes, methods are employed to optimise conditions to allow efficient composting. Such processes fall into two main categories, outdoor open windrow composting and IVC. Within Europe, including the UK, IVC is the only composting process used to treat organic materials separated from residual waste, as IVC processes are contained processes that can be managed to meet the requirements of animal by-product legislation. There are many forms of IVC technology from small-scale packaged units to largescale processes undertaken within buildings.

The active phase of composting, during which temperatures are thermophilic (around 50 to 70^{o}C), typically takes around 6 to 12 weeks and most of the degradation of organic material takes place in that time. When conditions are optimised, the temperature rises quickly in the early stages of active composting.

Many composting processes are followed by a period of maturation, during which active management of the process is minimal. Generally, limited active air input and no water are added, and only occasional turning takes place. During maturation, the temperature and rate of degradation gradually reduce, and the compost becomes 'matured'. Matured compost has a greater level of biostability than un-matured compost.

Composting duration is dependent upon the type of organic matter being composted, the design of the process, the operating conditions and the intended use of the compost.

Effective composting requires a careful balance of carbon and nitrogen within the waste feedstock and the presence of 'structure' materials within the waste mass, for example twigs and branches within green waste. Besides potentially compromising the biological process, a sub-optimal balance between carbon and nitrogen can cause odour issues. A feedstock with poor structure does not allow adequate air flow and can give rise to anaerobic zones within the waste mass, especially in liquid saturated zones.

Source segregated food waste generally has a high nitrogen content and poor structure, with high moisture content and a slop-like consistency. IVC of such feedstock typically requires addition of higher carbon content, higher structure materials such as green waste, woodchip or cardboard. However, organic feedstock separated from residual waste in an MBT-IVC facility typically has a lower moisture content, higher carbon content, principally resulting from paper and card, and improved structure due to the presence of plastics etc, when compared to source segregated food waste. There are examples, including in the UK, of the IVC of such residual waste organic feedstock without the addition of other materials.

Composting does not generate any usable energy and the heat generated typically rises to around 60 to 70^{o}C, which over a sustained period (e.g. one week at >60^{o}C) will beneficially kill pathogens and seeds.

With careful design and optimised operation, it is possible for residual waste to achieve the required Scottish biostabilisation criteria when treated in this way (see section 2.4 for criteria).

With enough retention time in the process and with appropriate control of operating conditions, the biological process will continue until such time as the organic material present is insufficient to sustain the process further. An MBT facility must be designed to allow the required retention time and conditions necessary to meet the required level of biostabilisation.

The end of waste criteria, and compost stability criteria, described in section 2.4 show that composting processes can biostabilise to a greater extent than necessary for the Scottish BMW landfill ban. Furthermore, Ricardo corresponded with two technology providers that confirmed that their processes can be designed to achieve the Scottish biostabilisation criteria.

3.3.2 Biodrying

Biodrying is a biological process with similarities to IVC, but the process is aimed at moisture reduction rather than biostabilisation.

Biodrying involves forced airflow through the waste mass, but no water is added, and the process typically takes only one to two weeks. The composting process commences during this time and the waste temperature rises, which, along with the air flow, drives off moisture. However, degradation of organic material will be limited over such a short time and a humus like composted material will not be produced.

Biodrying is often undertaken with a view to increasing the calorific value of the MSW for its use as RDF/SRF.

If undertaken prior to separation of waste components, as is common, biodrying can improve separation performance and recyclate quality as dry waste is less cohesive than wet waste.

Biodrying does not biostabilise organic components of residual waste to a level that would meet the requirements that would allow subsequent landfill of residual waste in Scotland from 2025 onwards.

3.3.3 Anaerobic digestion

The biological process in AD is very different to composting and utilises different microbes under very different environmental conditions, notably the absence of air. In AD, plant and animal organic matter is decomposed by microorganisms in the absence of air, to produce a methane-rich biogas and a solid or liquid known as digestate.

The main constituent gases present in biogas are methane (typically 50 to 60%) and carbon dioxide (typically 40 to 50%), with other gases generally only present at concentrations around 1 to 2%.

Industrial waste management AD can be undertaken using a wide variety of technology designs and variants. One fundamental consideration is whether the process is a wet or dry process.

In wastewater treatment, very low dry matter (e.g. 0.5% DM) feedstock can be treated in AD. Dry matter is the amount of solid material within the waste, measured with laboratory oven drying. However, where feedstocks are solid, perhaps with DM in the range of 35% up to 55%, reflecting source segregated food waste and residual waste organic fines respectively, they can be digested with (wet AD) or without (dry AD) addition of water or liquid waste.

Solid waste wet AD processes typically involve preparing a substrate to be input to the digesters (tanks where the AD process takes place) within the 5 to 15% DM range (a material with a DM of 15% contains 85% moisture). Above 15%/20% DM the process should be considered dry AD, which is a process that is designed and operated in a different manner to wet AD.

In Britain, wet AD is more commonplace than dry AD, although dry AD processes do exist. In continental Europe, dry AD is utilised more than in the UK, often at agricultural AD plants.

As water, or liquid waste, is often added to feedstocks to prepare them for wet-AD, the AD feedstock increases in volume, requiring larger digesters and greater heat input where pasteurisation is undertaken and for maintaining digester temperature at optimum levels (typically 37 to 40ºC for mesophilic processes and 50 to 55ºC for thermophilic processes[19]). However, the advantages are that wet AD digesters are relatively easy to mix and substrate and digestate transport through pumps and pipework is relatively straight forward. Mixing of wet-AD is necessary to prevent stratification of tank contents, into floating and settling material, and serves to distribute microorganisms and organic material throughout the digester.

The biological process in AD is more sensitive to disruption than composting. The process takes longer to establish and a sudden change in feedstock type or quantity, the presence of two incompatible feedstocks or a change in environmental conditions within the digester, can easily cause problems and slow down and hinder the biological process. A disrupted AD process can take a while to recover. In the worst case, an AD process will need to be restarted from scratch, which may take around three months, subject to feedstock type and size of the digesters. This period must not be confused with the normal retention time of substrate within the digester.

Substrate retention time, in normal operation, will vary subject to the size of the digesters and facility throughput, because increasing the rate of waste feedstock input requires taking more digestate out. Furthermore, different feedstock types require different retention periods for the organic material to break-down. The facility design, especially the size of the digesters, must be matched to the type of feedstock and volume throughput of the facility. A wet-AD process will typically have a retention time of between 20 and 60 days. Retention time is a consideration that affects the size of plant, whether AD or IVC, but is not a critical factor to consider when comparing the relative merits of technologies.

In contrast, composting processes will be initiated within a day and the process is far less susceptible to disruption.

Conditions should be maintained as near optimum and steady as possible, unless a dry batch AD process is employed. This is because dry batch AD involves processing waste in batches, such that conditions do not remain constant with time. In most instances other than dry batch AD, feedstock is input on a 'little and often' basis and digestate is removed in a similar manner such that digester

[19] Mesophilic and thermophilic are terms used to descr be bacteria that grow and thrive within certain temperature bands.

contents remain at broadly steady volume. This manner of operation does, however, mean that AD does not biostabilise feedstocks to such a level as can be achieved with IVC. That is because leaving the substrate in the digester to exhaust as much of the organic matter as possible would lead to microorganism stress and harm to the biological process. A greater degree of degradation might be possible with batch dry-AD processes, although batch processes are less suitable for high throughput facilities and are less efficient at producing biogas.

If AD is utilised, then it must be followed by IVC in order to achieve the level of biostabilisation necessary for it to be landfilled in Scotland. That is more problematic for digestate from wet AD than for digestate from dry AD, as explained below.

In an MBT-wet AD process, the organic substrate entering the digester must be as free as possible from contaminant materials such as grit and plastics, both of which can sink and float in the digester, and cause blockage and wear of pumps and pipework. These materials must be removed to a high level during dry and wet processing of the feedstock prior to entering the AD process. Where residual waste is processed, it is typical for much of the material removed to be utilised as RDF. The digestate exits with a low DM as a liquid, which is often separated out into a liquid fraction that can be treated for reuse in the process, and a solid cake, which can be further dried. The digestate cake has no structure and must be mixed with structural material for it to be processed in IVC.

The need to remove a large portion of the residual waste prior to wet AD, followed by the need to dewater and mix the digestate cake with a waste with more structure, e.g. green waste, means that wet AD is not a desirable technique to biostabilise waste prior to landfill.

In dry AD there is no need to remove material to such an extent prior to AD. In batch dry-AD processes, there is no need to remove any material. However, batch AD is not well suited to high capacity facilities and the process is less efficient than semi-continuous flow dry-AD. In semi-continuous flow dry-AD, there is a requirement to first remove RDF type materials to minimise contaminants, thus allowing better material handling, but it is not necessary to remove as much material as is necessary for wet-AD. The resultant digestate, which is relatively high in DM, will have much more structure than digestate from a wet AD process.

Dry-AD followed by IVC could potentially be used to biostabilise residual waste prior to it being landfilled, although the residual waste would need to be pre-treated to first remove RDF type materials.

The advantage that dry AD followed by IVC, versus IVC only, brings is that it produces biogas, which can be utilised as a fuel from which energy can be gained. That energy can be used to support facility operation and potentially for third party offsite use. The energy produced will be from a biogenic source and will potentially prevent or minimise use of energy from other sources, which may include some fossil-based carbon burning.

The disadvantage of dry-AD followed by IVC, versus IVC only, is that it adds to facility complexity, capital costs and maintenance demands and a facility needs to be designed to suit the quantity of organic material within the residual waste. If the organic content then reduces, for example due to the introduction of source segregation of domestic food waste, the financial viability of dry AD may then be compromised. Any waste facility needs to be designed around the intended input waste quantity and composition. However, the biogas and energy produced in an AD process is a key parameter in the facility energy balance and financial model and, therefore, contract/ performance expectations.

That an AD facility generates methane should not be viewed negatively from a carbon balance perspective. The subsequent combustion of the biogas or biomethane will result in carbon dioxide emission and AD facilities are designed to contain biogas and prevent air ingress. However, it is possible for an AD facility to emit methane to the environment in the following circumstances:

- Tanks containing biogas are fitted with pressure relief valves, which can emit biogas at times of undesirable high pressure within the tank headspace. This is a safety feature and pressure instrumentation on the tanks will identify that such an event has taken place. An operator should identify the cause of the over-pressure incident and should resolve it. Such emissions should be limited in frequency and quantity of gas escape such that they are negligible in environmental impact.

- Gas pipework and points where features, such as instrumentation, mixers and hatches, penetrate or attach to the digester can be sources of leaks. Such leaks might be evident from pressure records and should be identifiable during daily inspection activities. Biogas is odorous and corrosive, both of which can allow identification of even a small leak.
- A sudden loss of biogas can occur in the event of damage to a tank, gas holder or pipework. Such an event will be immediately evident to the operator who should take immediate measures to rectify the problem.

Biogas is a valuable fuel and its release can have safety implications, noting that it is both an asphyxiant and explosive gas when present in air at specific concentrations. Whilst biogas might escape in certain circumstances, as described above, it is an operator's interest to investigate and remedy such an event as an immediate priority. From an environmental impact perspective, emissions of methane from an AD facility should generally be negligible. The largest routine source of methane emission should be from engine exhausts (typically 99% methane destruction efficiency) or from 'methane slip' in the biomethane production process (this term and the treatment and use of biogas is discussed in section 3.5).

A summary of the comparison of dry and wet AD processes is provided in Table 2.

Table 2. Comparison of dry AD and wet AD

Aspect	Dry AD	Wet AD
Ability to meet Scotland's landfill ban biostabilisation criteria	Criteria can be met because the digestate has enough structure for subsequent treatment by IVC.	Low likelihood of suitability because the digestate would need to be dewatered and mixed with other materials to allow treatment in IVC in order to meet the criteria. This is the main factor making wet AD a contender of low interest if the intention is to biostabilise waste prior to landfill.
Extent of waste pre-treatment required (in addition to removal of recyclable materials)	Batch AD should require very little pre-treatment. Semi-continuous dry AD requires some removal of non-organic materials ('contaminants'- maximum level of contaminants in waste entering the digesters should be around 20% w/w), most commonly as RDF.	Requires a very high level of contaminant removal in pre-treatment. This is a significant disadvantage versus semi-continuous dry AD.
Ability to deal with high throughput of waste	Batch dry AD is not well suited to high throughput facilities. Although possible, it requires multiple reactors to prevent fluctuations in volumes of biogas production. Batch dry AD also requires considerable operator intervention to fill and empty reactors. Semi-continuous dry AD is suitable for high waste throughput.	Wet AD is suitable for high waste throughput.

Aspect	Dry AD	Wet AD
Ability to produce biogas (biogenic source of energy production)	Produces biogas. Unlike batch dry-AD, semi-continuous dry AD produces biogas more efficiently and with a more stable output.	Produces biogas. Produces biogas more efficiently than dry-AD because conditions (mixed state and temperature) are easier to control.
Ease of management	Harder to transfer and mix substrate and digestate than wet AD.	Greater ease of substrate and digestate handling than dry AD and with greater ease of maintaining optimal process conditions.
Main differences	Little or no water addition and little or no post AD digestate treatment (excluding the necessary IVC process) required. Requires a lower footprint area than wet AD and less pre-treatment (wet AD requires solid feedstock to be prepared into a homogenous slurry)	The opposite to what is stated for dry AD.

3.4 Facility flexibility

MBT is sometimes promoted by technology providers and waste management companies as being flexible to change in input waste composition. Certainly, a facility should be designed with some flexibility, but there are inherent limitations to that flexibility.

A Zero Waste Europe report[20] claims that an MRBT facility (material recovery and biological treatment) is '*inherently flexible*' since its processes may also be used for clean materials derived from separate collection. In this regard, the report refers to organic waste as well as different metals, different polymers and different paper grades. The report claims that MBT facilities that produce RDF cannot be adapted to process such clean materials.

The main distinction Zero Waste Europe makes between an MBT facility and an MRBT facility is that the latter does not generate RDF and is geared towards recovery of recyclable materials from residual waste, with biostabilisation of the remaining fraction prior to its landfill. It claims intensive use of equipment can allow recovery of very high percentages of recyclable material, albeit it acknowledges that the quality of recovered material will not be the same as for source segregated recyclable materials.

The Zero Waste Europe report references the possible use of plastic extruders for making low grade mixed polymer pellets. These are not typically found at MBT facilities. Extrusion of mixed polymers, bound to contain contaminants when sourced from residual waste, and making products from the resulting pellets, is a difficult process that often produces a low-grade product.

Ricardo disagrees with Zero Waste Europe's statements on facility flexibility, for the reasons listed below.

- If an MBT facility produces RDF, it does not mean that it cannot remove recyclable materials as well. There are examples of this amongst Britain's MBT facilities, and in two of the case studies discussed later in this report (both in Spain).

[20] Building a bridge strategy for residual waste- Material Recovery and Biological Treatment to manage residual waste within a circular economy- Policy Briefing, June 2020, Zero Waste Europe

- Whether or not an MBT facility produces RDF, a facility cannot simply be switched from processing residual waste to the processing of source segregated waste streams without considerable modification or process replacement. Residual waste and different source segregated waste streams have very different properties. Irrespective of the capacity of the main items of equipment, storage bays and conveyors would have to be of a size capable of handling different materials, and that is unlikely to be the case.

3.5 MBT outputs

Outputs from MBT facilities can include:

- Recyclable materials (wide range possible).
- A refuse derived fuel (RDF) or solid recovered fuel (SRF).
- Contaminants separated, that are unsuitable for the process, or cannot be recovered as a fuel or recycled and so must be landfilled.
- Processed organic material.
- Biogas or biomethane (AD only), and possibly heat and power generated from the gas.

Residual waste, input to an MBT facility, mostly contains materials for which there are no specific source segregation collection methods in place. It will, nonetheless, contain some materials for which there are other arrangements because source segregation measures are not always utilised correctly or by all service users.

Recyclable materials separated from residual waste are typically of low quality. In simple MBT processes, the only recyclables removed might be ferrous and non-ferrous metals, but all materials in MSW that are commonly recycled can be recovered in MBT processes.

- Food and drink waste, and other liquid waste, will adhere to and soak into other materials within the waste stream. That hinders the separation of food waste and reduces the quality of other materials streams.
- No separation process is perfect and non-target materials will be entrained and removed with target materials, and some target material will evade capture.
- The lower the proportion of a target material within residual waste, the harder it is to remove that material on a percentage recovered basis. Put another way, it is generally easier to recover 90% of a material that comprises a large portion of the input waste than to recover 90% of a material that comprises a small proportion of the input waste.
- To capture a large percentage of a material can sometimes require setting of equipment to ‘over recover’, wherein a high amount of the material is removed but, in so doing, a large amount of non-target material is also removed, which impacts quality. It is possible, for example, to over recover a greater mass of non-ferrous metal and contaminants than there is non-ferrous metal present within the incoming residual waste.
- If the operator’s priority is to recover material of high quality, it might have to set equipment to under-recover, wherein some of the target material remains uncaptured but the captured material is of reasonable quality.

In a similar manner, separating organic material from residual waste is more problematic when it is only present at low levels, and quality can be poor in such instances.

Processed organic material can be managed in several ways. The output from IVC processes is sometimes known as compost like output (CLO), stabilised organic material (SOM) and ‘stabilite’ is a term commonly used in continental Europe. The output from AD processes is known as digestate.

As it is not from a segregated source, CLO or digestate cannot comply with the requirements of PAS100 (publicly available specification for composted materials) or PAS110 (publicly available specification for whole digestate, separated liquor and separated fibre derived from anaerobic digestion), nor the Quality Protocols employed in England, Wales and Northern Ireland or the Additional Scheme Rules for Scotland. As such, it remains a waste following treatment and subject to continued regulation as a waste. Due to the quality of CLO and its regulation as waste, there is effectively no possibility for it to be utilised in agriculture where food production is involved.

For CLO or digestate to be applied to other (non-food production) land, where it is used in place of non-waste material to perform a particular function i.e. for land restoration purposes, regulator approval is required in each case to ensure that the waste recovery test is met for each particular scheme. This poses a problem for operators because MBT facilities are typically constructed with a 25-year life, and each land restoration project will have limited demand for the CLO or digestate. The experience of UK MBT operators has been one of difficulty finding such outlets for digestate and CLO, and sometimes difficulty in securing approval from the regulator.

- IVC output and dried digestate can be used as an RDF, used as landfill daily cover, landfill restoration layers or it can simply be landfilled.
- With regulator approval, CLO can be used for land reclamation, but not on land used for food production.
- Wet AD digestate can be dewatered with water treatment and water reuse or disposal. The solid cake can be used in a similar manner to CLO.
- Dry AD digestate can be subject to IVC processing to further biostabilise it. It can be used in a similar manner to CLO and wet digestate.

Biogas is commonly combusted on site, to produce heat and electricity, often in combined heat and power (CHP) engines or upgraded on site to biomethane. Biomethane has properties like natural gas, and can be injected to the mains gas network, compressed and used as a vehicle fuel or it can be compressed and transported by road.

Biomethane production has become increasingly popular at UK AD facilities in recent years. Upgrading biogas to biomethane can be undertaken using several processes, and the main process stage is the removal of other gases, the greatest of which in percentage terms is carbon dioxide (CO_2). The stripped CO_2 is often vented to atmosphere, but there are some examples of it being captured, purified and bottled for industrial use, albeit not at British MBT facilities.

The overwhelming majority of MBT facilities in the UK and continental Europe generate RDF/ SRF, which can be a significant portion of the total of all output materials, often around 50%. Both RDF and SRF can be subject to conventional incineration or advanced thermal technologies such as gasification. SRF is a more consistent and higher quality RDF and is often used at cement kilns.

4 British MBT facilities

4.1 Data reviewed

Ricardo identified existing British MBT facilities utilising its in-house facilities database (FALCON) and through internet research and review of waste return data for 2019, to establish information for each MBT facility. Much of the information discussed below reflects the situation with British MBT facilities in 2019, and some change may have occurred since then.

For each facility, Ricardo sought to establish whether it utilises biodrying, IVC, dry AD or wet AD as the biological stage of the MBT process and to determine whether RDF is produced.

Where waste returns data is discussed, it should be borne in mind that:

- Some sites report sitewide data rather than data at a process by process level, which means the data will not always accurately reflect outputs from the MBT facility. Many sites are integrated facilities that might, for example, include household waste recycling centres (HWRC), composting of source segregated organics, residual waste MBT etc. However, where the data and internet review indicate that an MBT process involves production of RDF/SRF, this is detailed within the discussion in this report.
- There is generally a difference in input and output tonnages that is due to process loss, principally the result of moisture loss and breakdown of organic material, but it can also reflect an onsite landfill or onsite incineration/gasification process. Where percentage outputs are detailed (Appendix A2), they reflect the percentage of all solid material outputs, i.e. no account is taken for process loss or onsite thermal treatment or landfill.
- Waste returns data obtained from Waste Data Interrogator[21] describes the fate of facility outputs as one of the following:
    - Incinerator[22]
    - Landfill
    - Recovery
    - Transfer (typically a small amount of total waste outputs from a facility)
    - Treatment (typically a small amount of total waste outputs from a facility)

  'Recovery' mostly refers to materials separated for recycling and outputs from biological processes (AD and composting) that qualify as 'recovery' (not likely in relation to biological processing of residual waste). In the context of Waste Data Interrogator, the term 'recovery' should not be confused with 'energy recovery', which in many other contexts is often simply called 'recovery'. However, it is evident that some operators, on occasion, include RDF in the 'recovery' category when submitting waste returns. The tonnages are comparatively low compared to the RDF included under 'Incineration'. Waste returns are not always submitted in correct or consistent form, but anomalies are not significant for the purposes of this report.
- Waste return data may not reflect 'normal' operation in instances where facility operation is disrupted such that waste is not processed in the normal manner. A snapshot (for 2019) has been presented.

Even with consideration to the above points, the data is useful in informing whether RDF is produced within the MBT process and to show the typical split in solid outputs.

4.2 Scottish MBT facilities

Scotland has two MBT facilities, which are the Glasgow Recycling and Renewable Energy Centre (GRREC) and Lochar Moss in Dumfries and Galloway.

At GRREC, mechanical processing is followed by wet AD (BTA international GmbH technology) and a gasification (Energos energy from waste) process is integrated with the residual waste MBT process.

[21] https://data.gov.uk/dataset/d409b2ba-796c-4436-82c7-eb1831a9ef25/2019-waste-data-interrogator
[22] In frequency and tonnage, this mostly refers to 'R1' recovery, but also includes some 'D10' disposal operations (codes from the EU Waste Framework Directive).

As such, the MBT facility is RDF and wet-AD focussed and, therefore, cannot biostabilise waste such that it could be landfilled following the 2025 ban. However, the process avoids the landfilling of BMW and so, assuming its waste is processed in the facility as intended and the total organic carbon in the ash is below the required limit, waste processed at the facility will be able to comply with the requirements of the biodegradable waste landfill ban.

The Lochar Moss facility is a biodrying/RDF facility (Ecodeco technology). Waste return data for 2019 shows that the single largest output fraction was RDF. Whilst the facility may potentially be able to meet the requirements of the ban, it will not do so by biostabilisation, as the MBT process employed is biodrying and RDF production.

There are three facilities in Argyll and Bute which some sources, including documents from Argyll and Bute council, describe as MBT. These facilities are Dalinlongart, Lingerton and Moleigh. However, it appears[23] that these facilities comprise landfill, HWRC, composting (non-residual) and transfer station i.e. not residual waste MBT. Waste return data for 2019 also supports that position.

Argyll and Bute Council is considering how to address the forthcoming ban on landfill of BMW and the operator of the above mentioned facilities (Renewi- under a public-private partnership, PPP, arrangement) has proposed replacing the facilities with MBT-IVC, with RDF production, as an option (with assumed 60% RDF production and 40% treated in IVC)[24]. The strategy for the council addressing the ban was still under development towards the end of 2020 although the MBT-IVC solution remained a key consideration, as was a 'Total Transfer Solution'[25].

Avondale Landfill (Falkirk) is home to an RDF production plant (material recovery facility- MRF), which opened in 2012 and then shut shortly afterwards, owing to financial considerations and is understood to now be operational again[26]. Around 2007 there was talk of the construction of an MBT facility on the site[27], although it is understood that did not progress further.

4.3 Welsh MBT facilities

Wales has one MBT facility, which is a biodrying facility that was commissioned in 2015 and is known as Wrexham Recycling Park (Phase 2)[28].

Waste return data for 2019 shows material outputs as comprising 81% destined for incineration and 19% destined for recovery, i.e. recycling.

4.4 English MBT facilities

Twenty MBT facilities have been identified in England and the split between organic processing type is detailed below.

- 6 Biodrying (all produce RDF/SRF)
- 8 Wet AD (all produce RDF/SRF in pre-treatment mechanical processing)
- 1 Dry AD with IVC (produces RDF)
- 5 IVC (four out of the five produced RDF in 2019)

The only English MBT facility that does not produce RDF is the Waterbeach MBT-IVC facility in Cambridgeshire, which is operated by AmeyCespa (East) Limited (Amey).

Waste return data shows that the composted output from the Waterbeach facility was landfilled in 2019. However, Amey is keen to develop an energy from waste facility at the site. A planning appeal for the energy from waste facility was rejected in June 2020[29].

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[23] https://www.sepa.org.uk/media/286895/waste_sites_capacity_2015.xlsx
[24] https://www.argyll-bute.gov.uk/sites/default/files/draft_waste_strategy_document.pdf
[25] https://www.argyll-bute.gov.uk/moderngov/documents/s166133/Waste%20Management%20Strategy%20Update.pdf
[26] [redacted]

The authors of this report have not established what level of biostabilisation is being achieved at the Waterbeach facility, which will be influenced by the waste input, the facility design and manner of operation. IVC technology can, subject to design and operation, achieve a level of biostabilisation that can meet the criteria associated with the forthcoming landfill ban in Scotland, but that criteria does not exist in England.

Details for the English MBT facilities, including 2019 waste return summary data for outputs, are provided in Appendix A2. A small number of the facilities are residual waste MRF only, as the organic fraction is sent to a biological processing facility operated by the same organisation but on another site. Where that is known to be the case, it is mentioned in Appendix A2 but still classed as an MBT facility, as the overall process is MBT, even if not undertaken at one site.

4.5 Britain's experience with MBT

Some of the discussion below has been informed by the experiences of Ricardo staff, whether gained at Ricardo or not, that have collectively worked on many MBT facility projects in the UK. For confidentiality reasons, it is not possible to elaborate on where and when that experience was gained.

There is only one British MBT facility (Waterbeach in Cambridgeshire) that was designed, and is operated, with the intention of not producing any RDF, but instead to remove recyclable material and to biostabilise the remainder for subsequent landfill. The remaining 22 British MBT facilities identified in this report all produce RDF, thus reducing the amount of material that might be landfilled.

The prevalence of RDF production and the desire to limit the amount of waste landfilled reflects the impact of policies and instruments in place, and some MBT facility designs benefit from prior removal of RDF materials that would otherwise prevent or hinder effective biological processing of the waste.

Policies and instruments include the landfill tax, the discontinued landfill allowance trading scheme (LATS) in England and discontinued landfill allowance scheme (LAS) in Scotland and Wales, both of which aimed to limit the landfill of BMW, the ban on certain wastes being landfilled (stemming from the Landfill Directive) and the waste hierarchy. The waste hierarchy involves disposal to landfill being the least favoured of all options and energy recovery sits above it in the hierarchy.

In its 'Waste Strategy for England 2007' document, Defra wrote:

> *'…markets are developed for secondary recovered fuel, of which England is expected to produce some 2 million tonnes a year from existing and planned mechanical biological treatment plant from 2009 onwards. Developing such markets has the potential for big benefits for the UK's most energy-intensive industries, protecting jobs and with benefits to social cohesion…'*

MBT has been discussed further by Defra in a detailed report, which includes positive comment of how MBT can help contribute to meeting national targets, first issued in 2007 and updated in 2013[30].

In excess of 20 MBT facilities have been constructed in Britain. Some of these facilities have been in operation for a notable number of years, and the construction of some has been informed by negative attitudes towards thermal treatment. However, there have been reports in trade press of issues at some British MBT facilities, including issues with technology design, under-performance against contract targets, poor financial performance, contractual disputes, contract termination and some facility closures. Such issues have also occurred with other residual MSW technologies and contracts, but it is nonetheless useful to be aware of the issues encountered with MBT implementation in Britain to date. The British experience has also often included difficulty in securing outlets for CLO/digestate and issues with the quality of recyclable material affecting the revenue, or cost, it attracts.

30
https://webarchive.nationalarchives.gov.uk/ukgwa/20130403153720/http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/mbt.pdf

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/221039/pb13890-treatment-solid-waste.pdf

In a 2017 briefing report on MBT[31], Tolvik Consulting considered the cost of waste management across 29 waste disposal authorities. The report notes that the five most expensive, per tonne of residual waste treated, primarily relied upon MBT, whereas only seven of the 29 primarily rely upon MBT. The authors noted that the analysis was '*not necessarily the most robust*' but that their findings were '*unlikely to be a co-incidence*'.

MBT processes vary significantly in terms of technology, complexity, scale and cost. Local authority contracts are generally in place for several years, and many MBT facilities have been developed under PPP and PFI agreements, with complex contractual terms, that include wider waste management services. Determining a cost for MBT, and then making comparisons with other technology options is therefore problematic at the national scale.

WRAP gate fee report information has been reviewed, with comparison between EfW and MBT, and is reported in Appendix A3.

The WRAP gate fee data for MBT contains limitations, as stated in its reports, and since 2018 WRAP no longer reports information for MBT. As such, the information should be treated with caution.

The WRAP gate fee data does not show a significant difference between reported gate fees for MBT and energy from waste facilities. However, the data for MBT facilities is only presented up until the 2017 WRAP report, which reports data for the 2016 calendar year.

For reasons explained above, it is difficult to arrive at a typical gate fee for British MBT. However, there is no evidence to suggest that it is a cheaper option than energy from waste and, in some instances, it may prove to be the more expensive option per tonne of waste treated.

Another factor that has influenced the experience of MBT in Britain has been the nature of the contractual arrangements between the parties involved in facility development and operation. This has often been long-term, complex, bespoke PPP/PFI, or similar, contracts between local authorities, waste management companies and lenders, with similar engineer, procure and construct (EPC) contracts between the main contractor and sub-contractors.

Some aspects of such contracts are associated with risk share, such as the payment mechanism, performance guarantees, performance deductions and liquidated damages. A local authority will sometimes be prepared to pay 'a bit more' to limit its exposure to fluctuations in market conditions. That might include fluctuations in downstream treatment and disposal costs and revenues from sale of materials and energy. The contractor will assume the risk but is hopefully compensated by receiving a good payment per tonne of waste treated, as determined by the payment mechanism. It is the contactor that factors in the risk when calculating its desired gate fee in contract negotiations. Similarly, the contract will typically make provisions for facility unavailability, or under-performance, wherein the local authority is afforded some protection. Again, the contractor will assume much of the risk alongside receipt of a good payment per tonne.

The risk share described above has merit and rationale. However, such contracts are typically in place for around 20 years, and a lot can change in a short space of time. Irrespective of cause, whether technical error in facility design, change in waste composition, or change in market conditions, there is plenty of scope for one or more parties to a contract to become dissatisfied. That might be a local authority paying a premium price when it sees that other, cheaper, options have become available, or it might be a contractor paying high penalties and liquidated damages. Sometimes the pain can be mutual. Complicating the picture is fast changing waste and resource policy and legislation. Quite often, disputes between parties involve discussion of waste composition.

The result of some contractual situations in the UK has been contract termination, companies going into administration, high insurance pay-outs and, on occasion, facility closure or significant modification. That situation can, and does, occur with any type of waste management facility and contract type. However, the technical complexity of MBT, its sensitivity to waste composition changes and its numerous material outputs lends itself to such problems.

3 [redacted]

A technical performance problem might, at face value, seem straight forward and relatively cheap to fix in capital expenditure terms, but the damages associated with facility downtime or landfill of waste that should be treated, can be quite the opposite. Similarly, the impact of a small change in waste composition might be limited in terms of physical facility performance but might have significant financial implications if damages are triggered under the contract, or contract provisions rendered void by out of specification waste; and that can be in the favour of either party.

5 France

5.1 Legislation and policy

Although France is a unitary state, some waste management responsibilities are delegated to the regions (départements) and that gives rise to differences in implementation. Whilst national requirements must be met, priorities vary at the regional level. Local authorities are responsible for the household waste management services. They are also responsible for the rules that apply to the finance of these services, such as taxes and duties. Commercial and industrial waste streams are the responsibility of the companies that generate them.

The first Grenelle law was implemented in 2009[32] and it introduced measures and specific, time-bound, targets such as:

- 7% reduction of the production of household waste and similar waste between 2009 and 2014.
- 15% reduction of waste sent to landfill or incineration between 2009 and 2012.
- Recycling rate, including organics, of 35% in 2012 from 24% in 2004.
- Introduction of economic instruments, including a variable payment scheme for collection, such as pay as you throw, between 2009 and 2014.
- Implementation of municipality level waste prevention plans.

In addition to the above targets, producers of significant quantities of organic waste were required to set up separate collection and treatment for their waste by 2012, aiming to reduce the greenhouse gas emissions impact and to return nutrients to the soil[33]. Householders are also expected to have access to separation at source for organic waste by 2025, either through home composting or collection by local authorities.

The extended producer responsibility (EPR), mostly implemented between 2001 and 2010, applies to tyres, printed/graphic paper, textiles and shoes, furniture, household healthcare products, chemicals from households and household natural gas cylinders, increasing the amount of materials separately collected.

In April 2018, the French government issued the French Circular Economy Roadmap[34] (feuille de route de l'économie circulaire), which set targets to:

- Reduce natural resource use associated with French consumption, in relation to gross domestic product (GDP), by 30% of 2010 levels by 2030.
- Reduce the amount of non-hazardous waste landfilled by 50% of 2010 levels by 2025.
- Reduce food waste by 50% between 2013 and 2025.

The "Programme national de prevention des déchets 2014-2020"[35] also set out several new waste prevention targets and revised the ones set in the, above mentioned, first Grenelle law. These targets, as well as targets reported by the government to the European Commission (EC)[36], are:

- A 10% decrease, between 2010 and 2020, in household and similar waste.
- 55% recycling of non-hazardous, non-inert, waste in 2020 and 65% in 2025.
- 50% collection target of textiles and shoes from households for the quantities placed on the market by 2019.
- 35-90% collection target of packaging and plastic waste for agricultural supplies in 2020.
- Reduction per unit of value in the quantity of waste from economic activities in 2020 compared with 2010.

[32] https://www.eea.europa.eu/publications/managing-municipal-solid-waste/france-municipal-waste-management
[33] https://www.municipalwasteeurope.eu/sites/default/files/FR%20National%20factsheet.pdf
[34] https://www.ecologie.gouv.fr/sites/default/files/FREC%20anglais.pdf
[35] https://www.ecologie.gouv.fr/sites/default/files/Programme_national_prevention_dechets_2014-2020.pdf
[36] https://www.eea.europa.eu/publications/even-more-from-less

- 60% reused or recycled building waste materials in road construction materials purchased by national and local authorities in 2020.

Act No. 2020-105 (Act 2020-2015), issued in February 2020, set a specific target, under Article L. 541-1 of the Environment Code, that 100% of plastic will be recycled by 1 January 2025. The Environment Code[37] introduced into national legislation the national strategy concerning waste regulation, as well as some EU directives. It also includes uplifts of several targets mentioned above and introduces new stricter ones:

- The decrease of 10% in household and similar waste between 2010 and 2020 is extended to 2030 and is now 15%.
- The quantities of household and similar waste sent to landfills in 2035 must be reduced to 10%.
- Energy recovery of at least 70% of waste that cannot be subject to material recovery by 2025.
- Separate collection of organic waste by 31 December 2023.
- As of 1 January 2027, it is prohibited to use organic waste treated in MBT facilities as compost.

All the above targets, which reflect the waste hierarchy and will have implications for existing MBT facilities in France, point to a reduction in residual waste tonnages and significant changes to its composition. Source segregation of organic wastes and the prohibition on the use of CLO on land as a compost will have notable impact on some MBT facilities, including the case study facility discussed in section 5.5.

5.2 Compost standard

For a material to be marketed as a compost product in France, it needs to meet the statutory NFU 44-051 standard[38]. The standard includes limit values for concentrations of trace metals, some organic compounds, contaminant materials (glass and plastic), pathogens and agronomic parameters. If the material complies with the requirements, it can be considered a product and not waste, irrespectively of its origin or whether it is formed by mixing materials. This does not apply to sewage sludge, which has a separate standard.

The CLO generated at MBT facilities in France can, therefore, be used in agriculture if the criteria of the standard are met. However, as detailed in section 5.1, this practice will only continue until 2027, as then any material that originates from non-source segregated waste will not be allowed to be used as a compost product that is not subject to regulation as a waste.

5.3 Biostabilisation criteria

The criteria and procedures for admitting waste to landfills in France are outlined in a document that transposes Council Decision 2003/33/EC[39]. On 1 July 2002, a ban on landfilling of untreated waste was imposed[40]. However, no degree of biodegradation was established. Thus, the main driver to biostabilise waste prior to landfill has been the requirement of the EU Landfill Directive to *'landfill a maximum of 75% of the total biodegradable municipal waste generated in 1995 by 2006, 50% by 2009 and 35% by 2016'*[32].

5.4 Landfill tax and gate fees

In France, landfilling and incineration activities are subject to the general tax on polluting activities (Taxe Générale sur les Activités Polluantes, TGAP)[32]. The landfill tax was first imposed at EUR 9.15 per tonne and did not change between 2001 and 2008. At landfills where the operators held environmental certification, such as ISO14001 or EMAS, there was a discount (EUR 7.5/t). A reform of the TGAP resulted in an increase of the tax by four times between 2009 and 2015 and an incineration tax was implemented between 2009 (EUR 7/t) and 2015 (EUR 14/t). However, a tax discount is allowed for

[37] https://www.legifrance.gouv.fr/codes/id/LEGITEXT000006074220/
[38] https://nord-pas-de-calais.chambre-agriculture.fr/fileadmin/user_upload/Hauts-de-France/028_Inst-Nord-Pas-de-Calais/Telechargements/Recyclage/fiche2-seuils-reglementaires-fixes-par-les-normes.pdf
[39] https://aida.ineris.fr/consultation_document/1595
[40] https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000000345400

incineration with energy recovery and high energy efficiency (EUR 1.5/t in 2009 to EUR 3/t in 2015). The efficacy of the tax is potentially reduced by the fact that more than 90% of all operators subject to the taxes benefit from the discount. The taxes apply to all types of waste and not specifically to MSW.

At present, the gate fee for an authorised landfill with 75% energy recovery from the captured biogas is EUR 37 per tonne, increasing to EUR 54 per tonne if no energy recovery takes places and to EUR 152 per tonne if the landfill is not authorised[41].

The ban on untreated waste to landfill appears to have influenced the rate of landfilling to a higher degree than the landfill tax.

5.5 Case study 1: ECOCEA, Chagny, France

A summary of this case study is provided in Table 3. Further detail is provided in Appendix A4.

Table 3. Case study 1 summary details

<table>
<tr><th>Facility</th><th>Technology</th><th>Inputs</th><th>Outputs</th></tr>
<tr><td>ECOCEA, Chagny, France

Commissioned in 2015</td><td>Dry AD and tunnel IVC</td><td>Residual MSW (73,000 tpa) with addition of green waste (8,000 tpa) prior to tunnel IVC.

Only the <10mm fraction is processed in AD.</td><td>RDF

Ferrous and non-ferrous metals

Compost for use in agriculture

Biogas upgraded to biomethane</td></tr>
<tr><td colspan="4">The organic fraction in MSW is typically concentrated in the smaller fractions and <10mm is a very fine fraction. That probably reflects the desire to ensure a good quality CLO for land application.

Addition of green waste prior to IVC provides material structure and assists meeting current French compost standards. In Scotland, CLO from non-source separated materials cannot gain end of waste status, limiting options for land application, whilst composted green waste can get end of waste status. In Scotland, it would not make sense to mix green waste with the AD digestate, including if the intention was to landfill the output. A larger particle size fraction (from MSW) would need to be subject to dry AD and IVC to ensure structural materials are present.

From 2027, CLO will no longer be classed as a compost product in France. This is likely to have notable implications for the facility.

At present there is no source separation of food waste in the area, whereas there is a push in France to do so. If that happens in the area, there will be a notable implication on the economics of the facility unless its mode of operation is changed, i.e. to treat source separated feedstock. Biomethane upgrading involves high capex and gas sales will be central to the facility's financial model.

This facility is quite new and the changes in legislation and potential changes to input waste composition will have serious implications to the mode of operation, and financial performance, in future.

Whilst it is unknown if the current facility biostabilises to the level of the Scottish ban (unlikely with 2 weeks of IVC), IVC processes can be designed to meet the criteria.</td></tr>
</table>

[41] https://www.cewep.eu/wp-content/uploads/2021/08/Landfill-taxes-and-bans-overview.pdf

6 Germany

6.1 Legislation and policy

Waste control, disposal and management in Germany are defined in the Circular Economy Act (Kreislaufwirtschaftsgesetz, KrWG) [42]. The act came into force on 1 June 2012 to transpose the Waste Framework Directive into national legislation and set out the fundamental principles of the circular economy, which include the polluter-pays principle, the waste hierarchy and the principle of shared public and private responsibility for waste management. The shared responsibility means that municipal waste management companies are responsible for organic and residual household waste, while private waste management companies are responsible for the recycling of household, commercial and industrial waste. The act aims to promote the circular economy to conserve natural resources and to protect human health and the environment from the impacts arising from the generation and management of waste.

In addition, the expanded Waste Prevention Programme required proper care in the management of goods and waste prevention measures to be taken by distributors and traders, as well as the preparation of products for reuse and recycling, which resulted in the obligation for separate collection of waste streams to be extended and further specified.

In 2010, 76 of 402 rural districts and urban municipalities, with a population of 10.8 million, did not collect organic waste separately. Section 11 (1) of the Circular Economy Act required that separate collections for organic waste must be set up from 1 January 2015. However, the law has not yet been implemented across the whole of Germany. Paper, metal, plastic and glass waste were also required to be collected separately. The new Commercial Wastes Ordinance, which came into force on 1 August 2017, expanded the obligation, to include cardboard, wood, textiles and other production-specific waste fractions.

The German resource efficiency programme was also issued in 2012 (ProgRess I) and updated in 2016 (ProgRess II)[36]. Among the action areas considered are the development of a resource-efficient circular economy and the support of policies on resource efficiency both on local and regional levels. The programme set a specific target to increase the quantity of separately collected organic waste by 50% and recycle and recover the same waste stream with high quality by 2020 relative to 2010.

Since mid-2005, under the Closed Cycle Management Act[43], organic waste was required to be treated prior to landfill, either in MBT or thermal treatment facilities, so that it could be specified as stabilised and not release significant amounts of leachate and landfill gas. The same applies to residual waste, from which any recoverable substances must be separated before landfilling and the energy from the materials must be utilised, unless the separation is shown to be technically impossible or economically unreasonable. Moreover, since 1 January 2019 sorting facilities must fulfil specific technical requirements, achieving a sorting rate of at least 85% and a recycling rate of at least 30%. The introduction of separate collection of organic materials and packaging waste has increased the recycling rate, which was 67% in 2020, and the volume of residual waste, which declined from 239 kg/capita/year in 1985 to 128 kg/capita/year in 2018.

In 2017, 45 MBT plants with a capacity of five million tonnes treated 4.5 million tonnes of waste, from which only around half a million tonnes was landfilled[42]. This can be attributed to the strict landfill requirements combined with the fact that most of the MBT facilities in Germany produce RDF.

6.2 Compost standard

The RAL quality assurance for compost was established in Germany in 1991 and, in recent years, approximately 70% of compost is labelled with the quality label RAL-GZ 251[44]. The utilisation of organic

[42] https://www.bmu.de/en/publication/waste-management-in-germany-2020/
[43] Nelles, M., Gruenes, J., & Morscheck, G. (2016). Waste management in Germany–development to a sustainable circular economy?. Procedia Environmental Sciences, 35, 6-14.
[44] https://www.kompost.de/uploads/media/Compost_Course_gesamt_01.pdf

waste on land used for agricultural, silvicultural and horticultural purposes is regulated via the Ordinance on Biowastes – BioAbfV 1998, which specifies the requirements on:

- The process.
- The hygienic and precautionary environmental aspects of the material.
- The requirements for application.

The requirements only apply to source-segregated organic waste and, thus, CLO cannot be applied on land used for food production.

6.3 Biostabilisation criteria

The requirements for waste landfilled in Germany are set out in the Landfill Ordinance (Deponieverordnung - DepV)[45]. More specifically, in Annex 3: Admissibility and assignment criteria, a set of parameters and their limits are set for each type of landfill. In addition, for outputs from MBT the following requirements also apply:

a) *The organic fraction of the dry residue of the original substance shall be deemed to be complied with if a TOC of 18% by mass or a calorific value of 6,000 kJ/kg DM is not exceeded;*
b) *A maximum DOC of 300 mg/l applies; and*
c) *the biodegradability of the dry residue of the original substance of 5mg/g (determined as respiration – AT_4) or 20 l/kg (determined as gas formation rate in the fermentation test – GB_{21}) is not exceeded.*

The respiration limit as set by the third criterion is stricter than the one set by the Scottish Government for the landfill ban which will be introduced in 2025. In addition, the criterion on the calorific value of the waste indicates that materials with a higher calorific value are considered suitable for incineration and should be diverted from landfill.

6.4 Landfill tax and gate fees

Germany hasn't imposed a landfill tax[41]. However, a landfill ban on untreated waste with TOC higher than 3% was introduced with an administrative regulation (TASi) in 1993 but was not fully implemented until mid-2005. The exceptions to this ban can be found in the previous section.

The German waste management system is financed by fees, applying the "polluter-pays" principle, where the producer has to pay for waste treatment or disposal[43].

6.5 Case study 2: Freienhufen, Germany

A summary of this case study is provided in Table 4. Further detail is provided in Appendix A4.

Table 4. Case study 2 summary details

Facility	Technology	Inputs	Outputs
Freienhufen, Germany Commissioned in 2007	Wet AD	Residual MSW Facility capacity was 50,000 tpa which includes a separate bulky waste process. In 2012, 27,327 tonnes of residual MSW was processed in the MBT facility, excluding around 7,000 to 8,000 tpa of bulky waste which was processed separately.	RDF (in 2012, this was 56.6% of total input waste) Ferrous and non-ferrous metals Dried digestate was landfilled (29% of input waste landfilled as dried digestate in 2012- meaning the input waste was rich in organics).

[45] https://www.gesetze-im-internet.de/depv_2009/index.html#BJNR090010009BJNE000401310

A facility upgrade took place in 2011/12 and further modifications were recently (since 2018) made to allow the facility to operate for the sole processing of source segregated biowaste (principally kitchen waste and green waste), i.e. residual MSW is no longer treated. This was the result of the mandatory introduction of source segregation of biowaste in the area. The changes required modifications including the addition of tunnel IVC with four-week retention time in order to process 20% kitchen waste with 80% green waste.

For the digestate from this facility to have been landfilled, it must have been deposited as a landfill restoration material, or it may have been used as daily cover material at the landfill. The facility was commissioned prior to the introduction of biostability criteria for waste to be landfilled in Germany.

This case study is an example of how changes in policy and legislation, reflecting a change in waste composition, can have significant impact upon the operation of an existing MBT facility.

Wet AD is not suitable to meet the Scottish biostabilisation for landfill criteria as it will not be possible to achieve the required level of biostabilisation without drying and IVC, and the dried digestate will have insufficient structure for IVC without mixing with other materials.

6.6 Case study 3: Lübeck, Germany

A summary of this case study is provided in Table 5. Further detail is provided in Appendix A4.

Table 5. Case study 3 summary details

Facility	Technology	Inputs	Outputs
Lübeck, Germany Commissioned in 2006/7	Wet AD	Residual MSW 120,000 tpa of residual waste and 26,000 tpa of sewage sludge. (The MBT has three lines, one for biowaste (source segregated organic waste) and sewage sludge, one for doorstep household residual waste and one for bulky waste, and there is some interaction between the residual waste line and the bulky and commercial waste line)	RDF Ferrous and non-ferrous metals Dried digestate is landfilled

The MBT facility forms part of wider waste treatment infrastructure at the Lübeck Waste Management Centre.

The area is served with separate biowaste collection and there is also a separate ‘biomass facility’ which receives green waste as well as woody material and digestate from the source segregated organics line from the MBT facility. The biomass facility utilises tunnel IVC (12 no.) technology followed by open windrow composting. The residual MSW does not go to the biomass facility.

The facility was developed as a result of a ban on untreated waste being landfilled, which came into force in Germany in 2005.

Ricardo’s research has not identified any issues with this facility. The facility has the benefit of being designed in the knowledge that biowaste is to be collected separately. As an integrated facility, including wet-AD of MSW organic fine fraction and source separated organics in separate digesters, the facility has a degree of flexibility to variation in organic content of the doorstep residual MSW. The biogas at the facility is combusted in CHP engines. If the organic fine fraction in the residual MSW reduces, it is likely to be alongside an increase in the source segregated food waste collected and so there will be no loss in overall biogas production.

Wet AD is not suitable to meet the Scottish biostabilisation for landfill criteria as it will not be possible to achieve the required level of biostabilisation without drying and IVC, and the dried digestate will have insufficient structure for IVC without mixing with other materials. For the digestate from this facility to have been landfilled, it must have been deposited as a landfill restoration material, or it may have been used as daily cover material at the landfill. The facility was commissioned prior to the introduction of biostability criteria for waste to be landfilled in Germany.

6.7 Case study 4: Vorketzin, Germany

A summary of this case study is provided in Table 6. Further detail is provided in Appendix A4.

Table 6. Case study 4 summary details

Facility	Technology	Inputs	Outputs
Vorketzin, Germany Commissioned in 2005	IVC	Residual MSW 180,000 tpa capacity	RDF Ferrous and non-ferrous metals CLO landfilled

The site was built as a response to the 2005 ban on landfilling untreated waste. However, the biological treatment process was stopped in 2012 and operations ceased altogether at the end of 2015. It is possible that the plant was affected by the introduction of separate organic waste collections in the catchment. Additionally, other residual waste reduction and diversion policies, such as the separate collection of recyclable streams, resulted in the reduction of the overall residual waste stream.

The districts that provided the facility with residual waste decided to send it to EfW plants because the gate fees were lower and that is the principal reason for the facility closure.

Whilst it is unknown if the facility biostabilised to the level of the Scottish ban, IVC processes can be designed to meet the criteria. The facility was commissioned prior to the introduction of biostability criteria for waste to be landfilled in Germany. It is possible that the introduction of the criteria had an influence on the viability of the facility.

7 Italy

7.1 Legislation and policy

The national programme for waste prevention[46,47] for Italy (2013 to 2020) was aimed at reducing organic, construction and demolition, hazardous, paper, packaging, batteries, electrical and electronic equipment waste. The programme set the following targets to be achieved by 2020, based on 2010 levels:

- Reduction of 5% in municipal solid waste relative to GDP unit.
- Reduction of 5% in special non-hazardous waste relative to GDP unit.
- Reduction of 10% in special hazardous waste relative to GDP unit.

Furthermore, the Report on Circular Economy in Italy[48] sets ten proposals for the Italian economy to move away from the linear economy model. With regards to waste, the aim is the *"rapid and effective implementation of the new European directives on waste and circular economy"* while taking into consideration the realities of the Italian system. The document includes targets on the preparation for reuse and recycling of municipal waste, which is set at 55% until 2025, 60% until 2030 and 65% until 2035, with specific targets per material, and a maximum of 10% of municipal waste sent to landfill. Waste prevention measures, such as food donations and repair and reuse of products, are also planned.

There are substantial differences among regions in Italy[36]. For instance, the Emilia Romagna region set targets for separate waste collection to reach 73% by 2020, the per-capita waste generation to decrease by 25% by 2020 relative to 2011 and recycling to increase to 70% by 2020, while the Lazio region only set a separate waste collection target of 65% by 2020. In addition, landfilling is higher in the southern regions, due to a shortfall in recycling facilities.

There is no clear national requirement for the separate collection of organic waste for the purposes of bio-treatment, although the practice is common[49].

7.2 Compost standard

The Italian Compost Association (CIC) is the national association for the compost industry. In 2016, 33% of Italy's total compost production was labelled with CIC's quality label for compost (CQL). The label is based on the limit values on the most important environmental parameters set by the National Law, D.Lgs 75/2010[50] and subsequent amendments, for use of source segregated organic waste as fertilisers or soil improvers.

CLO is used as landfill cover in some regions, based on the old regulation on "mixed MSW compost" (DCI 27/7/84)[51]. Older documents also outline the need for more specific guidelines and terms for the organic outputs of MBT facilities[52]. The latest guidance on compost from mixed waste was from 1984. The need to differentiate between the compost that derives from mixed waste and compost that derives from source segregated waste is emphasised by the Agency for the Protection of the Environment and for Technical Services (Agenzia per la protezione dell'ambiente e per i servizi tecnici, APAT), as the quality of the latter is much better.

[46] https://www.mite.gov.it/sites/default/files/archivio/normativa/dm_07_10_2013_programma.pdf
[47] https://www.eea.europa.eu/themes/waste/waste-prevention/countries/italy-waste-prevention-fact-sheet
[48] https://circulareconomynetwork.it/wp-content/uploads/2019/02/Rapporto-sulleconomia-circolare-in-Italia-2019.pdf
[49] https://www.municipalwasteeurope.eu/sites/default/files/IT%20National%20factsheet.pdf
[50] https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/10087
[51] https://www.aora.org.au/sites/default/files/uploaded-content/website-content/International_Comparison_AS4454_Final.pdf
[52] https://www.isprambiente.gov.it/contentfiles/00004100/4160-rapporto-biostabilizzato.pdf/

7.3 Biostabilisation criteria

The Ministerial Decree of 1 December 2010 defined the landfill waste acceptance criteria[53]. A parameter of interest to MBT outputs is the DOC, for which the limit is set at 100 mg/kg. However, this limit does not apply to:

- *"Outputs of mechanical or biological treatment that are characterised with the European Waste Catalogue (EWC) codes of 190501, 191210 and 191212;*
- *Outputs of biological treatment that are characterised with the EWC of 190503, 190604 and 190606, provided it is compliant with the programmes referred in article 5 of Legislative Decree 36/2003 and the dynamic breathing indicator, determined according to UNI/TS 11184, not greater than 1,000 mgO_2/ kg VS/h".*

The first exclusion refers to the 'non-composted fraction of municipal and similar wastes', while the second one refers to digestate and off-specification compost. This indicates that the outputs of the biological treatment of MBT facilities in Italy may be landfilled if the biodegradability of the CLO is below 1,000 mgO_2/ kg VS/h. This level of biostabilisation is equal to one of the two Scottish biostabilisation requirements, noting that the Scottish requirement is that either one or the other biostabilisation criteria must be met.

7.4 Landfill tax and gate fees

Italy introduced a landfill tax in 1996. Even though it contributed to the diversion of waste from landfill, the tax is low and no longer provides enough incentives for alternative treatment[54]. The Law 549/1995, which imposed the landfill tax, is applied at a regional level and the tax is directly paid to the regions by landfill operators.

Landfill tax varies between regions, from EUR 5.3 per tonne to EUR 25.82 per tonne, which is the maximum tax allowed from national legislation[41]. The tax also varies if the waste is pre-treated.

Italy has no ban on waste sent to landfill. A ban on waste with calorific value higher than 13,000 kJ / kg was introduced in the 2003 landfill law, for implementation by 2007, but the implementation was delayed six times, until 2016/2017 when the ban was abrogated[41].

[53] https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=2010-12-01&atto.codiceRedazionale=10A14538&elenco30giorni=false
[54] https://www.eea.europa.eu/publications/managing-municipal-solid-waste/italy-municipal-waste-management/at_download/file

8 Spain

8.1 Legislation and policy

The State Programme for Waste Prevention 2014-2020[55] has four strategic objectives to:

- *"Reduce the quantity of waste.*
- *Reuse products and extend their life.*
- *Reduce the content of harmful substances in materials and products.*
- *Reduce the environmental impacts of waste, as well as its impact on human health".*

The target on waste reduction aims at reducing waste generation by 10% by 2020, relative to the amount generated in 2010. Additionally, Spain aims at reducing construction and demolition waste by 10% by 2020 relative to 2010 levels and to recycle, at least 50% by weight, paper, glass, plastic, organic waste and other recyclables of household and commercial origin[36].

Separate collection of organic waste is not a requirement in Spain, although it is undertaken in some regions[56].

8.2 Compost standard

The Royal Decree 506/2013[57] on fertiliser products specifies the requirements for any compost used on land. For Class C compost, which is the compost that derives from mixed waste, there is an annual limit of 5 tonnes of dry matter per hectare. No other limitation is applied on compost from mixed waste.

8.3 Biostabilisation criteria

There is no requirement for waste sent to landfill to meet any criteria on biostabilisation. However, some regions have implemented a ban on biodegradable or non-treated waste[41].

8.4 Landfill tax and gate fees

The landfill tax in Spain varies from zero in some regions to EUR 53.1 per tonne in Catalonia. The different rates across the country affect the degree to which each region acts upon waste reduction and recycling.

8.5 Case study 5: Barcelona Ecoparc 4, Spain

A summary of this case study is provided in Table 7. Further detail is provided in Appendix A4.

Table 7. Case study 5 summary details

Facility	Technology	Inputs	Outputs
Ecoparc 4, Barcelona, Spain Commissioned in 2010/11	IVC	Residual MSW 285,000 tpa capacity (the facility also has a separate process for treatment of source separated organics at 75,000 tpa capacity)	SRF Ferrous metal, non-ferrous metal, paper, HDPE plastic, PET plastic, brick and plastic film are sent for recycling. CLO (around 8% of the input waste mass)
A range of materials within the area are subject to separate collection, including Organics (small garden and food waste) (introduced in 2010).			

[55] https://www.eea.europa.eu/themes/waste/waste-prevention/countries/spain-waste-prevention-fact-sheet
[56] https://www.nature.com/articles/s41598-021-90957-2
[57] https://www.boe.es/boe/dias/2013/07/10/pdfs/BOE-A-2013-7540.pdf

This facility was selected as a case study owing to its large capacity and sophisticated mechanical processing stage, which removes a range of recyclable materials. This does, however, come at a capex and opex cost. Some British MBT facilities have also been designed to remove a range of recyclable materials, often with use of manual hand-sorting.

Other than odour issues, which are not uncommon at MBT facilities, no issues were identified in Ricardo's desk study review.

Whilst it is unknown if the facility biostabilised to the level of the Scottish ban, IVC processes can be designed to meet the criteria.

8.6 Case study 6: CTR Vallès Occidental, Vacarisses, Barcelona, Spain

A summary of this case study is provided in Table 8. Further detail is provided in Appendix A4.

Table 8. Case study 6 summary details

Facility	Technology	Inputs	Outputs
CTR Vallès Occidental, Spain Commissioned in 2010	IVC	Residual MSW 245,000 tpa capacity	Recyclable materials (paper, metals, packaging, etc.) CLO, which is reported to meet European Standards and to be suitable for landscaping or gardening. However, some data sources state that it is either used for restoration of quarries and landfills or it is packed in shrink-wrapped bales with a very small percentage of biodegradability, which suggests it is landfilled.

This facility utilises power generated from landfill gas from an adjacent landfill.

As with the Ecoparc 4 facility, organic waste is collected separately in the area, the facility has a high annual capacity and a range of recyclable materials are removed in the MBT process.

Available information suggests that RDF/SRF is not produced but the situation regarding facility outputs is unclear, including whether CLO is utilised or landfilled. The presence of conflicting information suggests that it is possible, but unconfirmed, that material is being landfilled which was originally anticipated would be used as CLO. The experience in Britain has been that finding outlets for CLO is problematic, which has sometimes led to it being landfilled.

A 2017 audit report, produced by the audit office of Catalonia, highlights a range of issues with this facility, some of which include:

- The cost of sending waste to the MBT facility was so high that some municipalities decided to take their waste to other MBT facilities in the area.
- Construction and commissioning were both delayed, and the latter was held-up by performance issues.
- The MBT facility was 'definitively received', which means the client accepted it (taken over), despite not having the necessary environmental licence and not passing the performance tests for the biostabilisation system and the quality of the biostabilised material, nor of the air treatment system performance and emissions.
- In 2016 it was announced that adjacent landfill would shortly close and disposal costs for MBT facility outputs would rise owing to a need to send them further afield.

It is evident from the audit report that there were irregularities in what took place, from a contractual and financial perspective, and that technical performance of the facility was problematic such that performance tests could not be achieved. It is unclear if those issues were ever resolved. These issues, combined with the conflicting information on fate of outputs, suggest the facility has not performed as anticipated. It appears that the facility was designed with CLO production and without RDF production. The issues may be linked, in part, to those decisions.

9 Comparative analysis of country and case study information

9.1 Country information

Some differences exist between waste policies in France, Germany, Italy, Spain and Scotland. However, at a high-level, waste reduction and diversion from landfill are common themes.

- Unlike Germany and Italy, France and Spain both allow CLO to be applied to land for agricultural purposes, i.e. as compost, if national compost standards are met. In Scotland, CLO cannot gain end of waste status, because it is not from source segregated organics, and so its application to land will be restricted. The ability to apply CLO to land with relative ease is a significant advantage to an MBT operator because it avoids landfill or EfW gate fees. However, from 2027 onwards, the practice of applying CLO of residual waste origin to agricultural land in France will cease. That is likely to make MBT less favourable in France, and will have a financial implication, if not an existential implication, for some existing French MBT facilities.
- All five countries, including Scotland, have developed policies and legislation aimed at reducing waste, diverting waste from landfill, and increasing recycling. However, the approach has not been consistent between the countries:
  - France and Spain do not have specific biostabilisation criteria for the landfill of BMW, whereas Germany and Italy do. Some regions in Spain have, however, banned the landfill of BMW or untreated BMW.
  - France and Germany have measures in place to encourage EfW over landfill. In France, 70% of material unsuitable for material recovery must be subject to energy recovery. In Germany, material that is not recycled and has calorific value over a certain threshold cannot be landfilled, meaning it must instead be sent for EfW. Italy considered a ban on the landfill of high calorific value waste, but the proposal has now been dropped.
  - Separate collection of organics is widespread in Germany, which was a requirement to be met by January 2015, albeit it had not been fully enacted in all regions by that point. It is considered likely that was one influencing factor affecting modification or closure of German case study MBT facilities reviewed in this report. From the end of 2023, it will become a requirement in France. Italy does not have robust requirements in place that make separate collection for bio-treatment mandatory, although it is common practice in some areas. It is not a requirement in Spain, although it is implemented in some regions. Of these countries, Spain has the lowest proportion of separately collected organic waste, which is something in favour of MBT.
  - There is no landfill tax in Germany, but there is a strong emphasis on the polluter pays principal. One German case study local authority cited charges for residual waste at the doorstep as having a notable influence within its area. France has both landfill tax and an incineration tax, but there are discounts available for some circumstances and they apply to most operators, which limits the potential influence of the tax. Italy has a very low landfill tax which is reported to have little influence on diverting waste from landfill. Landfill tax in Spain varies by region, with some regions not applying a tax. Catalonia has the highest rate of landfill tax in Spain, and it has a relatively high amount of MBT facilities.

9.2 Case study information

Of the six case study sites (one in France, three in Germany and two in Spain):

- Five case study sites produce RDF and are heavily focused at minimising the amount of waste landfilled, as opposed to biostabilisation prior to landfill. This is also the case for almost all UK MBT facilities (see section 4) and reflects common policies that promote energy recovery above landfill.
- A ban on energy from waste is explicitly cited as one of the drivers for MBT facility development in one of the case studies. Ricardo is aware of several UK MBT facilities that

were developed alongside local authority decisions to rule out EfW development, based upon opposition to EfW expressed by residents within the local authority area.

- Two case study sites no longer process residual waste, influenced by the introduction of source segregated biowaste collections and, in one instance, due to EfW being a cheaper option. A third site will be significantly impacted by a change in legislation that will significantly impact the mode of operation, potentially threatening the future of the facility.
- Only one case study facility was required to biostabilise waste to a contractual limit, with the intention for it to be subsequently landfilled, and that limit was not achieved in performance testing.

The extent of biostabilisation achieved at the case study sites is not known to Ricardo. Because the purpose of five of the facilities is not to biostabilise waste prior to landfill, it is unlikely that the level of biostabilisation being achieved would meet the stringent level required to allow landfill in Scotland after 2025. It would not be possible at the sites that utilise wet AD.

Considering that the case study facilities were selected with no prior knowledge of any issues at the sites, it is notable that issues at several of the case study sites have been experienced.

As described in section 3, MBT facilities are designed to produce a range of outputs and around assumptions on waste composition, and typically for a lifespan of 20 to 25 years.

MBT facilities are typically promoted as having a high level of flexibility with respect to input waste composition. The composition of residual waste can be expected to change as consumer habits change and with changes in policy and legislation. However, at several UK MBT facilities, Ricardo staff have observed how facility design, based around assumptions on physical properties of waste (e.g. density, moisture level, particle size etc.), composition and behaviour of the waste within the process have not allowed sufficient flexibility for the input waste. The case study information reviewed does not provide a thorough insight into specific problems encountered at the sites, but it is evident that a drop in organic content within the waste has led to significant changes at two of the sites, and it is probable that it will be encountered at a third site.

Whilst the drivers and experiences of MBT implementation in France, Germany, Italy and Spain are of interest, and perhaps offer some lessons, the combined conditions in which MBT facilities have been developed are different for each country. Furthermore, conditions in Scotland do not closely align with those countries.

If further consideration is to be given to MBT development in Scotland, Ricardo recommends that an in-depth review is made of the experience of MBT implementation in England. That might include liaison with UK waste management companies and local authorities that have experience of MBT implementation. As described in section 4, MBT implementation in England has been problematic at times, and there will be some valuable ‘lessons learnt’ to be gained from review of English case studies.

10 Carbon life cycle assessment

10.1 Approach

To assess the carbon implications of biostabilisation prior to landfill as a means of treating residual waste in Scotland, an MS Excel spreadsheet model of the process was developed. The model uses a life cycle analysis (LCA) approach to measuring greenhouse gas impacts in terms of the mass of carbon dioxide equivalent emitted or avoided per tonne of MSW treated (kg CO_2 eq/t).

Source data is summarised in Appendix A5 and section 10.3.

The carbon LCA considers carbon emissions and carbon savings (avoided emissions) of fossil origin, and methane of biogenic origin. Biogenic carbon means that the carbon is of recent plant or animal origin, whereas fossil carbon means it is of ancient origin. Biogenic carbon dioxide emissions are not considered, because they are in balance with the carbon dioxide recently removed from the atmosphere by plant growth. Put another way, if you compost plant material, you will release the carbon dioxide back into the atmosphere that the plant only recently removed from the atmosphere as it grew.

Ricardo's remit did not include making comparisons to other treatment methods, i.e. EfW. However, the model draws upon input waste datasets and approaches, such as the allocation of carbon emissions including avoided emissions from recycling and energy generation, utilised by Zero Waste Scotland in a model it developed for EfW. Such consistency will assist interested parties when comparing treatment options.

Anticipated mass and energy balances were provided by two established technology providers, one of which operates in the IVC market and the other in the dry-AD market. The companies were approached as both have multiple reference facilities, across several countries, that treat a variety of waste types and compositions. The information was provided upon review of the waste composition provided by Zero Waste Scotland and is based on the experience of the two companies. The information was not provided following detailed engineering design, but is nonetheless appropriate for the purposes of the carbon LCA modelling.

Ricardo incorporated its own mass balance assumptions, based on its experience, for removal of recyclables and RDF in mechanical pre-treatment. Neither of the two technology providers specialise in that part of the process and their information provided was primarily focussed on the biological process.

Landfill emission assessment involved the use of GasSimlite[58] software. GasSim/GasSimlite software has been in use in the UK, for modelling emissions and risks from landfills, for approaching 20 years and was determined to be the most appropriate way to assess the carbon emissions from the landfill of stabilised waste from an MBT facility.

The model does not follow the input waste carbon assumptions all the way through the model on a material by material basis. The model developed is a hybrid of:

- Input waste composition and carbon content supplied by Zero Waste Scotland.
- The two technology provider's, and Ricardo's, mass balance information.
- GasSimlite software modelling.

The hybrid approach, drawing upon the experience of the two technology providers and the sophistication of the GasSimlite software, was deemed preferable to the academic approach of forming assumptions for the fate of carbon on a material by material basis from arriving at the MBT facility to being landfilled.

The various data sources, described above, are explained in further detail below.

The model is based upon 1,000 tonnes of residual waste sent to MBT, although users can select an alternative value. The choice of input waste tonnage does not alter the end result of the model, as

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[58] http://www.gassim.co.uk/

results are provided on a per tonne input waste basis, but does affect interim values in terms of how user friendly they are (too low a value causes interim numbers within the model that are not user friendly, i.e. low values to many decimal places).

10.2 System boundary

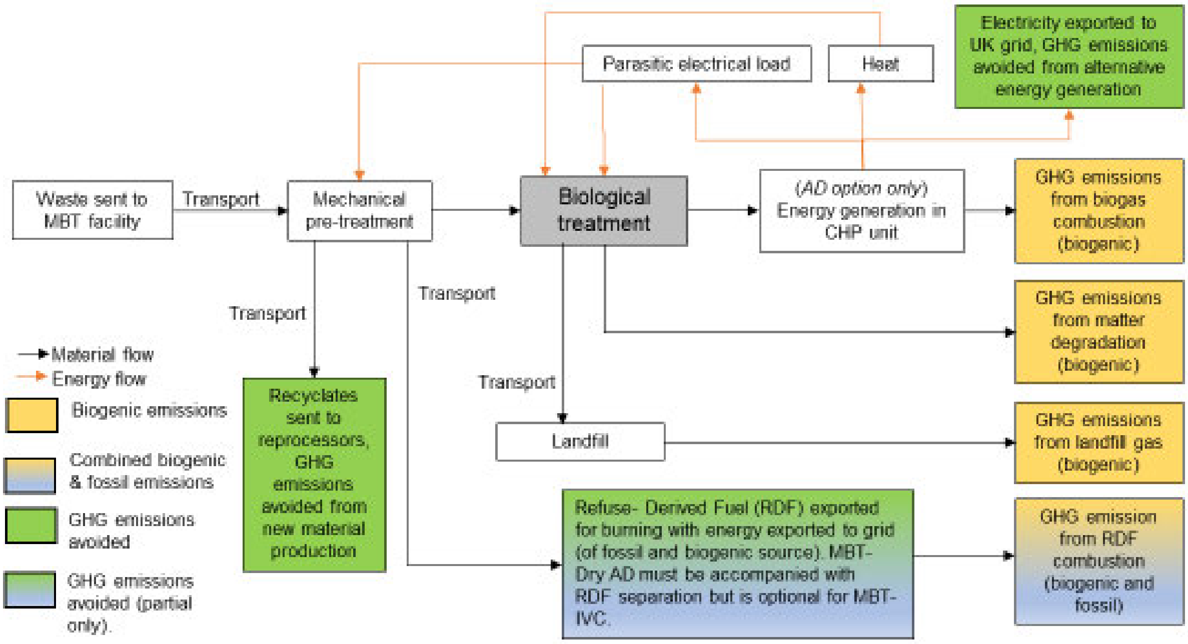
The system boundary for the model starts with residual waste arising at a waste transfer station (WTS). This is driven to the MBT facility, where pre-sorting removes metals, glass and plastics for recycling, as well as RDF in some instances. The model allows users to switch-off RDF removal for MBT-IVC, but RDF removal is a necessary step at MBT-Dry AD facilities. After biological treatment, the remaining biostabilised material is sent to landfill for final disposal.

The model takes account of various activities, for example the recycling of materials, that may potentially be undertaken by third parties (scope 3 activities) to the organisation operating the MBT facility (scope 1 and 2 activities).

The model does not consider the carbon impacts of facility construction, noting that they will exist for any MBT facility construction.

The process is depicted schematically in Figure 2.

Figure 2: Schematic diagram of MBT carbon model



10.3 Source data

10.3.1 Waste composition and carbon content

Waste composition[59] and carbon content[60] data was provided by Zero Waste Scotland and is shown in Table 9. The model also contains provision for the use of WRATE[61] carbon content data.

[59] For year 2018
[60] The biogenic and fossil content are based on assumptions used in a DEFRA (2014) EfW and landfill comparison study.
[61] The Waste and Resources Assessment Tool for the Environment; see [redacted]

Table 9. Default residual waste composition for MBT carbon model

Waste fraction	Proportion of waste	Carbon content	Proportion of carbon which is biogenic	Proportion of carbon which is fossil
Animal and mixed food wastes	27%	14%	100%	0%
Discarded equipment (excluding discarded vehicles, batteries and accumulator wastes)	2%	0%	0%	0%
Glass wastes	3%	0%	0%	0%
Health care and biological wastes	10%	19%	79%	21%
Household and similar wastes (refuse and furniture)	7%	45%	50%	50%
Metallic wastes (mixed ferrous and non-ferrous)	3%	0%	0%	0%
Mineral waste from construction and demolition	4%	7%	50%	50%
Paper and cardboard wastes	16%	32%	100%	0%
Plastic wastes	15%	52%	0%	100%
Rubber wastes	0%	0%	0%	100%
Textile wastes	6%	40%	50%	50%
Vegetal wastes	6%	24%	100%	0%
Wood wastes	1%	44%	100%	0%
Total	**100%**	**26.5%**	**15.2%**	**11.2%**

Waste composition will affect the carbon performance of different waste treatment technologies and it will change over time. This should be kept in mind when reviewing the LCA. However, the LCA was undertaken utilising a single waste composition provided by Zero Waste Scotland.

Net calorific value (net CV – the energy that is in the waste that would be released on combustion) and moisture (the proportion of the waste that comprises water, expressed in % mass terms) data for the input waste components were obtained from WRATE.

10.3.2 Carbon emission factors

Carbon emission factors were taken from the BEIS Greenhouse gas reporting: conversion factors[62], although not necessarily from the latest year of reporting, so that the factors were consistent with Zero Waste Scotland's EfW model. The GWP of methane (at 28 kg CO_2eq/kg CH_4 over a 100-year period) was taken from Assessment Report 5 from the IPCC[63], still used as the basis for UK government reporting. The 100-year period is the most widely used period within LCA reporting and was deemed relevant to the scenarios modelled, especially because landfill emissions will be generated long after an MBT ceases operation.

10.3.3 Transport activities

The default modelling assumes the distances and associated emission factors (EF) presented in Table 10, which can be changed by the user. The factors assume only full truck loads will be taken from the MBT to the landfill, but waste from the WTS to the MBT will be in average laden trucks.

[62] See https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021
[63] See [redacted]

Table 10. Key model parameters for IVC-alone treatment

Parameter	Value	Unit	Commentary
Distance from WTS to MBT	15	km	From Zero Waste Scotland Carbon Metric 2018
Distance from MBT to landfill	50	km	From Zero Waste Scotland Carbon Metric 2018
Emission factor for waste to MBT	0.14054	$kgCO_2e/t.km$	BEIS (2018) Conversion factors, Freighting goods tab - HGV (all diesel) - Articulated (>3.5 - 33t) - t.km - Average Laden
Emission factor for waste from MBT to landfill	0.07723	$kgCO_2e/t.km$	BEIS (2018) Conversion factors, Freighting goods tab - HGV (all diesel) - Articulated (>3.5 - 33t) - t.km - 100% Laden
Emission factor for RDF from MBT to end user	27.64520	$kgCO_2e/t$	From Zero Waste Scotland EfW model (it is the average of EFs for export to Scotland, rest of UK and Europe, in-turn based upon distance and mode of travel from Carbon Metric 2018 and EFs from BEIS (2018))

The EF for RDF transport is in different units to that for the transport of other waste fractions. The highest transport emissions come from the transport of RDF, because it is the average of EFs for transport to a range of locations, including shipping by sea to locations beyond the UK. If it was assumed that the end user for RDF was in Scotland, the EF for RDF transport would be 7.72 $kgCO_2e/t$, considerably below the value used. However, the model is not sensitive to such variance in transport assumptions, because transport impacts are small compared to other impacts.

10.3.4 Mechanical pre-sort recyclables

The level and sophistication of recyclate pre-sorting technology varies by MBT facility, so the level of material diversion was set to be one of the input parameters for the model that can be adjusted by the user. For the default, the values (for both Dry-AD+IVC and IVC alone) chosen are presented in Table 11.

Table 11: Default diversion rates for recyclates in MBT pre-sort

Metal diversion rate	75%
Glass diversion rate	50%
Plastic diversion rate	30%

In general, not specific to the waste composition provided Zero Waste Scotland, nor the model's system boundaries, MBT facilities that remove metal only might typically recover around 2 or 3% of the input waste for recycling. At the other extreme, facilities that employ comprehensive methods to extract recyclables, and assuming the materials are within the input waste in enough quantity, might typically recycle around 10%, maybe as high as 15%, of input waste. Such a high level might reflect poor capture rates at the doorstep and therefore high concentration within the residual waste. A reasonable performance to assume would be in the range of 5 to 10%.

The diversion rates in Table 11, coupled with the model's input waste composition, provide a modelled removal of recyclable materials of 7.9% of input waste, which Ricardo considers to be a credible value.

Published Scottish Carbon Metric emission factors (for 2018) for the recycling of materials were obtained from Zero Waste Scotland.

10.3.5 RDF Separation

As discussed elsewhere in this report, many MBT facilities are designed to produce RDF, so this option can be enabled in the MBT model for MBT-IVC if desired. A continuous operation MBT-Dry

AD+IVC process would need to first produce RDF for the biological process to function, and so there is no option within the model to not remove RDF.

For simplicity, the diversion of RDF is modelled to occur post recyclate pre-sorting, although RDF and recyclate removal will occur at various stages within the mechanical pre-sort process and is subject to facility design. Based on Ricardo's experience of the performance of certain confidential MBT facilities, the model diverts waste between the RDF and residual fractions according to the splits presented in Table 12.

Table 12: Assumed waste fraction split between RDF and residual waste (after recyclate removal)

Waste Fraction	RDF	Residual
Animal and mixed food waste	5%	95%
Discarded equipment (excluding…)	10%	90%
Glass wastes	0%	100%
Health care and biological wastes	70%	30%
Household and similar wastes	50%	50%
Metallic wastes, mixed ferrous and non-ferrous	31%	69%
Mineral waste from construction and demolition	5%	95%
Paper and cardboard wastes	95%	5%
Plastic wastes	65%	35%
Rubber wastes	65%	35%
Textile wastes	95%	5%
Vegetal wastes	35%	65%
Wood wastes	75%	25%

The assumptions in Table 12, when coupled with the modelled input waste composition, provide a modelled RDF diversion of 43% of input waste. Waste composition and facility design varies between MBT facilities, but typically around half of all waste is removed as RDF, and so the modelled assumptions are considered reasonable.

10.3.6 Biological treatment process (Option 1: Dry-AD plus IVC)

Key data for the Dry-AD+IVC part of the model is provided in Table 13 and has been derived from information supplied by a dry-AD technology provider.

Table 13: Key model parameters for AD+IVC treatment

Parameter	Value	Unit	Commentary
Electricity input to pre-sort	17.66	kWh/t	Ricardo assumption (not provided by technology provider). This is for the waste mass input at the very front of the MBT facility.
Electricity input to balance of facility	60	kWh/t	Per tonne of waste treated in AD (which is 50% of waste input to facility)
Electricity output from gas engines	285	kWh/t	Per tonne of waste treated in AD (which is 50% of waste input to facility)
Rate of use of additives	20.5	%w/w	Including steam, iron chloride and polymer solution- as a proportion of waste processed in AD (which is 50% of waste input to facility)
Rate of production of biogas	16.8	%w/w	As a proportion of waste processed in AD (which is 50% of waste input to facility).
Rate of production of effluent	23.6	%w/w	As a proportion of waste processed in AD (which is 50% of waste input to facility)
Rate of material loss	23.0	%w/w	As a proportion of waste processed in AD (which is 50% of waste input to facility)

Parameter	Value	Unit	Commentary
Rate of production of output (biostabilised waste for landfill)	57.2	%w/w	As a proportion of waste processed in AD (which is 50% of waste input to facility)

10.3.7 Biological treatment process (Option 2: IVC alone)

Key data for the 'IVC only' part of the model is provided in Table 14 and was provided by an IVC technology provider.

Table 14: Key model parameters for IVC-alone treatment

Parameter	Value	Unit	Commentary
Electricity input to facility (high level of recyclables removal and no RDF removal)	39	kWh/t	Range of 38-40 provided by technology provider
Electricity input to facility (typical level of recyclables removal and no RDF removal)	36.5	kWh/t	Range of 35-38 provided by technology provider
Electricity input to facility (high level of recyclables removal and with RDF removal)	44	kWh/t	Range of 43-45 provided by technology provider
Electricity input to facility (typical level of recyclables removal and with RDF removal)	41	kWh/t	Range of 40-42 provided by technology provider
Rate of recyclable removal	7.5	%w/w	Range of 5-10 provided by technology provider. The model only uses this to inform electricity consumption. The modelled value is determined by Ricardo/user assumptions (see section 10.3.4).
Rate of process loss (moisture and carbon dioxide)	22.5	%w/w	Range of 20-25 provided by technology provider. Ricardo assumed a quarter of this is moisture loss and the remainder is gases (predominantly CO_2).
Rate of production of biostabilised material (for landfill)	70	%w/w	This is the balance following removal of recyclables and process loss. If RDF is removed (see section 10.3.5) then this will impact the process loss and biostabilised material to landfill.

10.3.8 Landfill emissions

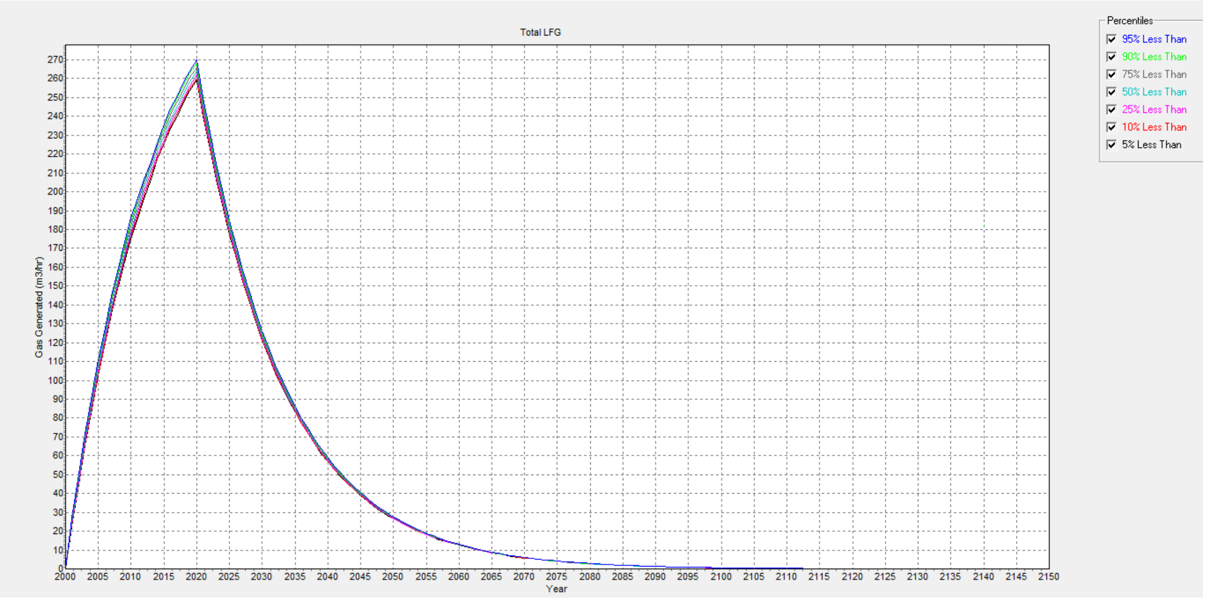
The methane emission from the landfill of biostablised residual waste has been determined using GasSimlite software. The main input assumptions used in the model are provided in Appendix A6, and some of the most pertinent assumptions are listed below:

- 70,000 tonnes per annum of composted organic material are landfilled over a twenty-year period.
- The waste is progressively capped every four years, i.e. on five occasions.
- The landfill gas is flared, noting generation of landfill gas would be so low as to not warrant use of an engine to generate energy (and any co-landfilled waste is assumed to have similarly low biodegradability). The modelled highest rate of gas generation is around 260 or 350 m^3/h (subject to assumptions used), which is only achieved for a brief period.
- The lower rate of landfill gas generation that the flare will operate at is 100 m^3/h.

- The flare destruction efficiency for methane is 99%.
- 10% of landfill gas passing through capping soils is biologically oxidised as it passes through the soil.
- The landfill gas is 50% methane and 50% carbon dioxide.
- The period of interest is 100 years (120 years from commencement of landfill operations, or 100 years from ending of landfill operations).

During the operation of a landfill site, the total landfill gas generated will rise as more waste is input each year. On cessation of waste input, the total gas generation will reduce exponentially. The modelled total landfill gas generation chart is shown in Figure 3.

Figure 3. Total landfill gas generated



There is a lower limit of gas production, below which it is not technically and economically feasible to collect landfill gas to flare it or to combust it to produce energy. That limit is more significant when it applies to a large landfill area, because abstracting a small amount of landfill gas from a large landfill is technically challenging.

The gas generation, on a per tonne of input waste basis, is low which is because the waste has been through a composting process prior to landfill. At face value, a peak of 260m^3/hr may seem a lot, but that is for the landfill of 1,400,000 tonnes of composted organic material (70,000 tonnes per year over 20 years) and is not a large amount for such a high mass of landfilled material.

The software contains default properties for 'composted organic material' which were utilised (default hemi-cellulose in the range of 7.47% to 9.59% with an assumption that 57% will decompose in the landfill, and the same values again for cellulose), albeit in varied form as described below. The results were then adjusted within the LCA model to account for the other materials, that are non-biodegradable, that would also be present in biostabilised residual waste. Put another way, the biostabilised residual waste is a mix of both 'composted organic material' and all the non-biodegradable waste fractions that have not been removed as recyclable or RDF materials.

Landfills can be designed and operated in many ways and the landfill gas emissions will vary considerably subject to how and when the landfill is capped to allow the landfill gas to be flared or utilised for energy production. If landfill gas is combusted, emissions are primarily characterised by carbon dioxide (GWP of 1) in combustion products and most of the methane (GWP of 28 over 100-year period) generated in the landfill will be converted to carbon dioxide in this manner, rather than being emitted directly to atmosphere from the landfill surface.

Prior to capping, most landfill gas generated will be lost to atmosphere. Temporary capping, sacrificial local gas collection and small portable flares are sometimes utilised prior to final capping, although collection efficiency is lower than from a permanent cap and permanent gas collection system.

However, for waste that is only generating a low level of gas, such measures are of limited practicality and were not considered in the model. On the flip side, the model assumption that permanent capping would be undertaken on a five-cell phased approach is of more significance, because the greatest gas collection efficiency is from permanently capped areas. If it was, for example, assumed that permanent capping only occurred in two phases (e.g. capping in year 10 and year 20) then emissions of methane to atmosphere would be much greater than for the five-phase capping approach modelled.

Ricardo chose a balance of assumptions that was considered reasonable in practice for the type and volume of waste being landfilled.

Four model runs were performed with some changes to assumptions for each model run, as listed below:

- Model 1: Default hemi-cellulose and cellulose content of the composted organic material and a minimum flare capacity, below which gas cannot be flared, of 100 m^3/hr.
- Model 2: As model 1, but with a 25% reduction in hemi-cellulose and cellulose content. This assumes that meeting the Scottish ban's biostabilisation criteria will require a high degree of biostabilisation.
- Model 3: As model 1, but with a lower end flare capacity of 50 m^3/hr. However, most modern enclosed ground mounted flares, that meet necessary regulatory requirements, have a low-end capacity of 100 m^3/hr.
- Model 4: Hemi-cellulose and cellulose content, and flare, modified as described in models 2 and 3.

The GasSimlite model provides the methane and carbon dioxide quantities (mass) emissions (with the latter split by combustion products or direct emission) for each year. The total mass of each gas was derived for the whole period (120 years) and then divided by the total mass of composted organic material landfilled. The results are provided in Table 15. Any non-biodegradable materials in the biostabilised waste from an MBT facility, such as minerals, metals, plastics and so forth, are excluded from the emission calculations as Ricardo's carbon model adjusts for these.

Table 15: Assumed rates of emissions

Scenario	Methane (t CH_4 / t composted organic material)	Total carbon dioxide (t CO_2 / t composted organic material)
Model 1	0.006755	0.091141
Model 2	**0.005650**	**0.066634**
Model 3	0.004842	0.096694
Model 4	0.003992	0.071576

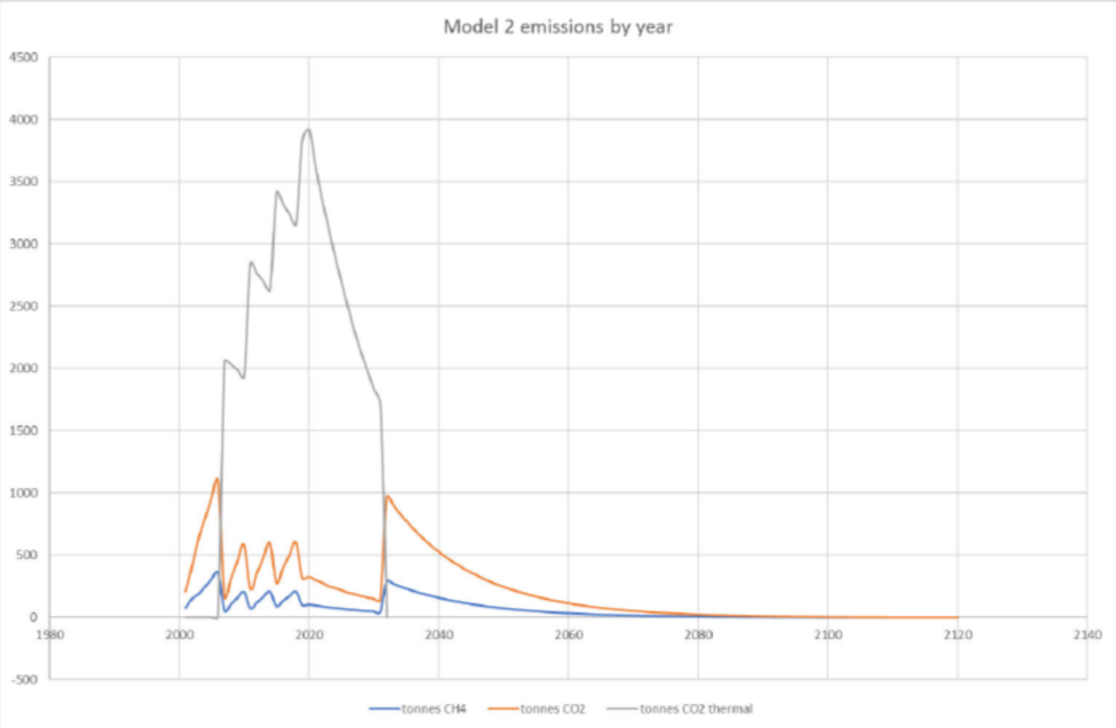
The model 2 results were selected for use in the carbon model.

Figure 4 shows the 'model 2' emissions profile (mass) across the 120 years considered and demonstrates:

- When gas is flared, the greatest mass emission is CO_2 within combustion products ('thermal CO_2).
- Progressive capping leads to a 'jagged' emissions profile because the percent of waste capped fluctuates as more waste is continually added when capping only occurs on five occasions.
- If no gas was collected, the profile of mass emissions would be similar to the profile of the volume emission of total landfill gas generated (see Figure 3). Figure 4 shows the impact that gas collection has upon gas emitted from the landfill surface, methane (GWP of 28 over 100-year period) emissions are significantly curtailed. This shows the importance of effective capping and gas collection.

- Gas can only be collected and combusted when there is enough gas present. Either side of the period when this is possible, all global warming gases will be emitted directly to atmosphere. This highlights the need to avoid the landfill of organic material, and that if it is to happen there is significant benefit in prior biostabilisation. However well designed, constructed and operated a landfill is, some direct emissions to atmosphere are inevitable, even when gas is being collected for combustion.
- When composted organic material is landfilled (same applies to biostabilised residual waste), emissions in 100 years' time are almost nil.

Figure 4. Model 2 emissions profile



10.4 Results

10.4.1 Default carbon modelling

As described above, many assumptions had to be made to arrive at a complete model of the fate of residual waste through an MBT process, and its associated carbon impacts.

Using the default inputs within the model, the overall carbon results are as follows:

- **Treatment of residual waste through an MBT facility employing Dry-AD and IVC technologies (which must involve RDF removal prior to biostabilisation), followed by landfill, yields a carbon impact of 66 kgCO$_2$e per tonne.**
- **Treatment of residual waste through an MBT facility employing IVC technology alone (without RDF removal), followed by landfill, yields a carbon impact of 12 kgCO$_2$e per tonne.**

Further detail, showing constituent components of the results, are provided in Table 16 at the end of section 10.4

The following conclusions can be made:

Dry-AD+IVC versus IVC only

- Both Dry-AD+IVC and IVC only create a carbon impact.

- Dry-AD+IVC provides the greatest impact (66kg CO_2e/t versus 12kg CO_2e/t for IVC only), principally due to the requirement to produce RDF and the net impact of combusting that RDF to generate electricity. From a carbon LCA perspective, IVC performs better than Dry-AD+IVC.
- The carbon saving from extracting materials for recycling is the same for both MBT options, because the removal of recyclable materials in pre-sort is independent to the form of biological processing subsequently employed.
- Transport and materials only contribute to the overall impact at a low level.
- The impact from landfill methane emissions is greater for IVC only than for Dry-AD+IVC (81kg CO_2e/t versus 33kg CO_2e/t). The difference is because RDF removal reduces the amount of waste landfilled and that RDF is rich in biogenic carbon (modelled biogenic carbon content of RDF is 20.4% versus 13.0% for residual waste after RDF removal).

<u>Dry-AD+IVC (with obligatory RDF production)</u>

- The overall result is predominantly driven by RDF production (impact of 128kg CO_2e/t, comprising combustion emissions of 216kg CO_2e/t, only partially compensated for by a benefit from electricity generation of 88kg CO_2e/t). RDF removal in pre-sort is an unavoidable requirement for continuous operation Dry-AD+IVC processes.
- The second largest contribution to the result is a carbon saving of 84kg CO_2e/t resulting from the recycling of materials extracted in pre-sort. The biggest saving is from the recycling of metals.
- Transport and materials make the lowest contributions (impacts of 15kg CO_2e/t and 3kg CO_2e/t respectively). That is despite the model assuming that the emission factors for RDF transport are the average of transport within Scotland, within the remainder of the UK and overseas transport involving transport by sea.
- The electricity produced by the AD process (burning biogas in a CHP engine) more than offsets the electricity consumed by the facility. The overall carbon saving, after the offset, is 28kg CO_2e/t. However, that saving from the AD process can only be achieved by first removing RDF materials from the waste in pre-sort, and the impact of RDF combustion greatly outweighs that saving.
- Methane emissions from landfill provide a modest impact, at 33kg CO_2e/t. That impact would be greater if RDF was not removed in pre-sort. RDF comprises 43% of all input waste and has a high biogenic carbon content, with paper and cardboard making the largest single contribution. If that RDF was landfilled the methane emissions from landfill would increase. However, that is not possible because the RDF would not comply with the Scottish ban biostabilisation criteria. Whilst paper and cardboard extracted from residual waste can be recycled in theory, in practice the quality of paper and cardboard removed from residual is poor and so the model assumes that it is not removed for recycling.

<u>IVC only (without RDF production)</u>

- The overall result is predominantly driven by recycling of materials (carbon saving of 84kg CO_2e/t) and methane emissions from landfill (carbon impact of 81kg CO_2e/t).
- Transport and energy consumption are minor contributors to the overall impact.

In future years, the mix of the supply of electricity to the grid in Britain is expected to decarbonise substantially to meet legally binding targets. A grid mix with lower carbon intensity will entail lower carbon emissions from the production of electricity consumed at MBT facilities, as well as lower carbon benefits associated with electricity generation at Dry AD facilities or generated from the combustion of RDF separated at MBT facilities. Overall, this is likely to make IVC without RDF production even more advantageous, from a carbon performance perspective, compared to Dry-AD with IVC and IVC with RDF production.

10.4.2 Diversion of RDF stream in IVC only MBT

The first sensitivity test was to enable diversion and subsequent combustion of RDF for the IVC only option. This would simultaneously provide carbon impacts and savings as follows:

- Impact from the combustion of fossil carbon in the waste to create CO_2.
- Saving from the associated generation of electricity from the heat produced by combustion (electricity production assumed to be 24% efficient- based on the average of three Scottish facilities reported in Zero Waste Scotland's EfW model).
- Reduced impact from the lower mass of biostabilised waste landfilled, noting that the RDF has greater biogenic carbon content than the residual waste remaining after its removal.

The results are presented in Table 16 and, when compared to Dry-AD+IVC and IVC only with no RDF production, demonstrates:

- IVC with RDF production has a greater overall carbon impact (115kg CO_2e/t) than IVC without RDF production (12kg CO_2e/t), which is due to the large impact of combusting RDF that contains fossil carbon that would be 'stored' if deposited in landfill. That impact is the greatest contributor to the overall result for IVC with RDF production.
- IVC with RDF production is the worst of all options, from a carbon LCA perspective, noting that it does not have the positive saving gained from electricity production from biogas generated in the Dry-AD process (the overall impact of the Dry-AD+IVC process is 64kg CO_2e/t).
- The landfill methane emissions are broadly similar for IVC with RDF production (45kg CO_2e/t) and Dry-AD+IVC (with obligatory RDF production) (33kg CO_2e/t). Those emissions are much lower than landfill methane emissions for IVC without RDF production (81kg CO_2e/t).

Table 16. Carbon impact assessment results (NB. +ve value is benefit and –ve value is impact)

		Dry AD+IVC (kg CO_2eq/t MSW)	IVC (no RDF) (kg CO_2eq/t MSW)	IVC (RDF) (kg CO_2eq/t MSW)
Pre sort	Glass (50%)	+11	+11	+11
	Fe/non-Fe Metal (75%)	+49	+49	+49
	Plastic (30%)	+24	+24	+24
	Sub-total	**+84**	**+84**	**+84**
Transport	To MBT	-2	-2	-2
	From MBT	-1	-3	-2
	From MBT (RDF)	-12		-12
	Sub-total	**-15**	**-5**	**-16**
Materials	Water supply	0		
	Auxiliary materials	-3		
	Water treatment	0		
	Sub-total	**-3**		
RDF	Electricity generation	+88		+88
	RDF combustion	-216		-216
	Sub-total	**-128**		**-128**
Energy	Electricity consumed	-14	-10	-12
	Electricity produced	+43		

		Dry AD+IVC (kg CO_2eq/t MSW)	IVC (no RDF) (kg CO_2eq/t MSW)	IVC (RDF) (kg CO_2eq/t MSW)
	Sub-total	**+28**	**-10**	**-12**
Landfill	Methane emissions	**-33**	**-81**	**-45**
	Grand total	**-66**	**-12**	**-115**

10.4.3 Wider sensitivity tests

With the above results in mind, the next step was to explore the sensitivities in the results to the numerous assumptions made in the calculations and described above. It was not practicable to explore how the results responded to changes in every input, so it was decided to focus on the following parameters:

- Glass recycling
- Metal recycling
- Plastic recycling
- Landfill gas emissions
- RDF combustion efficiency

For each of the above parameters, the input values were reduced by 20% or increased by 20% from the default value, to see what influence the change would have on the final GHG benefit. The results are presented schematically in Figure 5, where:

- The green circles reveal the, pre-sensitivity analysis, default values for the overall GHG benefit.
- In most cases, increasing the parameter by 20% increases the GHG benefit (so the orange triangle appears above the green circles). However, this is reversed for landfill gas emissions, where higher emissions reduce the GHG benefit.
- The variance between the three MBT types is similar for the same parameters, other than for two exceptions. Where RDF is not produced, in the scenario of IVC only without RDF production (the middle of the three scenarios in Figure 5) the impact upon GHG benefit of adjusting the percentage of plastic recycled is less than for the other two scenarios. The quantity of plastic within RDF will be influenced by the amount of plastic removed for recycling and it has a notable impact upon GHG benefit when it is incinerated. However, if no RDF is produced, any plastic not recycled will be landfilled without creating emissions. The second exception is the influence of landfill gas emissions in the IVC scenario without RDF production. In this case, more material will be landfilled, than in the other two scenarios, and that will include biodegradable materials such as cardboard, which will cause more landfill gas to be generated.
- The parameter of most impact, for the scenarios with RDF, is RDF combustion, while for the IVC without RDF, the landfill gas emissions impact the results the most.

As with any model, Ricardo's model contains many assumptions and changes in some assumptions can be expected to influence the overall model results. However, the sensitivity analysis demonstrates that, whilst some impact is seen for all three scenarios, the overall finding remains unchanged; from a carbon perspective, IVC without RDF production performs best, IVC with RDF production performs worst and dry AD+IVC sits between the two.

Figure 5: Schematic presentation of sensitivity analysis

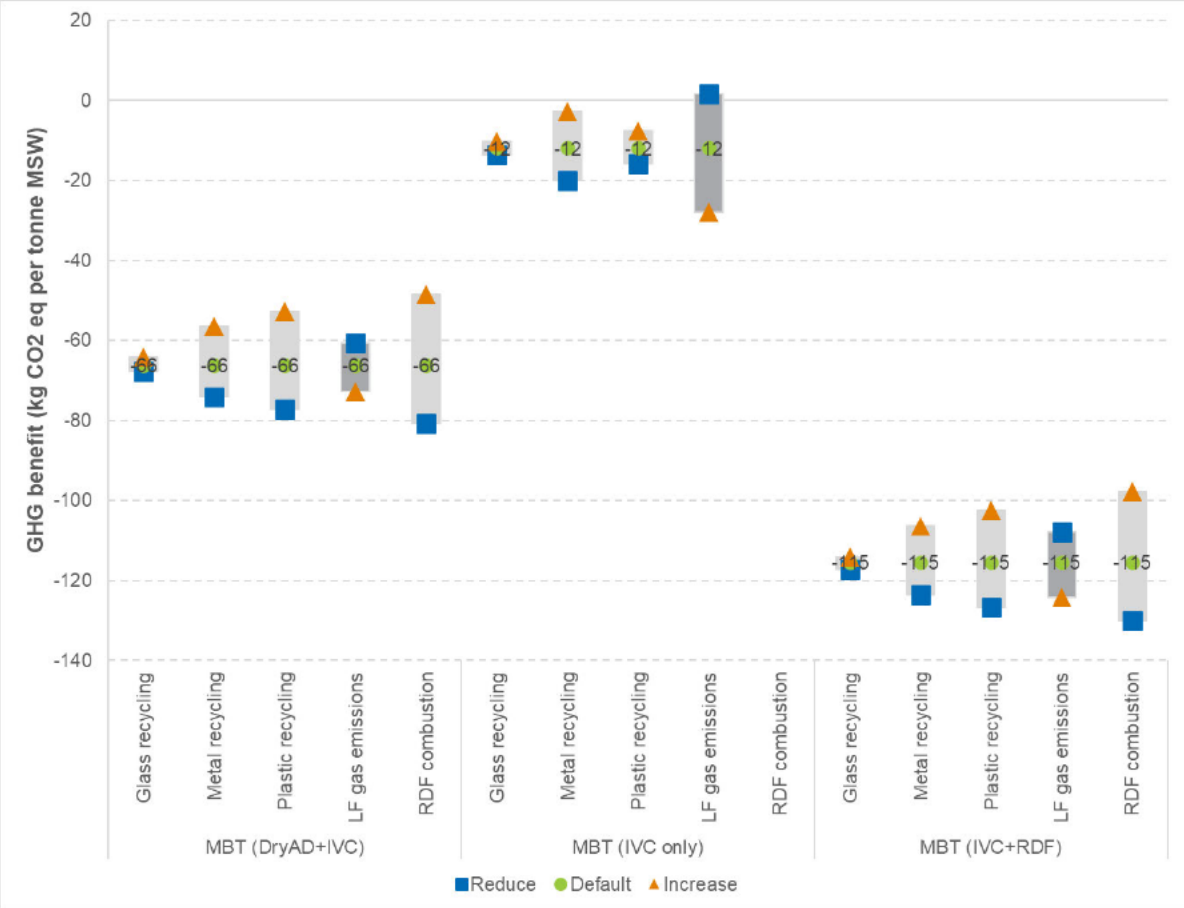


Table 17 presents the sensitivity analysis results in more detail.

Table 17: GHG Benefit (kg CO_2eq per tonne MSW) and impact of parameters

	Dry AD+IVC	% change (from default)	IVC (no RDF)	% change (from default)	IVC (with RDF)	% change (from default)
Overall GHG benefit (default- no sensitivity analysis)	-66	-	-12	-	-115	-
Effect of 20% increase in glass recycling	-64	3%	-10	13%	-114	1%
Effect of 20% decrease in glass recycling	-68	-2%	-14	-15%	-117	-2%
Effect of 20% increase in metal recycling	-56	15%	-3	77%	-106	8%
Effect of 20% decrease in metal recycling	-74	-12%	-20	-69%	-124	-7%
Effect of 20% increase in plastic recycling	-53	20%	-8	35%	-102	11%

	Dry AD+IVC	% change (from default)	IVC (no RDF)	% change (from default)	IVC (with RDF)	% change (from default)
Effect of 20% decrease in plastic recycling	-77	-17%	-16	-34%	-127	-10%
Effect of 20% increase in RDF combustion efficiency	-49	27%	n/a	n/a	-98	15%
Effect of 20% decrease in RDF combustion efficiency	-81	-22%	n/a	n/a	-130	-13%
Effect of 20% increase in landfill gas emissions	-73	-10%	-28	-137%	-124	-8%
Effect of 20% decrease in landfill gas emissions	-61	8%	2	114%	-108	6%

10.5 Biogenic carbon stored in landfill

When waste decomposes in a landfill some biogenic carbon will remain as it is not all degraded. Fossil carbon, e.g. plastic of petroleum origin, will practically remain in entirety as it degrades extremely slowly compared to biogenic carbon, and not to a meaningful level within the 100/120-year timeframe considered in the landfill emission assessment. It is the stored/sequestered fossil carbon that will make the biggest difference when it is landfilled rather than incinerated.

This stored carbon, whether biogenic or fossil, is neither an emission nor a carbon saving and so does not form part of Ricardo's carbon LCA. However, Zero Waste Scotland requested that an assessment be made of the biogenic carbon remaining in the landfill. Zero Waste Scotland was interested because most of that biogenic carbon would be released as carbon dioxide if the waste was incinerated and the information will assist interested parties when making carbon balance comparisons between different methods of treating residual waste.

The approach agreed between Zero Waste Scotland and Ricardo, was to determine the biogenic carbon present in the incoming waste (152.08 tonnes of biogenic carbon for 1,000 tonnes of residual waste input into the MBT facility) (using the Zero Waste Scotland supplied data presented in Table 9) and to deduct all emissions of biogenic carbon throughout the MBT and landfill processes. This required the determination of those biogenic emissions, whether carbon dioxide or methane, and establishing the carbon present within those emissions. The emissions considered are listed below.

For Dry-AD+IVC, the following biogenic emissions were discounted (for 1,000 tonnes of residual waste input into the MBT facility):

- Biogenic carbon removed with the RDF (88.84 tonnes)
- Biogenic carbon in CO_2 emitted by the IVC process (4.37 tonnes)
- Biogenic carbon in effluent (3.94 tonnes)
- Biogenic carbon in CO_2 entering and exiting the CHP engine at the AD facility, i.e. not a combustion product (16.35 tonnes)
- Biogenic carbon in CO_2 generated by the combustion of CH_4 in the CHP engine at the AD facility (21.45 tonnes)
- Biogenic carbon in CH_4 landfill emissions (0.88 tonnes)
- Biogenic carbon in CO_2 landfill emissions (3.79 tonnes)

For IVC without RDF production, the following biogenic emissions were discounted (for 1,000 tonnes of residual waste input into the MBT facility):

- Biogenic carbon in CO_2 emitted by the IVC process (46.02 tonnes)
- Biogenic carbon in effluent (there will be effluent produced, but data was not provided by the technology provider- however, this is a minor impact upon the carbon balance)
- Biogenic carbon in CH_4 landfill emissions (2.17 tonnes)
- Biogenic carbon in CO_2 landfill emissions (9.30 tonnes)

For IVC with RDF production, the following biogenic emissions were discounted (for 1,000 tonnes of residual waste input into the MBT facility):

- Biogenic carbon removed with the RDF (88.84 tonnes)
- Biogenic carbon in CO_2 emitted by the IVC process (19.14 tonnes)
- Biogenic carbon in effluent (there will be effluent produced, but data was not provided by the technology provider- however, this is a minor impact upon the carbon balance)
- Biogenic carbon in CH_4 landfill emissions (1.2 tonnes)
- Biogenic carbon in CO_2 landfill emissions (5.14 tonnes)

The biogenic carbon remaining in the landfill (after 100/120 years) for each of the three scenarios is presented in Table 18.

Table 18. Biogenic carbon remaining in landfill after 100/120 years.

MBT Scenario	Biogenic carbon stored / 1,000 tonne input to MBT (tonne)	Biogenic carbon stored / 1,000 tonne input to MBT (kgCO_2e)	Biogenic carbon stored / 1 tonne input to MBT (kgCO_2e)
Dry-AD+IVC (RDF removal obligatory)	12	45,703	45.7
IVC without RDF production	95	346,826	346.8
IVC with RDF production	38	138,470	138.5

11 Non-carbon environmental impacts

Many of the non-carbon potential environmental risks of MBT are similar in nature to most other forms of residual waste treatment, and measures can be put in place to help mitigate impacts. Risks may include:

- Traffic
- Noise
- Litter
- Dust
- Odour
- Bioaerosols
- Pests (rodents, birds, flies etc.)
- Liquids and effluents (leachate, wastewater and process chemicals)
- Animal by-products

As reported in trade press, several British MBT facilities have been subject to high levels of complaints and regulatory attention in relation to odour and pests, notably flies.

The nature of MBT processes means that waste is typically temporarily stored in several areas of the facility, including incoming waste, separated outputs awaiting collection or waste undergoing biodrying or full IVC processing. Furthermore, mechanical separation processes involve waste being transported on conveyors and being thrown around within equipment.

With the extent of waste storage and mechanical handling that takes place at MBT facilities, the potential for odour issues is often greater than for EfW facilities, where the main source of odour is limited to reception areas for delivered waste.

MBT facilities involving aerobic processes, which is likely to include any facility designed to biostabilise waste destined for landfill in Scotland, draw air through the waste and that air can contain high levels of odour, especially if the waste contains high nitrogen content or there are anaerobic zones within the waste mass. The air removed from composting processes will also contain bioaerosols which can be harmful if inhaled.

Biogas at AD facilities is odorous, but it should not be routinely released to atmosphere. Careful maintenance and process control can mitigate emission of biogas to atmosphere.

Risks from odour and bioaerosols can be mitigated with careful design and careful selection of facility location and activities should take place within buildings maintained under negative pressure with thorough treatment of extracted air prior to emission.

Employees at MBT facilities are also at risk from inhalation of bioaerosols, dust and gases such as ammonia and hydrogen sulphide. The risk can be managed with careful attention to building ventilation, monitoring and gas alarms and personal protective equipment.

12 Conclusions

12.1 MBT technology and ability to achieve ban criteria

Some MBT technologies can treat BMW to a level of biostabilisation that will meet the Scottish ban criteria, and it performs well from a carbon emissions perspective. However, MBT can take many forms and its implementation can be problematic.

Some forms of MBT, wet-AD and biodrying, will not stabilise BMW enough for it to meet the Scottish ban criteria. Such MBT approaches could, nonetheless, have a role to play in diverting waste from landfill. However, the brief for this study was to consider biostabilisation to allow subsequent landfill of waste, informed by an interest in understanding the carbon balance performance of such a practice.

In all instances, IVC is necessary to achieve the required extent of biostabilisation for subsequent landfill of the waste. Where that is preceded by dry-AD, it will be necessary to first remove materials that are best suited for use as RDF. IVC alone can be undertaken without RDF removal.

The brief for this study had a focus on biostabilisation of waste with a view to it being landfilled. Some MBT facilities do that, but it is not common[64].

Some MBT facilities biostabilise, or biodry, waste followed by refining of the IVC output for use as RDF, and many more remove RDF materials in mechanical pre-treatment irrespective of what happens to the output of the biological process. It is very common for MBT facilities to generate RDF at some point in the process. If that RDF is combusted such that the carbon content of its ash is below the ban criteria, then such practice will help Scotland in complying with the ban. However, RDF combustion has a greater carbon impact than the landfill of that same material if it has first been biostabilised.

12.2 Carbon lifecycle assessment

All scenarios modelled in the Carbon LCA showed a calculated carbon impact (not benefit), per tonne of residual waste treated, as shown below.

- IVC only, without RDF production: 12kg CO_2eq/t
- Dry-AD+IVC (must involve RDF production): 66kg CO_2eq/t
- IVC only, with RDF production: 115kg CO_2eq/t

The greatest influences on the carbon balance are whether RDF is produced, and subsequently combusted elsewhere for energy recovery, and whether materials are recycled. The former unfavourably impacts the carbon balance whereas the latter benefits it.

The combustion of RDF has a net impact (not benefit) of high significance to the overall carbon balance, as is evident from the difference between the two IVC only scenarios considered (see above). That is due to the combustion of fossil carbon, which is ‘stored’ if landfilled under an MBT scenario wherein RDF is not generated and the MBT output is landfilled.

Dry-AD+IVC has the benefit that biogas, of biogenic origin, is produced and combusted to generate electricity, but that advantage comes with a need to remove RDF and the impact associated with RDF combustion.

In future years, the mix of the supply of electricity to the grid in Britain is expected to decarbonise substantially to meet legally binding targets. Overall, this is likely to make IVC without RDF production even more advantageous, from a carbon performance perspective, compared to Dry-AD with IVC and IVC with RDF production.

For many years, waste policy and waste legislation within Europe has focussed on reducing reliance upon landfill and on applying the waste hierarchy. The carbon impacts of waste management options have had some bearing on those drivers, e.g. fugitive methane emissions from landfills have

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[64] For example, the Waterbeach MBT facility in Cambridgeshire is the only British facility identified as doing that (see section 4.4).

influenced thinking, as has the carbon and resource benefits of recycling of materials. However, the consideration of the holistic net carbon balance of waste management options has not played a central role in informing decision making, although it is likely to become more prominent in future decision making.

Carbon impacts are not the only aspect that needs to be considered. Any solution must be sustainable, in all senses of the word, for the anticipated lifetime of a waste facility. Other aspects that have been considered in this study are discussed below.

12.3 Experience of MBT implementation in Britain, France, Germany, Italy and Spain

On paper, MBT looks good and promises a lot. Nonetheless, EfW is more popular, in terms of number of facilities and tonnage treated, than MBT in Britain.

The experience of MBT in Britain and in mainland Europe has been heavily focussed on processes that generate RDF. Some projects have failed, and some have had issues associated with accommodating the waste composition and changes to it.

All but one of Britain's 23 MBT facilities produced RDF in 2019. The operator of the facility that does not produce RDF wishes to construct an energy from waste facility at the site.

Ricardo staff have, collectively and including experiences outside of Ricardo, worked on several British MBT projects in a range of roles and including facilities that have been subject to disputes, insurance claims and some ceasing to operate with MBT processes.

Five of the case study sites featured in this report, all located in France, Germany and Spain produce RDF. It is unclear whether the sixth case study site, located in Spain, produces RDF. The authors of this report are not aware of any Italian MBT facilities that do not produce RDF.

The case studies reviewed in this study number just six, and they were not selected with any prior knowledge of any issues that might have been experienced. However, some of the facilities have encountered issues, sometimes linked to a change in waste composition and sometimes resulting in a need to modify the process or cease input of residual waste. The four countries reviewed differ considerably in waste policy and tax instruments, including policies and approaches that may or may not favour MBT over other residual waste management methods. They do all, however, have high level similarities aimed at diverting waste from landfill, waste reduction and application of the waste hierarchy.

Zero Waste Europe published a report promoting alleged benefits of MBT facilities that have possible high recycling levels, including via extrusion of mixed plastics, and that do not produce RDF. The report stated that such facilities have a high degree of flexibility. These statements do not reflect the experiences of Ricardo staff. The extrusion of mixed plastics separated at MBT facilities is not normal practice, and Ricardo is aware of a waste contractor that investigated its feasibility and did not proceed with implementation.

MBT processes involve separation of different components of residual waste, for recycling or further treatment. Any waste component separated will inevitably, with a practicable degree of processing, be of lower quality than it would be if it arose through source segregation; residual waste is a low-quality waste stream and its reduction must be given high priority.

Source segregated organics are much better quality than organic fines from MSW, i.e. organic material separated in an MBT facility. In most instances, source segregated organics can be treated to reach end of waste status. In France and Spain, compost and digestate of residual BMW origin can gain end of waste status, albeit that is to stop in France from 2027. At present, that is a factor in favour of MBT in France and Spain. In Scotland, it is not possible for organic material from residual waste to gain end of waste status.

MBT processes can be complex and sensitive to changes in waste composition over time, for example introducing source segregated organics collection can have a significant impact. Such impact is likely to be greatest at an AD facility, whose design and anticipated performance involve electricity, heat or biomethane production from the organic fraction of the waste. However, the process loss will be reduced in an IVC facility if the organic content in the input waste reduces. If the aim of the facility is to stabilise waste prior to landfill, the impact may not be too significant for an IVC facility. If the aim is to minimise waste sent to landfill, it may be more significant because low process loss reduces the benefit that the biological process brings in terms of mass reduction.

With consideration to Scotland's BMW, MBT with biostabilisation of waste prior to landfill is bound to result in more waste being landfilled than would result from the landfill of ash and air pollution control residues from EfW processes.

How the contract between a local authority and waste management company is structured, and what performance guarantees and penalties are within that contract, is important to the long-term sustainability of the contract. That applies to any waste management contract, but the complexity of MBT processes and the range of facility outputs can increase the chance of contractual disputes.

The performance of an MBT facility contract will also be greatly influenced by available markets for outputs and the UK experience has shown that securing outlets for CLO is particularly problematic. Furthermore, the quality of recyclable materials separated at MBT facilities can be poor and market prices highly variable. However, if residual waste was subject to removal of recyclable materials, biostabilisation and landfill, without RDF production, there would be no need to find an outlet for CLO.

12.4 Recommendations

To employ MBT in Scotland, with landfill of most of the facility outputs, would require a step-change in attitude and approach by many involved, in whatever manner, in waste management. That approach is not currently practiced in Scotland, and only one English facility has been identified that does so.

If employed, the result would be unlikely to cause a decrease in waste landfilled. It would most likely increase, and it would not be in keeping with the waste hierarchy, wherein energy recovery is deemed preferable to landfill.

If further consideration is to be given to MBT development in Scotland, Ricardo's recommendations for future consideration are detailed below:

1. Priority should always be given to minimising waste generation, and to collection of source segregated waste wherever practicable. The carbon LCA undertaken for this study demonstrates the carbon benefits that recycling brings. However, recovering and recycling components of residual waste is more difficult than for source segregated materials. Furthermore, unlike organic fines from MBT of residual waste, source segregated organics can be processed to gain end of waste status in Scotland. If successful source separation of recyclable materials and organic waste in Scotland limits opportunities for MBT in Scotland, then that must be considered a good outcome so long as residual waste generation is minimised as much as possible.
2. Establishing a typical gate fee cost for MBT processes is hindered by the wide variety of processes and outputs that MBT can involve, as well as the cost often being wrapped-up within wider waste management costs under complex PPP/PFI contracts. However, the available evidence indicates that it is not a cheaper option than EfW but instead a similar, or potentially greater, cost. If MBT was to be promoted in Scotland, it is likely that policy or financial instruments would need to be developed to allow it to become the favoured option. If MBT aimed at landfill and not RDF production was to be promoted, then a review could be undertaken into how landfill tax might be applied to support such practice.
3. A review could be made of the waste hierarchy and whether it requires amendment, in a time when the carbon balance of waste management is becoming ever more prominent in decision making. The carbon LCA undertaken in this study demonstrates a marked difference in incinerating RDF versus its landfill, if that material is biostabilised prior to landfill.
4. A review could be made of the experience of MBT implementation in England. That might include liaison with UK waste management companies and local authorities that have experience of MBT implementation. That was not within the remit of this study, which was primarily aimed at understanding practices in continental Europe. However, the regulatory

and market environment in England has more similarity to Scotland, and the technologies employed in different countries are broadly similar. A lot of the technology installed at English MBT facilities is supplied by companies based in continental Europe.

5. A review could be made of the remaining landfill capacity in Scotland and changes in the tonnage and volume inputs to Scottish landfills that might result from the landfilling of biostabilised residual waste in Scotland. That was outside the remit of the current study.
6. A review could be made of the practice of producing mixed polymer pellets from materials separated at MBT facilities. To begin with, that could involve liaison with Zero Waste Europe to understand the evidence base informing its statements.
7. Because most designers and operators of MBT facilities are familiar with RDF production, greater due diligence will be needed if selecting MBT-IVC technologies that do not involve RDF production. With no RDF production, there will be more waste input to biological treatment processes. It is likely that waste will have a different density, particle size profile and potentially materials that may have a negative impact on the ability to turn the waste. The suitability of MBT will have to be assessed on a case by case basis and with consideration to the local authority specific residual waste composition and any forecast future variation.

Appendices

A1 – Typical mechanical pre-treatment technologies

A2 – English MBT facilities

A3 – WRAP gate fee data

A4 – Facility case studies

A5 – Carbon LCA assumptions

A6 – GasSimLite assumptions

A1 Typical mechanical pre-treatment technologies

Wet AD of residual waste requires addition of water and equipment to produce a homogenous organic slurry, along with equipment to remove grit and plastic contaminants. However, for the reasons explained in section 3.1.3 of this report, wet AD is not appropriate to the focus of this report and so this equipment is not considered further here.

Equipment commonly found in the 'pre-treatment' (prior to the biological process) part of an MBT process is described in the table below.

Equipment	Description/purpose
Grabs	For inputting waste. These are typically mounted on mobile plant or overhead crane rails.
Conveyors	An MBT facility mechanical pre-treatment process will feature conveyors, often belt conveyors, to convey waste through the process and between items of equipment.
Bag openers	To open bags to liberate contents, without shredding the waste.
Shredders	For size reduction. Sometimes situated near the beginning of the process, but not in all instances, although generally present somewhere within the process flow. Often employed as a final step in an RDF line at MBT facilities. They are often installed with screen baskets beneath the cutting rotors, such that material will only exit once its size is reduced sufficiently to allow its exit.
Trommel screens	A trommel screen (often simply called a 'trommel') is an inclined cylindrical screen/s that rotates along its axis. Trommel apertures can be round or square and formed of wire mesh, punch-plate holes or thick metal bars. When waste enters, it is churned around such that most waste particles, if small enough, should have an opportunity to pass through the screen. A trommel can have one or more screen sizes installed in series and will also generate an 'oversize fraction' formed of material too large to fit through the screen apertures. Trommels are often found near the start of the MBT process and the smallest particle size output fraction is often the fraction that contains the most organic material. Trommel screens are also often employed to remove oversize material in CLO refining. Some oversize material will make it through the screen if it is only oversize in one dimension, such that it can potentially pass through the screen apertures if presented 'end-on', as is possible with any screen. Similarly, some fine fraction material will make it into all fraction flows, owing to entrainment within the larger particle size materials. No separation process is perfect.
Vibrating screens	These are flat screens and normally have two outputs, being undersize and oversize. Vibrating screen can be a single screen or can be formed of a deck of screens. There are a variety of other screen types, including star screens and finger screens.
Ballistic separators	These take advantage of individual waste component shape, to separate flat fractions, e.g. paper and card, from rolling fractions, e.g. bottles and cans. They also act as screens to capture fine material. A series of slightly inclined 'steps' rapidly move up and down with a small front and back oscillating movement. The upper plate of the steps has apertures in it, through which fine material can fall through. Rolling fraction materials roll back down the steps, while flat fraction materials are 'walked' in the opposite direction.
Overband magnets	Used to remove ferrous metals. These electromagnets sit above conveyor belts and have their own short conveyor belt that circulates around the magnet. The magnet attracts the metal object from the conveyor beneath and the integral belt around the magnet then moves

Equipment	Description/purpose
	the metal object to the side, away from the magnet. Once the metal object has been moved away from the magnet, it drops into a bin or bunker.
Eddy current separators	Used to remove non-ferrous metals. The waste enters the unit, often via a vibrating plate to distribute the waste in a thin layer, and travels along a short fast-moving conveyor belt. The waste that is not non-ferrous metal drops from the end of the conveyor via a chute. The chute has a partition 'splitter wall' within it. Non-ferrous metals are repelled from the end of the conveyor via fast spinning rotor magnets within the conveyor's end pulley. The non-ferrous metal items are flung over the splitter wall into the second half of the chute from where they typically drop into a bin or bunker.
Optical sorters	Used to remove selected waste by material type, often different types of polymers. As waste passes along a conveyor belt, it passes beneath overhead instrumentation oriented across the width of the conveyor belt. The overhead equipment emits near infrared light and measures the wavelength of returned light reflected from the waste. This allows material identification, and the equipment detects the location of the desired material across the width of the belt. Running across the width of the head end of the conveyor, is a strip of nozzles attached to compressed air. The optical sorting equipment utilises the measured location of the desired material, and the speed of the conveyor belt to discharge a short burst of compressed air from the appropriate nozzle as the desired waste item passes over it. The main waste stream drops through a chute from the end of the belt. However, the discharge of compressed air blasts the desired waste component over a splitter wall in the chute in order to separate it from the main waste flow.
Air classification equipment	This can take various forms and relies upon a flow of fast-moving air to strip away light fractions such as plastic film.
Baling equipment	Used to produce bales of separated materials, typically with wire or plastic ties.
Compacting bins	Used to compact waste into a container for removal from site. Often utilised for RDF.

A2 English MBT facilities

MBT facility/ fate of outputs (2019 waste return)	Type of biological process/ fate of outputs (2019 waste return)
North Manchester MBT (Reliance Street)	Wet AD The MBT process generates RDF in pre-treatment. Data is available for two environmental permits, which is understood to reflect the handover of operations in mid-2019 from Viridor to Suez. Under one permit 'incinerator' accounted for 30% of outputs, whereas for the other it accounted for 70% of outputs. The lower number was associated with a higher 'transfer' value, which included a lot of RDF. RDF is a notable output.
Total tonnes of solid outputs	120,513
Incinerator	39%
Landfill	24%
Recovery	5%
Transfer	30%
Treatment	1%
Bredbury Parkway MBT (Manchester)	Wet AD The facility includes HWRC, transfer station, IVC and MBT-Wet AD. The MBT process generates RDF in pre-treatment. The 'treatment' and 'recovery' material percentages cited are largely formed of 'biodegradable kitchen and canteen waste' and so would not be associated with the MBT facility. The MBT facility is, therefore, likely to have generated >42% RDF in 2019.
Total tonnes	172,670
Incinerator	42%
Landfill	1%
Recovery	22%
Transfer	3%
Treatment	31%
Arkwright Street Resource Recovery Centre (Manchester)	Wet AD The site is actually a residual waste MRF (organic fines are sent to Bredbury Parkway wet AD)
Total tonnes	88,935
Incinerator	20%
Landfill	3%
Recovery	18%
Transfer	60%
Treatment	0%
South Manchester Resource Recovery Centre (Longley Lane)	Wet AD
Total tonnes	267,818
Incinerator	55%
Landfill	5%

MBT facility/ fate of outputs (2019 waste return)	Type of biological process/ fate of outputs (2019 waste return)
Recovery	38%
Transfer	2%
Treatment	0%
Cobden Street MBT (Manchester)	Wet AD
Total tonnes	97,000
Incinerator	50%
Landfill	7%
Recovery	7%
Transfer	34%
Treatment	3%
Byker Resource Recovery Centre (Newcastle Upon Tyne)	MRF (organic fines are sent to Ellington IVC)
Total tonnes	114,319
Incinerator	56%
Landfill	14%
Recovery	29%
Transfer	1%
Treatment	0%
Brookhurst Wood MBT (Horsham, West Sussex)	Wet AD
Total tonnes	179,948
Incinerator	41%
Landfill	17%
Recovery	5%
Transfer	24%
Treatment	12%
Bursom Waste Treatment Facility (Leicester)	MRF (organic fines are sent to Wanlip wet AD)
Total tonnes	114,246
Incinerator	36%
Landfill	31%
Recovery	31%
Transfer	1%
Treatment	0%
Waterbeach MBT (Cambridgeshire)	IVC The main destination of the output from the IVC process is landfill. However, the operator (Amey) is keen to construct an energy from waste plant to prevent the landfill of the output. A planning appeal was rejected in June 2020.

MBT facility/ fate of outputs (2019 waste return)	Type of biological process/ fate of outputs (2019 waste return)
Total tonnes	101,723
Incinerator	0%
Landfill	90%
Recovery	2%
Transfer	8%
Treatment	0%
Southwark IWMF (London)	Biodrying The facility includes a co-mingled MRF, MBT (aimed at RDF production), reuse and recycling centre and transfer station. The high recovery percentage reflects the other activities undertaken separately from the MBT.
Total tonnes	214,486
Incinerator	14%
Landfill	2%
Recovery	84%
Transfer	0%
Treatment	0%
Frog Island (London)	Biodrying
Total tonnes	146,227
Incinerator	41%
Landfill	1%
Recovery	33%
Transfer	25%
Treatment	0%
Jenkins Lane (London)	Biodrying
Total tonnes	148,307
Incinerator	42%
Landfill	0%
Recovery	20%
Transfer	38%
Treatment	0%
Hespin Wood Resource Park (Cumbria)	Biodrying It is unrealistic that 95% of residual waste is recovered (recycled) and more likely that the waste return included RDF under 'recovered' in error. The majority of the 'recovered material' was described as '*other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11*' in the waste return. That description could be used for RDF. Online sources describe this facility as producing RDF.
Total tonnes	44,729
Incinerator	0%
Landfill	0%

MBT facility/ fate of outputs (2019 waste return)	Type of biological process/ fate of outputs (2019 waste return)
Recovery	95%
Transfer	0%
Treatment	4%
Sowerby Woods Resource Park (Barrow-in-Furness, Cumbria)	Biodrying It is unrealistic that 87% of residual waste is recovered (recycled) and more likely that the waste return included RDF under 'recovered' in error. The majority of the 'recovered material' was described as '*other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11*' in the waste return. That description could be used for RDF. Online sources describe this facility as producing RDF.
Total tonnes	38,228
Incinerator	0%
Landfill	0%
Recovery	87%
Transfer	0%
Treatment	13%
Bolton Road (Rotherham)	Biodrying with SRF production and dry AD followed by IVC for the organic fines (i.e. mainly dry AD/IVC)
Total tonnes	168,856
Incinerator	82%
Landfill	3%
Recovery	6%
Transfer	1%
Treatment	9%
Northacre Resource Recovery Centre (Westbury, Wiltshire)	Biodrying
Total tonnes	49,141
Incinerator	57%
Landfill	39%
Recovery	0%
Transfer	0%
Treatment	4%
Canford MBT (near Poole, Dorset)	IVC
Total tonnes	109,678
Incinerator	76%
Landfill	6%
Recovery	6%
Transfer	0%
Treatment	12%

MBT facility/ fate of outputs (2019 waste return)	Type of biological process/ fate of outputs (2019 waste return)
Avonmouth MBT (Bristol)	IVC This facility is for sale and its current operational status is unknown.
Total tonnes	146,869
Incinerator	72%
Landfill	7%
Recovery	14%
Transfer	1%
Treatment	5%
Tovi Eco Park (Essex)	IVC
Total tonnes	192,668
Incinerator	81%
Landfill	3%
Recovery	14%
Transfer	0%
Treatment	2%
Renesciene Northwich	Wet AD This facility is the first of its kind (commercial scale prototype) for the technology employed, which involves addition of enzymes prior to wet AD to help maximise production of an AD substrate where the organic material is made readily available for the microbes in the wet-AD process.
Total tonnes	36,776
Incinerator	36%
Landfill	0%
Recovery	37%
Transfer	0%
Treatment	27%

A3 WRAP gate fee data

At the end of its 2014 Gate Fee Report, WRAP summarises gate fee data for 2012/13 and that includes Defra supplied information on PPP/PFI energy from waste projects that had been procured since 2005 (not all of which had reached contractual close at the time of the report). The information from Defra is provided in the table below.

Defra supplied gate fee information for PPP/PFI energy from waste projects (source: WRAP's 2014 Gate Fee Report)

Facility size (tonnes per year)	Median gate fee (per tonne)	Gate fee range
<200kt	£111	£80 - £135
200kt to 300kt	£78	£57 - £105
350kt to 450kt	£68	£59 - £80

Economies of scale can be expected with waste facilities and that is evidenced by the energy from waste gate fees presented in the table above. However, in recent years, several large EfW facilities have been constructed, and subsequently expanded, in Britain. The throughput at some of those sites considerably exceeds a typical large capacity MBT facility's throughput.

The construction of numerous EfW facilities in Britain in recent years, especially those of very large scale, is likely to have caused energy from waste facilities to offer competitive gate fees.

WRAP's 2011 Gate Fees Report comments upon the difficulties in researching and reporting MBT gate fees:

- *'The wide range of facility types and the variety of treatment processes to which the label of MBT is attached makes it difficult to provide an analysis of gate fees.*
- *The quality of the MBT output has a significant impact on the gate fee, as low quality process residues may attract a higher rate of landfill tax. Other major influencing factors on MBT gate fees are the SRF market, recovered materials prices, the feed in tariff and the allocation of contractual risk.*
- *Factors expected to influence the market for MBT in future were increases in the landfill tax and developments in market prices for MBT outputs (metals, plastics, SRF). Feedback from WMCs* [waste management companies] *indicated that the latter may lead to lower gate fees or an increase in the use of reward share mechanisms in future contracts'.*

The 2015 WRAP Gate Fee Report notes that it was not always possible to determine MBT gate fees from data submitted by local authorities, as the cost was included within a broader PPP or PFI contract. The data presented is reliant upon those local authorities that supply data and, of those, the authorities that supply data that can allow determination of the MBT gate fee.

The WRAP gate fee reports stopped reporting MBT gate fees altogether from 2018 onwards, and whilst the exact reason is not provided in the reports, the report authors state it was removed at the request of WRAP.

The WRAP gate fee report information should be reviewed with consideration to the above points, and wider caveats provided within the reports. A summary of the gate fee information, for WRAP reports published between 2011 and 2020, is provided in the table below. The reports contain data that predominantly applies to the previous year.

Summary of WRAP Gate Fee Report gate fees (local authority reported)

Report (£/tonne)	MBT	EfW (pre 2000 facilities)	EfW (post 2000 facilities)	EfW (pre and post 2000 combined)
2011	£84 (median)	£54 (median)	£73 (median)	Not stated

Report (£/tonne)	MBT	EfW (pre 2000 facilities)	EfW (post 2000 facilities)	EfW (pre and post 2000 combined)
	£57 - £100 (range)	£35 - £79 (range)	£54 - £97 (range)	
2013	£76 (median) £66 - £82 (range)	£58 (median) £32 - £76 (range)	£90 (median) £62 - £126 (range)	Not stated
2014	£84 (median) £25 - £104 (range)	£58 (median) £35 - £100 (range)	£94 (median) £62 - £112 (range)	Not stated
2015	£88 (median) £68 - £107 (range)	£73 (median) £36 - £110 (range)	£65 (median) £65 - £132 (range)	Not stated
2016	£85 (median) £67 - £111 (range)	£58 (median) £22 - £90 (range)	£95 (median) £65 - £131 (range)	£86 (median) £22 - £131 (range)
2017	£88 (median) £66 - £170 (range)	£56 (median) £26 - £90 (range)	£91 (median) £50 - £144 (range)	£83 (median) £26 - £144 (range)
2018	Not included	£57 (median) £44 - £94 (range)	£89 (median) £33 - £117 (range)	£86 (median) £33 - £117 (range)
2019	Not included	£65 (median) £44 - £89 (range)	£93 (median) £50 - £121 (range)	£89 (median) £44 - £125 (range)
2020	Not included	£62 (median) £49 - £104 (range)	£95 (median) £48 - £150 (range)	£93 (median) £48 - £150 (range)

A4 Facility case studies

Case study 1: ECOCEA, Chagny, France

Case study 2: Freienhufen, Germany

Case study 3: Lübeck, Germany

Case study 4: Vorketzin, Germany

Case study 5: Barcelona Ecoparc 4, Spain

Case study 6: CTR Vallès Occidental, Vacarisses, Barcelona, Spain

Case study 1: ECOCEA, Chagny, France

Parties

The facility was constructed for, and serves, SMET 71 (Syndicat Mixte d'Etude et de Traitement: mixed syndicate of study and treatment), which is the Saône-et-Loire department waste management association. A department in France is equivalent to a Scottish local authority and the Saône-et-Loire department is the 71st department of 96 French metropolitan departments. SMET 71 is responsible for the waste generated by ten-member local authorities (315,000 inhabitants).

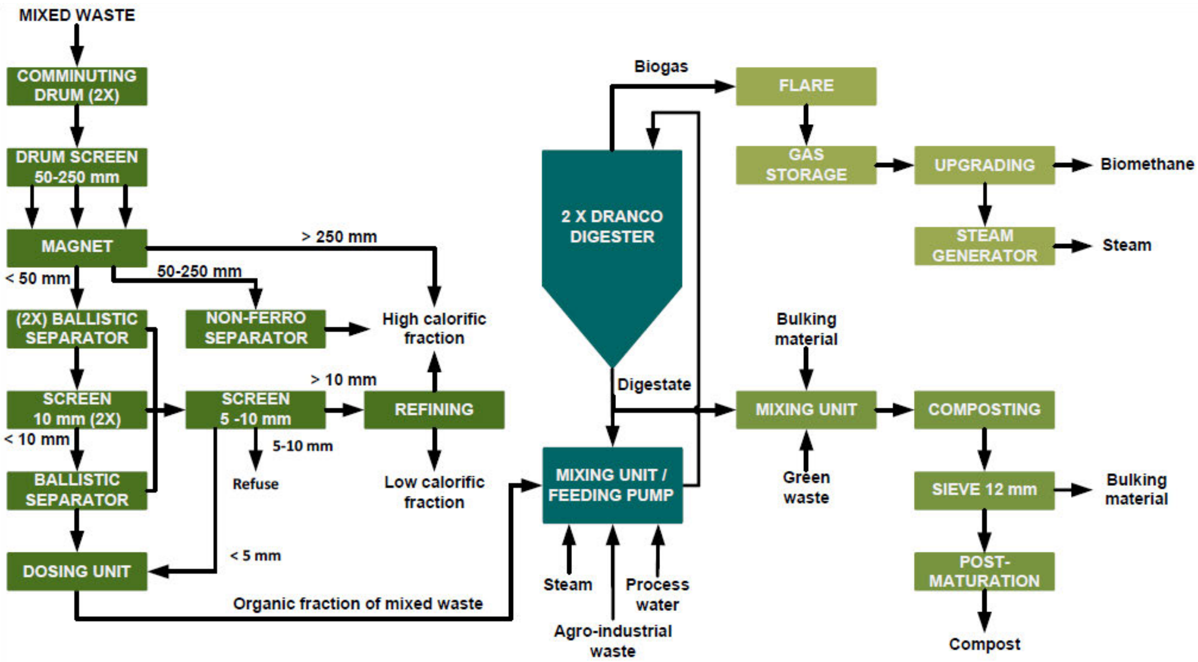
Tiru (Traitement Industriel des Résidus Urbains: Industrial Treatment of Urban Waste) is the designer, builder and operator. Tiru is a subsidiary of Dalkia and the EDF Group and operates 37 waste management facilities (thermal, biological and MRF), mostly in France (27 no.) but also in Britain (3 no.), Canada (5 no.) and the Caribbean (2 no.).

GRT-Gaz (75% owned by Gaz de France-Suez- 'GDF' and 25% by the French government) is the operator of the national high-pressure natural gas network that supplies industry. Biomethane from the facility is input into the network.

Technology

Commissioned in 2015 and employing around 18 staff, the facility utilises mechanical processing followed by dry AD (supplied by OWS/Dranco) of residual MSW, followed by tunnel composting of the dry AD digestate mixed with green waste. The biogas is upgraded to biomethane. The process flow is provided in the figure below.

Flow diagram of the Chagny facility (source: OWS/Dranco)



The comminuting drums are long-inclined solid cylinders that rotate along their axis, churning the waste inside to open bags and shake and separate individual waste components.

The drum screen is a literal translation from the German and Dutch word 'Trommel'. However, in the UK we use 'trommel' instead of 'drum' to describe the equipment. In this instance, there are two screen sizes, one of 50mm and one of 250mm aperture size, meaning that there are three streams exiting the trommel:

- <50mm fraction (first screen size on the entry of the trommel and first material to exit the trommel), which is where the organic fraction will be concentrated

- 50mm to 250mm fraction (second and final screen size on the latter part of the trommel and second size fraction to exit the trommel)
- >250mm fraction that simply spills from the end of the trommel as it is too large to pass through the screen.

The <50mm fraction from the trommel is further processed through various screening devices to recover combustible material that goes to form low and high calorific RDF and, in so doing, the quality of the material sent to the AD process should be fairly good because it is of <10mm particle size. This is pertinent because the destination of the composted organic output from the facility is application to agricultural land in accordance with French Norme NFU 44-051.

The Dranco AD technology utilises a high dry solids, unmixed, continuous digester that is a cylindrical vertical tank fed by pumping the prepared feedstock, which is first mixed with a small amount of output digestate, to the digester entry point at the top of the tank. The contents of the tank passage through the tank under gravity to exit at the centre point of the base of the digester. There are two digesters with a combined capacity of 35,000 tonnes per annum. The digesters are unmixed and operate at thermophilic temperature (around 55ºC) with a retention time of around 25 days.

Biogas is stored in a ground mounted ‘gas bubble’, which helps to stabilise gas pressure within digesters and pipework, provides a short-term buffer storage for biogas and helps to stabilise gas flows.

The biogas is upgraded to biomethane in an upgrader plant with injection to the national high-pressure natural gas distribution network that supplies industry, with supply to a local tile manufacturer.

The addition of green waste prior to composting will help to provide structure to the waste and helps to produce a compost quality which meets current French compost standards. The green waste is shredded prior to input and tunnel composting, with 14 day residence time, is employed.

Outputs

The facility was designed to process 73,000 tonnes of residual MSW and 8,000 tonnes of green waste.

The facility produces around 30,000 tonnes per annum of compost per year for application to agricultural land, under French Norme NFU 44-051, and 2,600,000 m^3 per year of biomethane. Other outputs comprise:

- High-CV RDF (utilised in cement kilns)
- Low-CV RDF
- Rejects (landfilled)
- Ferrous and non-ferrous metals (sent for recycling)

From 2027, the CLO will no longer be classed as a compost product and this is likely to have notable implications for SMET-71 and the facility. Furthermore, the push in France to introduce source segregation of organics is also likely, if introduced in the area, to have a notable implication on the operation and economics of the facility. It is only very fine fraction (<10mm) that is input into the digester tanks and so it is mixed with green waste prior to IVC to provide structure. However, the forthcoming changes will most likely mean it would be more beneficial to open windrow compost the green waste for it to still be possible to apply it to agricultural land.

Regional waste collection

Plastic, paper, cardboard, metals and glass are collected at the doorstep and at bring banks. Textiles bring banks are available and home composters are also promoted.

The remaining residual waste typically contains 30 to 40% organic content, as there is no doorstep food waste collection.

The local authorities collect waste and SMET-71 is responsible for its treatment. Some local authorities in France collect segregated organic waste at the doorstep. However, in this authority area it was deemed too expensive, owing to a large geographic area relative to the population within it.

Influencing policies

Prior to the development of this facility, the residual waste was landfilled. The development of the facility was informed by the waste hierarchy, i.e. a desire to divert waste from landfill and move the management of residual waste up the waste hierarchy.

At the time of facility development, the region's household waste elimination plan did not sanction incineration.

At the time of facility development, France's general tax on polluting activities (TGAP) was increasing for landfill, and it was anticipated that the cost of operating an AD plant would soon be equivalent to that of landfilling the residual waste, i.e. that AD would represent a similar or better financial option.

Additional information

The capital cost was US$46m and the facility took 21-months to construct and created around 20 to 25 jobs.

Case study 2: Freienhufen, Germany

Parties

The facility operator is Abfallentsorgungsverbandes Schwarze Elster (AEV) (Schwarze Elster waste disposal association). AEV is a public waste disposal company formed by the districts of Elbe-Elster and Oberspreewald-Lausitz within the state of Brandenburg.

The technology provider was HAASE Anlagengau AG.

Technology

In the UK, HAASE technology is present at three of the Manchester MBT facilities (Viridor was the EPC contractor) and in West Sussex (Biffa was the EPC Contractor).

The facility has been modified to treat source segregated biowaste, which is principally kitchen waste and green waste, instead of residual MSW. This was the result of the mandatory introduction of source segregation of biowaste.

The process described below describes the facility prior to the modification.

- Two stage wet AD of residual MSW (household and similar commercial)
    - Pre-sorting using mobile plant on the floor of the waste reception area to remove large items or items unsuitable for processing in the facility.
    - Trommel screening into three size fractions: <56mm, 56-105mm and >105mm.
    - Removal of ferrous metal on each of the above three output lines from the trommel.
    - The >105mm is conveyed to a compactor container.
    - The 56mm and 56-105mm each pass through a non-ferrous metal separator (eddy current separator).
    - The waste is then screened using a 35mm screen.
    - The 35-105mm fraction goes to join the >105mm fraction in the compactor container.
    - The <35mm fraction goes on to wet pre-treatment to prepare it for AD.
    - Wet mechanical pre-treatment of the organic fraction including water addition (recirculated process water) and production of homogenous slurry.
    - 2-stage (hydrolysis and methanation) wet AD with biogas production and CHP electricity generation (heat used on site).
    - On exit from the digesters, the digestate enters a tank where it is aerated to stop the anaerobic process.
    - Digestate is separated (dewatered) and the solid fraction is subject to thermal drying.
    - Treatment of odorous air, removed from process buildings and pre-AD tanks, using regenerative thermal oxidation.
    - Process water treatment using ultrafiltration and 2-stage reverse osmosis.

The facility has a separate line for bulky waste processing, which involves pre-sort by mobile plant, shredding, screening and ferrous and non-ferrous metal recovery. Besides metals, the other outputs from bulky waste processing are wood that is recycled and the remainder is sent for energy from waste.

The total approved plant capacity is 50,000 tpa (includes bulky waste processing).

Facility construction began in 2006 and operation began in 2007. A facility upgrade took place in 2011/12 and further modifications were recently made to allow the facility to operate for the sole processing of source segregated biowaste.

Outputs

In 2012, when residual waste was still being processed, the facility mass balance was as shown below.

- Input waste: 27,327 tonnes (residual waste only- not including bulky waste which is processed separately at around 7,000 to 8,000 tpa).
- Sent for EfW (non-AD) (56.6% of total input waste):

  - Output from pre-sort sent for use as fuel in EFW facility (different plant to high CV fuel): 2,156 tonnes (7.9%)
  - Sent for use as high-calorific value fuel in EfW facility: 12,673 tonnes (46.4%)
  - Clinical waste for incineration: 641 tonnes (2.3%)
- Sent for recycling (1.3% of total input waste):
  - Ferrous metal: 316 tonnes (1.2%)
  - Non-ferrous metal: 14 tonnes (0.1%)
- Landfilled:
  - Dried digestate: 7,923 tonnes (29.0%)
  - Pre-treatment rejects: 1,221 tonnes (4.5%)
  - Other : 10 tonnes (0.04%)
- Process loss (AD): 2,373 tonnes (8.7%)

AEV class the material sent for use as a fuel in an energy recovery plant as being 'recycled'.

Regional waste collection

Biowaste (food and garden waste, paper towels and newspaper), paper and card, metals and plastics (including films) are collected in separate streams and glass is collected in bring banks.

Most waste collection, including residual waste, is undertaken by third parties on behalf of AEV.

Residents pay a basic fee for their waste management service, and then a charge per collection of residual waste that is based on the container volume that is collected. Alternatively, an annual fee can be paid for a specific container volume which is then collected on all collection days. Excess residual waste can be deposited in a separate bag that is first purchased.

Influencing policies

Landfill diversion was the main driver behind the facility construction.

In 2013, AEV explored the potential of more intensive cooperation with other waste authorities in the region (state of Brandenburg) in the context of residual waste treatment in order to find the most economical overall solutions.

In 2018, the operator considered switching the operation of the facility from residual MSW AD to source segregated organics (i.e. biowaste) AD. That was due to the introduction of source segregated biowaste in the area, resulting from the requirements of the Recycling Management Act (Kreislaufwirtschaftsgesetz- KrWG) and the Brandenburg State Waste Management Plan. This is understood to have now taken place, with some modifications and the addition of tunnel IVC with four-week retention time in order to process 20% kitchen waste with 80% green waste.

AEV place high importance upon the fee model it utilises for residual waste to encourage waste avoidance and to increase recycling[65].

[65] https://www.schwarze-elster.de/wp-content/uploads/2015/02/AWKAEV2014.pdf

Case study 3: Lübeck, Germany

Parties

The facility was constructed for Entsorgungsbetriebe Lübeck (EBL- Lübeck Waste Disposal Company) and was developed by Ingenieurbüro für Abfallwirtschaft und Energietechnik GmbH (IBA-Engineering Office for Waste Management and Energy Technology) utilising technology supplied by HAASE Anlagengau AG.

The facility is operated by Stadtreinigung Lübeck GmbH (SRL- City Cleaning Lübeck), which was set-up in 2008 under a PPP model and is formed by EBL and Nehlsen GmbH & Co. The PPP arrangement is for 20 years.

Technology

As with the Freienhufen facility (case study 2 above), the Lübeck facility processes residual waste utilising the HAASE MBT process, including wet AD.

Construction commenced in 2004 and waste receipt and commissioning took place in 2005/2006.

The residual waste process is described below.

- Pre-shredding of input residual waste.
- Separation of metals, RDF, organic fine fraction and impurities with screens, magnets, optical sorters and air separation, and post-shredding of RDF.
- Wet pre-treatment involving four mixers, where water is added and a homogenous ‘soup’ is produced, followed by contaminant grit removal.
- Hydrolysis tank (1 x 4,500m^3)
- Two digesters (2 x 5,000m^3)
- Post digestion aeration tank (1 x 8,000m^3)
- Digestate separation (solid/liquid)
- Thermal drying of solid fraction (drum) prior to landfill
- Process water treatment using ultrafiltration and 2-stage reverse osmosis
- Power generation from biogas via CHP (around 15.0 MWh/a including biogas from the biowaste line).

The MBT facility forms part of wider waste treatment infrastructure at the Lübeck Waste Management Centre.

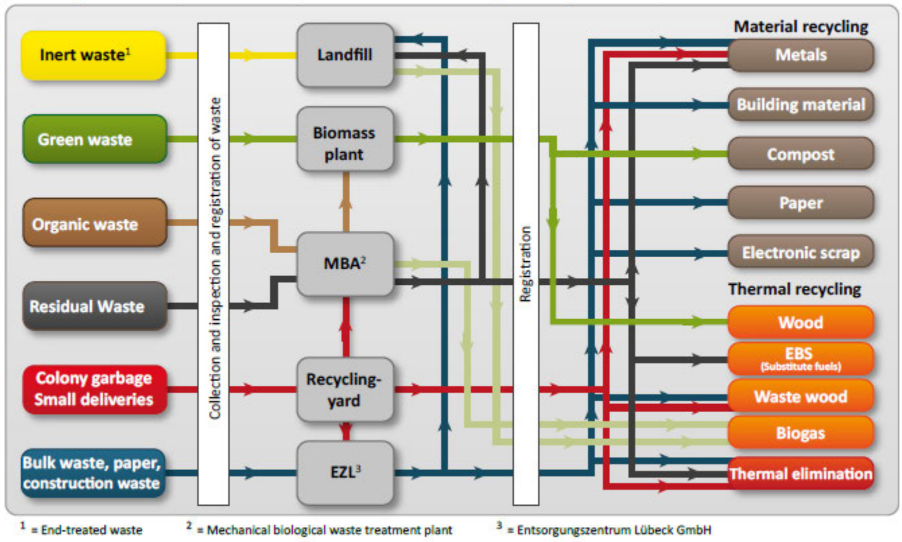
The MBT has three lines, one for biowaste (source segregated organic waste) and sewage sludge, one for doorstep household residual waste and one for bulky waste, and there is some interaction between the residual waste line and the bulky and commercial waste line.

There is also a separate ‘biomass facility’ which receives green waste as well as woody material and digestate from the source segregated organics line from the MBT facility. The biomass facility utilises tunnel IVC (12 no.) technology followed by open windrow composting.

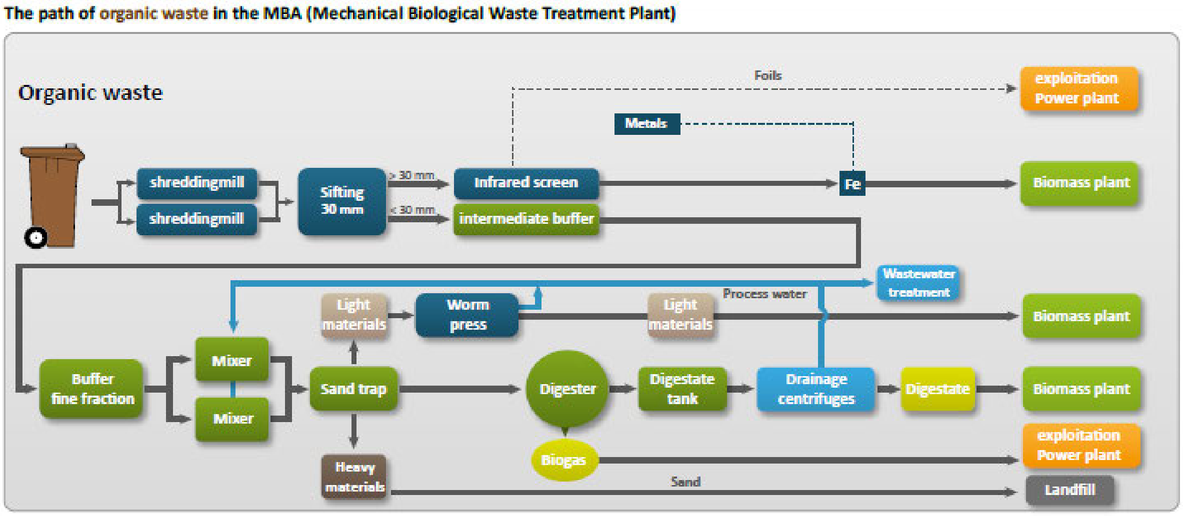
The whole MBT process was originally designed for around 120,000 tonnes per annum of residual waste and 26,000 tonnes per annum of sewage sludge.

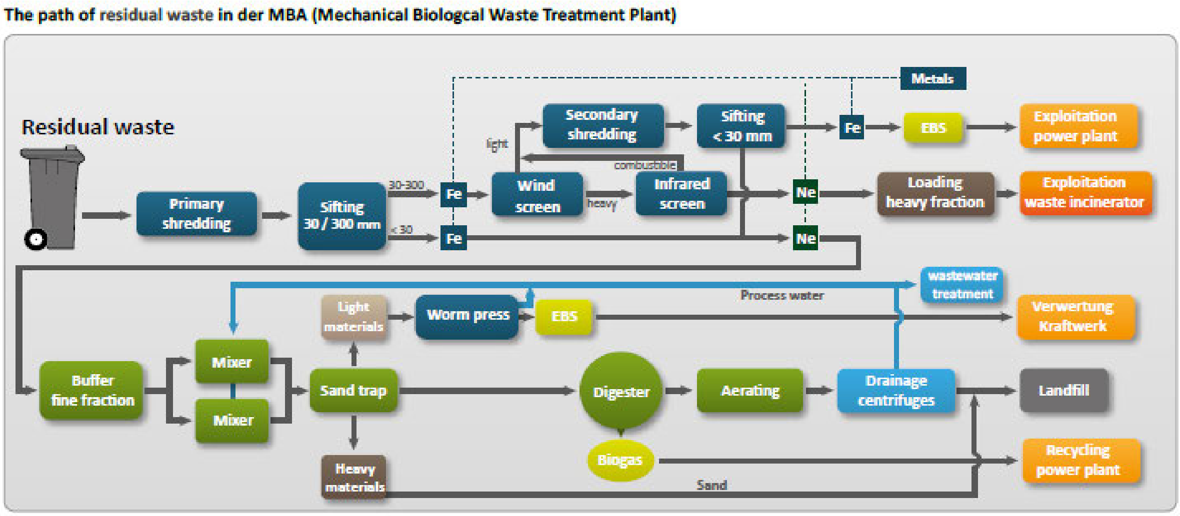
The interaction of the various facilities in Lübeck is shown in the figures below.

Integration of waste facilities (source: operator literature[66])



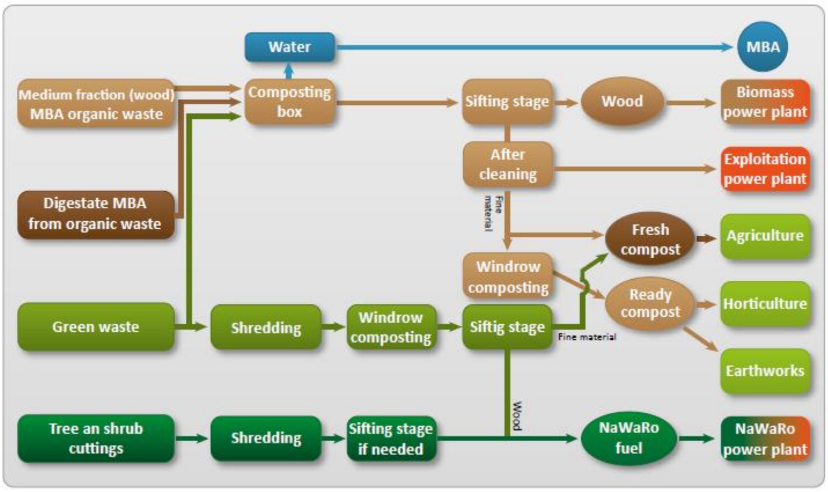
Flow of waste within the MBT facility (source: operator literature[66])





66 https://www.entsorgung.luebeck.de/files/Flyer/brosch_abfallwirtschaftszentrum_englisch.pdf

Flow of waste within the biomass facility (source: operator literature[66])



Outputs

The reported[67] 2017 outputs are detailed below.

- 22,800 tpa RDF produced
- 1,210 tpa metals recovered for recycling
- 25,170 tpa landfilled
- 15,920 tpa of woody material and digestate from the source segregated process line material was sent to the biomass plant.
- 5,000,000 m^3 of biogas produced [approximately 5,750 tonnes]. Biogas is combusted in CHP plant (2 no. totalling 1.9 MW capacity) with heat and electricity used on site and electricity exported to the national grid.

Regional waste collection

Biowaste (food and garden waste, paper towels and newspaper), paper and card, plastics (including polystyrene), metals and glass are collected in separate streams.

Influencing policies

The facility was developed as a result of a ban on untreated waste being landfilled, which came into force in Germany in 2005.

Additional information

- €30M capital cost
- Delivery hall area is 3,240 m^2.
- Processing hall area is 2,160 m^2.
- The area of external roadways and yards is 18,000 m^2.
- The following description is taken from operator literature66: With a CO2 credit of more than 200 kg per ton of waste, the MBA of Lübeck is well above the national average of incinerators. In a treated waste of about 100,000 tons per year, this is a major contribution to sustainability and conservation of resources. But not only can the amount of biogas obtained be recycled energetically. Even the alternative fuels produced from residual waste and the coarse material from the treated organic waste (wood) are sent for recovery of energy in various power plants. The digestate produced during biological treatment of organic waste and sorting residues freed and crushed from impurities are further processed in the local biomass plant.

[67] The 2017 MBT facility annual emissions report (Jahresbericht Emissionen 2017 Mechanisch-Biologische Abfallbehandlungsanlage (MBA) Lübeck)

Case study 4: Vorketzin, Germany

Parties

The facility was constructed through the collaboration of ARGE MBA Vorketzin, Horstmann GmbH & Co. KG, Fechtelkord&Eggersmann GmbH and Heilit+Wörner Bau GmbH.

Iba & Energietechnik GmbH was the technology provider for the biological treatment equipment and the operator was MEAB (Märkische Entsorgungsanlagen Betriebsgesellschaft) mbH.

Technology

The facility started operating in 2005 and stopped the biological treatment of waste in 2012[68] and operations ceased altogether on 31/12/2015[69].

The facility had a capacity of 180,000 tonnes/ year and involved:

- Pre-shredding.
- 2-stage screening.
- multi-stage screening.
- Fe-metal separation.
- 2-stage aerobic tunnel and windrow composting.
- Air treatment: biofilter and RTO.

Outputs

The facility had an annual capacity of 180,000 tonnes, of which 96,000 tonnes were treated biologically and landfilled in 2009. The metals that were recovered within the mechanical pre-treatment were sent for recycling, while the RDF was sent to EfW facilities[70].

Regional waste collection

The district where the facility was located introduced separate kitchen and garden waste collection systems in 2016[71]. A press release from the district council[72] shows that in 2011 there was separate collection of paper and recyclables, but the archives do not indicate when the collections were introduced.

Influencing policies

The site was built as a response to the 2005 ban on landfilling untreated waste. However, the biological treatment process was stopped in 2012. It is possible that the plant was affected by the introduction of separate organic waste collections in the catchment. Additionally, other residual waste reduction and diversion policies, such as the separate collection of recyclable streams, resulted in the reduction of the overall residual waste stream.

MEAB decided to stop the operation of the Vorketzin MBT, principally because the districts that provided the facility with residual waste decided to send it to EfW plants because the gate fees were lower[73].

Additional information

- Site area: 5 ha
- Site area occupied by buildings and infrastructure: 2.3 ha
    - Reception hall: 0.33 ha
    - Process hall: 0.27 ha
    - IVC hall: 0.86 ha

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[68] https://www.meab.de/informationen-der-oeffentlichkeit/
[69] https://www.meab.de/unternehmen/
[70] https://opus4.kobv.de/opus4-s bp/files/10143/Amtsblatt_Ketzin_Nr._04_2010.pdf
[71] https://www.havelland.de/presse/einzelansicht/news/detail/article/landkreis-havelland-fuehrt-die-biotonne-ein/
[72] https://www.havelland.de/presse/einzelansicht/news/detail/article/neuer-abfallkalender-wird-ausgeliefert-aenderungen-bei-entsorgungstouren/
[73] https://www.maz-online.de/Lokales/Havelland/Land-fordert-Abbiegespur-zur-Deponie

  - Maturation: 0.73 ha
  - Roads: 0.12 ha
- 4.7 MW load (electrical connected load)
- 3.5 years development time (13 months in construction)

Case study 5: Barcelona Ecoparc 4, Spain

Parties

The facility is located in, and serves 48 municipalities in, the Barcelona metropolitan area and is owned by the ECOP4RC Consortium. The consortium is a public entity, created in 2006, formed by the Agència de Residus de Catalunya (ARC), the Barcelona Metropolitan Area (AMB) and the Hostalets de Pierola City Council.

The management and operation of the Ecoparc 4 facility is carried out on a concession basis by Ecoparc de Can Mata SL, which is 100% owned by the CESPA Gestió de Residus SA. CESPA SA was responsible for facility construction.

The main technology providers are TOMRA (mechanical pre-treatment) and Sorain Cecchini Tecno (SCT) (IVC).

Technology

Although undertaken within the same buildings, source segregated organic waste (brown bin) and residual MSW (grey bin) are processed separately at the facility. As to be expected, the mechanical treatment of the source separated organic waste is much simpler than the residual waste and the organic waste line has one IVC hall (reactor) compared to two for the residual waste.

The facility was constructed between 2008 and 2010 and full commercial operation began in 2011. It has a treatment capacity of 365,000 tonnes per year (75,000 tonnes source segregated organics and 285,000 tonnes of residual waste).

The residual waste pre-treatment process is extensive and separates the waste into fine organic fraction, RDF, recyclables and material for landfill. The residual waste process is described below.

- Waste unloaded into pits that are emptied by overhead grab.
- 350mm trommel.
- The trommel oversize fraction is hand-sorted to remove paper, cardboard, film and metal for recycling. The remainder of the oversize fraction is landfilled.
- The trommel undersize is hand-sorted to remove contaminants/undesirable materials, including glass which is recycled, metal which is recycled and residues that are landfilled.
- Primary shredder.
- Multi-stage trommel <90mm (organic fraction) and 150x200mm screens (three outputs: small, medium and large).
- Ballistic separator for the medium and large outputs from the multi-stage trommel. This separates medium and large-sized waste that has come out of the multi-stage trommel into three types: flat and light packaging, fine and rolling waste. Flat and light packaging includes, amongst others, folded bags and card. Rolling waste includes cans and plastic jars. Fine waste is mostly organic waste. Flat and rolling wastes continue with the pre-treatment to completely separate them by material. Fine organic waste is put together with the small waste from the multi-stage trommel and is sent for IVC.
- Conveyor head wind-sifter to remove plastic bags and film carried into the rolling fraction of the ballistic separator.
- Over-band magnets to remove ferrous metals (located after multi-stage trommel and ballistic separator).
- Optical sorters on the rolling fraction line from the ballistic separator to remove PET and natural and coloured HDPE for subsequent recycling.
- Eddy current separator to remove non-ferrous metal (predominantly aluminium) from the rolling fraction line from the ballistic separator. The material not removed is destined for landfill.
- Optical sorting on the flat waste line from the ballistic separator to remove paper and cardboard for recycling.
- Conveyor head wind-sifter to remove plastic film from the flat fraction line from the ballistic separator.

- Manual sorting of certain final lines from the automated separation lines. Material is removed for recycling with the remainder destined for RDF.
- Shredder (20 to 30mm) to shred the flat fraction line output once paper and film have been removed (i.e. mostly paper and film not removed).
- High speed trommel: Paper is hurled out through the trommel apertures, while plastic forms a central ball and gets to the end of the cylinder. The dirty, wet, paper joins the conveyor that goes to composting. The remaining shredded plastics are sent for RDF.
- Composting in in-building IVC reactors (2 no.) with recycling of leachate and addition of water and air to both reactors. Residual MSW organics are composted for 42 days. The waste spends 14 days in reactor 1 after which it is processed in a 40mm trommel. The trommel small fraction will be mostly organic whereas the oversize fraction will be mostly small plastic packaging materials that were not removed in the pre-treatment process. The oversize material is landfilled. The undersize material is sent to the reactor 2 where it is matured for 28 days. The output from reactor 2 goes through a 10mm trommel and the oversize fraction (mostly stone and glass) is landfilled. Lastly, the organic material passes through cyclones to remove small fraction dense materials that are also landfilled.

There are ten TOMRA AUTOSORT optical separators, four of which are single-valve separators to recover the paper from the flat fraction, four are double-valve separators placed at the exit of the rolling or heavy fraction, where the first valve separates plastic and the second Tetra-Pak, and lastly two further double-valve optical separators that separate the PET in the first and the HDPE in the second from the plastic fraction of the first optical separators.

The source segregated organics process is simpler than the residual waste process. Owing to the poor structure associated with such waste, shredded green waste (30% w/w) is added prior to IVC. Source segregated organics line are composted for 36 days.

Outputs

Around 22,225 tonnes per annum of biostabilised compost like output is produced, which is around 8% of the residual waste input.

Ferrous metal, non-ferrous metal, paper, HDPE plastic, PET plastic, brick and plastic film are sent for recycling. Most materials are baled prior to leaving the facility.

Waste that cannot be recycled or used as SRF is baled or compacted and sent to the adjacent Can Mata landfill, reportedly with an organic matter content <15%.

SRF is sent to a waste to energy facility and compost like output can be used for soil restoration, slope filling in civil engineering works, in landfill restoration and in non-food plant production (these applications are mentioned on the AMB website). All material landfilled accounts for around 48%w/w, meaning that around 52% of the waste input (source segregated and residual waste lines) is recovered.

Regional waste collection

Wastes that are source segregated within the MBT facility catchment are listed below.

- Organics (small garden and food waste) (introduced in 2010)
- Glass (introduced in 1980)
- Paper and card (introduced in 1985)
- Metal packaging and plastics (introduced in 1997)

Influencing policies

The waste hierarchy and a desire to limit disposal to landfill were two guiding principles that informed the choice of the MBT technology to treat residual waste.

Additional information

The facility has created 70 direct jobs and 150 indirect jobs.

The facility has a 5ha area, was constructed between 2008 to 2010 and the construction cost was originally forecast to be EUR 55.08 million, although it is reported that the final cost was EUR 65.71 million.

The cost of waste treatment at Ecopark 4 in 2012 was EUR 16 million.

The facility and adjacent landfill have been subject to frequent complaints regarding odour, which it is claimed increased once the MBT facility had been constructed.

Case study 6: CTR Vallès Occidental, Vacarisses, Barcelona, Spain

Parties

The facility is operated by Consorci per a la Gestió de Residus del Vallès Occidental (Consortium for waste management of the Valles Occidental). The Valles Occidental is a county in Catalonia, Spain.

The consortium is a public body and was formed in 2001 and now comprises 19 member councils, of a total 23 councils in the region. The consortium's role is varied and includes planning the management of waste, development of waste infrastructure, establishment of separate waste collections, promoting waste awareness and recycling and the undertaking and commissioning of research aimed at developing waste management policies. Some services are developed across the whole consortium, whereas others might only apply to two or three councils.

The consortium manages two facilities: the Vallès Occidental Waste Treatment Center (CTR-Vallès), located in Vacarisses and the facility discussed here, and the Can Barba AD facility in Terrassa. In addition, the Vallès Occidental has an extensive network of municipal landfills managed by the town councils.

The facility was jointly funded by the Agencia de Residus de Catalunya and the consortium and it was constructed by Grupo Hera, FCC and Urbaser. The pre-treatment and refining technology was supplied by Masias (now Bianna Recycling) and the composting process technology was designed and supplied by Taim Weser, both of which are companies of Spanish origin.

Technology

Commissioned in 2010, the MBT facility has been designed with a 245,000 tonnes per annum capacity to treat residual MSW.

The MBT facility is located upon the Coll Cardús landfill, which was near to closure at facility construction, and utilises 3.5 MW of power from the landfill gas.

The technology employed at the MBT facility comprises:

- Masias pre-treatment technology (three pre-treatment lines of 25 t/h capacity per line), including removal of recyclable material (paper, metals, packaging, etc .)
- Taim Weser in building IVC comprising of two automatic infeed systems, two automatic stack turning machines (overhead gantry mounted Rotopala turning equipment) , a discharge system and an aeration system. The composting halls have a capacity of 154,000 tpa, meaning that they are designed to process 63% of the waste input to the facility.
- Masias post IVC compost refining equipment (one line of 20 t/h capacity).
- Wastewater treatment and reuse.

Taim Weser and Masias have supplied technology to UK MBT facilities, including the Tovi Eco Park facility in Essex (Urbaser is the EPC Contractor) and the Waterbeach facility in Cambridge (Amey-Cespa is the EPC Contractor).

As part of the contract, the construction of a source segregated organics treatment facility was also originally planned, to treat 20,000 tonnes per year, but it was never built.

Outputs

The facility produces:

- Recyclable materials (paper, metals, packaging, etc.) (recycled)
- Reject materials (landfill)
- CLO, which is reported to meet European Standards and to be suitable for landscaping or gardening. However, some data sources state that it is either used for restoration of quarries and landfills or it is packed in shrink-wrapped bales with a very small percentage of biodegradability, which suggests it is landfilled.

Regional waste collection

Organic waste, paper and cardboard, glass, plastic, metals, coffee capsules and used oils are collected separately.

Influencing policies

The idea for the MBT facility, the Can Barba AD facility and the source segregation of various recyclable waste streams came from an independent consultancy study undertaken in the early 2000's[74]. At that time, it was anticipated that the Coll Cardús landfill would be completely filled in 2005 and an alternative to landfill was required.

Additional information

The area of the facility is 43.9 ha, of which 37.1 ha is developed, and approaching 80 jobs were created at the facility.

The Can Barba AD facility (25,000 tonnes/year) has been in operation since the end of 2006 and utilises Dranco AD technology for processing of kitchen waste, followed by mixing with green waste and tunnel and windrow composting. The facility was constructed at the location of a former composting plant.

In 2017, the audit office of Catalonia published an audit of the El Vallès Occidental County Council for the 2013 financial year. Several matters discussed in the report are listed below.

- The cost of sending waste to the MBT facility was so high that some municipalities, such as Sant Cugat del Vallès, decided not to use the centre and, instead, to take the their waste to ecoparks II and IV, which are other facilities in the Barcelona area.
- The feasibility study for the MBT facility was completed in July 2006 and the contract for the facility was signed in 2008. The contract included a 25,000 tonnes/year source segregated organics treatment plant (tunnel composting), which is separate to the MBT facility and not to be confused with the existing Can Barba AD facility.
- The original contract price was EUR 74.90 million including VAT (EUR 56.96 million for the residual waste MBT facility and EUR 17.94 million for the source segregated organics facility), which increased in 2010 by EUR 15.69 million (20.9%) (EUR 15.31 million for the MBT facility and EUR 0.38 million for the organics facility). The final cost for the MBT facility was higher again, at EUR 76.77 million (which included EUR 1.74 million paid due to the partial resolution of the contract not to construct the source segregated organics facility). Therefore, the final cost of the MBT facility was 31.7% higher than the original contract price.
- In 2010 the construction and commissioning programme slipped for the first time. In 2013 it was determined that the MBT facility was not in a state to pass warranty tests and the contractor was granted a further six months to resolve the situation.
- On 19 June 2013, the contractor requested the partial termination of the contract in order not to remove construction of the source segregated organics facility, although the work had already started, due to the sharp decrease in the collection forecasts for the organic fraction, which made the projected capacities were significantly higher than actual needs. The facility construction ceased, and liquidated damages were paid.
- On 1 April 2014 the MBT facility appears to have been 'definitively received' (i.e. contractual obligations have been accepted as being met), despite not having the necessary environmental licence and not passing the performance tests for the biostabilisation system and the quality of the biostabilised material, nor of the air treatment system performance and emissions. The remedy was an undertaking to take the pertinent measures necessary to comply with the parameters of the failed tests and the deposit of a EUR 2.80 million guarantee. This stage of the contract should originally have occurred on 19 July 2013.
- The capital cost of the facility was paid for by the Government of the Generalitat de Catalunya, whereas at the time the contractor bid for the project the intention was for the initial capital cost to be contractor funded.

[74] http://www.sindicatura.cat/reportssearcher/download/2016_14_es.pdf

- In the 2013 financial year, 142,030 tonnes of residual waste entered the MBT facility at a gate fee to the municipalities of EUR 70.43 / tonne.

In August 2016 it was reported[75] that the receipt of waste from the MBT facility at the Coll Cardús landfill would cease in one years' time when the landfill closes. The report stated that the sending of waste, from the MBT facility, to facilities further afield would increase the MBT gate fee paid by councils by 1.85% per tonne, so they will pay EUR 77.89 / tonne, a price that includes the treatment, deposit and waste tax.

[75] http://www.elpuntavui.cat/territori/article/11-mediambient/992431-coll-cardus-rebra-20-000-m-de-residus-mentre-es-fa-el-pla-de-clausura-en-un-any.html

A5 Carbon LCA assumptions

<table>
<tr><th>Item</th><th>Assumption</th><th>Function</th><th>Source</th></tr>
<tr><td>Efficiency of RDF combustion</td><td>24%</td><td>Electricity generated from RDF combustion</td><td>Industry knowledge</td></tr>
<tr><td>Target moisture content pre-organic stage</td><td>50%</td><td>Water content target for dry AD</td><td>Technology provider assumption</td></tr>
<tr><td>Distance from waste transfer station to facility</td><td>15km</td><td>Transport emissions</td><td>ZWS EfW Model</td></tr>
<tr><td>Distance from facility to landfill</td><td>50km</td><td>Transport emissions</td><td>ZWS EfW Model</td></tr>
<tr><td>Glass diversion rate</td><td>50%</td><td rowspan="3">Amount of material recovered in mechanical pre-treatment</td><td rowspan="3">Industry knowledge</td></tr>
<tr><td>Metal diversion rate</td><td>75%</td></tr>
<tr><td>Plastic diversion rate</td><td>30%</td></tr>
<tr><td>Waste composition</td><td>
<table>
<tr><th>Material</th><th>%</th></tr>
<tr><td>Animal and mixed food waste</td><td>27%</td></tr>
<tr><td>Discarded equipment (excluding discarded vehicles, batteries and accumulators wastes)</td><td>2%</td></tr>
<tr><td>Glass wastes</td><td>3%</td></tr>
<tr><td>Health care and biological wastes</td><td>10%</td></tr>
<tr><td>Household and similar wastes</td><td>7%</td></tr>
<tr><td>Metallic wastes, mixed ferrous and non-ferrous</td><td>3%</td></tr>
<tr><td>Mineral waste from construction and demolition</td><td>4%</td></tr>
<tr><td>Paper and cardboard wastes</td><td>16%</td></tr>
<tr><td>Plastic wastes</td><td>15%</td></tr>
<tr><td>Rubber wastes</td><td>0%</td></tr>
<tr><td>Textile wastes</td><td>6%</td></tr>
<tr><td>Vegetal wastes</td><td>6%</td></tr>
</table>
</td><td>Input to MBT facility</td><td>SEPA (2019) Waste composition update, reflecting food waste collection impacts</td></tr>
</table>

<table>
<tr><th>Item</th><th>Assumption</th><th>Function</th><th>Source</th></tr>
<tr><td></td><td><table><tr><td>Wood wastes</td><td>1%</td></tr></table></td><td></td><td></td></tr>
<tr><td>Moisture data</td><td>Data available in model (Waste_Props tab)</td><td>Moisture calculation of MBT inputs</td><td>WRATE</td></tr>
<tr><td>Fossil carbon content</td><td>Data available in model (Waste_Props tab)</td><td>Biogenic carbon calculations</td><td>ZWS EfW Model</td></tr>
<tr><td>Carbon emission factors</td><td>Data available in model (Waste_Props tab)</td><td>Calculating carbon emissions</td><td>Chosen for consistency with ZWS EfW model
BEIS Greenhouse gas reporting: conversion factors
-
The global warming potential of methane: Report 5 from the IPCC</td></tr>
<tr><td>RDF Diversion</td><td><table>
<tr><th>Waste Fraction</th><th>RDF</th><th>Residual</th></tr>
<tr><td>Animal and mixed food waste</td><td>5%</td><td>95%</td></tr>
<tr><td>Discarded equipment (excluding discarded vehicles, batteries and accumulators wastes)</td><td>10%</td><td>90%</td></tr>
<tr><td>Glass wastes</td><td>0%</td><td>100%</td></tr>
<tr><td>Health care and biological wastes</td><td>70%</td><td>30%</td></tr>
<tr><td>Household and similar wastes</td><td>50%</td><td>50%</td></tr>
<tr><td>Metallic wastes, mixed ferrous and non-ferrous</td><td>31%</td><td>69%</td></tr>
<tr><td>Mineral waste from construction and demolition</td><td>5%</td><td>95%</td></tr>
<tr><td>Paper and cardboard wastes</td><td>95%</td><td>5%</td></tr>
<tr><td>Plastic wastes</td><td>65%</td><td>35%</td></tr>
<tr><td>Rubber wastes</td><td>65%</td><td>35%</td></tr>
<tr><td>Textile wastes</td><td>95%</td><td>5%</td></tr>
<tr><td>Vegetal wastes</td><td>35%</td><td>65%</td></tr>
<tr><td>Wood wastes</td><td>75%</td><td>25%</td></tr>
</table></td><td>Materials removed during RDF separation stage</td><td>Industry knowledge (based on confidential information held by Ricardo for operational facilities)</td></tr>
</table>

<table>
<tr><th>Item</th><th>Assumption</th><th>Function</th><th>Source</th></tr>
<tr><td colspan="4">Dry AD</td></tr>
<tr><td>Energy data - Input electricity to pre-treatment</td><td>5kg CO_2e/ tonne</td><td>Energy consumption calculation</td><td>ZWS EfW Model</td></tr>
<tr><td>Energy data - Input electricity to AD/IVC</td><td>3,000,000 kWh/a</td><td>Energy consumption calculation</td><td>Technology provider</td></tr>
<tr><td>Energy data - Output electricity</td><td>14,250,000 kWh/a</td><td>Energy consumption calculation</td><td>Technology provider</td></tr>
<tr><td>CH_4 content of biogas (volume)</td><td>57%</td><td>Biogenic carbon in landfill</td><td>Technology provider</td></tr>
<tr><td>Mass Balance data</td><td><table>
<tr><th>Material</th><th>Mass / tpa</th></tr>
<tr><td>Post-pretreatment MSW</td><td>50,000</td></tr>
<tr><td>Iron Chloride</td><td>500</td></tr>
<tr><td>Liquid recycling</td><td>5,000</td></tr>
<tr><td>Steam</td><td>1,010</td></tr>
<tr><td>Biogas</td><td>8,402</td></tr>
<tr><td>Digestate</td><td>48,108</td></tr>
<tr><td>Polymer solution</td><td>8,754</td></tr>
<tr><td>Effluent</td><td>11,777</td></tr>
<tr><td>Pre-stabilisation</td><td>40,085</td></tr>
<tr><td>Losses</td><td>11,485</td></tr>
<tr><td>Stabilite</td><td>28,600</td></tr>
</table></td><td>Mass balance for AD+IVC (dry AD)</td><td>Technology provider</td></tr>
<tr><td>Biogas volume generated per tonne input to AD</td><td>127 Nm^3/tonne</td><td>Biogenic Carbon in landfill</td><td>Technology provider</td></tr>
<tr><td>Destruction efficiency of gas flare or engine</td><td>99%</td><td>Biogenic Carbon in landfill</td><td>GasSim Manual</td></tr>
<tr><td colspan="4">IVC</td></tr>
<tr><td>Process loss</td><td>22.5% (average of 20-25% range)</td><td>Calculation of moisture loss and biostabilised outputs (for landfill)</td><td>Technology provider</td></tr>
<tr><td>Recyclables removed</td><td>7.5% (average of 5-10% range)</td><td>Calculation of biostabilised</td><td>Technology provider</td></tr>
</table>

Item	Assumption	Function	Source
		outputs (for landfill)	
Energy use (typical recyclables)	36.5 kWh/t (range quoted 35-38kWh/t)	Electricity produced calculation	Technology provider
Energy use (high level of recyclables)	39 kWh/t (range quoted 38-40kWh/t)	Electricity produced calculation	Technology provider
Energy use with RDF(typical recyclables)	41 kWh/t (range quoted 40-42kWh/t)	Electricity produced calculation	Technology provider
Energy use with RDF(high level of recyclables)	44 kWh/t (range quoted 43-45kWh/t)	Electricity produced calculation	Technology provider
Portion of process loss due to moisture	25%	Calculation of moisture loss	Ricardo's judgement
Portion of process loss due to CO_2	75%	Calculation of moisture loss and carbon dioxide loss	Ricardo's judgement
Landfill model			
Annual tonnage landfilled	70,000 tonnes	Calculation of emissions from landfill	Selected to be a high number of an order that might be landfilled (but the interest is the per tonne emissions)
Operational lifetime	20 years	Calculation of emissions from landfill	Assumed MBT contract length
Other assumptions	GasSim model inputs	Calculation of emissions from landfill	See Appendix A6

A6 GasSimLite assumptions

The GasSimLite (and full GasSim) model is a probabilistic model (uses an iterative Monte Carlo simulation approach) and so assumptions can be input as distributions (SINGLE, UNIFORM, TRIANGULAR etc.).

In many instances, especially as the model is not for a specific existing landfill, the GasSim default assumptions have been used.

<table>
<tr><th colspan="2">Source Module</th></tr>
<tr><td>Proportion to CO_2 (%) and CH_4 (%)</td><td>SINGLE (50) for both

[Default used]</td></tr>
<tr><td>100% capped at end of operational period</td><td>Yes

[There is no reason to assume a delay to capping]</td></tr>
<tr><td>% Waste in place capped</td><td>Assumed capping over 20 years done in 5 phases:
<table>
<tr><th>Year</th><th>% waste in place capped</th></tr>
<tr><td>2000</td><td>0.0%</td></tr>
<tr><td>2001</td><td>0.0%</td></tr>
<tr><td>2002</td><td>0.0%</td></tr>
<tr><td>2003</td><td>100.0%</td></tr>
<tr><td>2004</td><td>80.0%</td></tr>
<tr><td>2005</td><td>66.7%</td></tr>
<tr><td>2006</td><td>57.1%</td></tr>
<tr><td>2007</td><td>100.0%</td></tr>
<tr><td>2008</td><td>88.9%</td></tr>
<tr><td>2009</td><td>80.0%</td></tr>
<tr><td>2010</td><td>72.7%</td></tr>
<tr><td>2011</td><td>100.0%</td></tr>
<tr><td>2012</td><td>92.3%</td></tr>
<tr><td>2013</td><td>85.7%</td></tr>
<tr><td>2014</td><td>80.0%</td></tr>
<tr><td>2015</td><td>100.0%</td></tr>
<tr><td>2016</td><td>94.1%</td></tr>
<tr><td>2017</td><td>88.9%</td></tr>
<tr><td>2018</td><td>84.2%</td></tr>
<tr><td>2019</td><td>100.0%</td></tr>
</table>
GasSim assumes gas is only collected for utilisation (combustion) from capped areas and so when waste is capped is an important consideration for the model. However, the design of the landfill and its phasing will vary between landfills and operators. The scenario input is considered realistic.</td></tr>
<tr><td>Waste composition</td><td>Default used for ‘Scotland 2020+ waste streams’</td></tr>
<tr><td>Waste breakdown</td><td>100% composted organic material input for each year at 70ktpa and for a period of 20 years from year 2000 onwards.

The purpose of the modelling is to derive a per tonne landfilled emission for CO_2 and CH_4 and so the actual GasSim input tonnage is not too important. 70 ktpa was chosen as it is a large number (provides output easier to work with and allows realistic use of flare or engine- although there is insufficient gas for the latter) that is also broadly reflective of what might be landfilled from an MBT facility of over 100 kpta input capacity.</td></tr>
</table>

	The year of input commencing has no bearing on the model output (can be past, present or future). An MBT facility might typically operate (have a long-term contract for local authority waste) for 20 to 25 years and so it was assumed that waste would be landfilled over 20 years. NB: Ricardo's carbon LCA model adjusts the emissions derived from GasSim to accommodate the presence of non-biodegradable materials that will be landfilled inter-mixed with the composted organic material.
Cellulose decay rates	Moderate [Default used. Default values are within GasSim for slow, moderate and fast cellulose decay rates and moderate was selected. The cellulose decay rate is the half-life values for the degradation of carbon and thus generation of landfill gas. Table 6.1 of the GasSim manual confirms that composted organic material has a moderate decay rate].
Waste Moisture content	Moisture content = Average [Defaults exist for 'Dry' (<30% moisture), 'Average' (30 to 60% moisture) and 'Wet' moisture content (>60% moisture). This is an important parameter that affects waste degradation and gas production. The emphasis of the MBT-IVC process is waste degradation and not drying and hence 'Average' was selected- it is anticipated that the material to be landfilled will have around 35% to 45% moisture. Arguably, 'Dry' could have been selected. However, over the course of 100 years, this is likely to affect when gas is generated but it can be assumed that towards the end of the period gas production would be minimal whether 'Dry' or 'Average' is used]. Waste density (t/m3) = UNIFORM (0.8,1.2) [This is the GasSim default, irrespective of waste composition. Uncompacted compost density ranges from around 0.3 to 0.7, but the material landfilled will be compacted and will be alongside other non-biodegradable fractions of MSW. For reference, a value of 0.9 is commonly used for unprocessed MSW when landfill modelling, and around 1.7 for inert materials (soils/rubble etc) the default UNIFORM range selected is considered appropriate for the waste being modelled]. Leachate head (m) = SINGLE (1) [Default and it is the value that regulators in Scotland wish to see not exceeded at a landfill] Hydraulic conductivity (m/s) = LOGUNIFORM (1.00e-09, 1.00e-05) [Default used].
Landfill Characteristics	

Landfill geometry	Input as 374m x 374m = 139,876 m^2 [Landfill geometry will vary considerably from one landfill to another. With an assumed waste depth of 10m and 1,400,000 tonnes of waste deposited (70ktpa for 20 years) at assumed density of 1t/m3, the landfill area will be 140,000 m^2 (14 hectares)].
Biological methane oxidation in the cap (%)	SINGLE(10) [Default used]
Cap and liner	Single clay cap of 1m thickness input. Single clay liner of 5m thickness input. Hydraulic conductivity of $1x10^{-9}$ m/s input for cap and liner. [The above inputs satisfy modern landfill engineering requirements and are typical].
Infiltration (mm/year)	SINGLE(50) Typical value used. This is the volume of water per unit area which passes into the waste mass.
Gas Plant	It was assumed that a flare with capability to flare down to 100Nm/hr of landfill gas would be available throughout the landfill life. There was insufficient gas produced to allow realistic use of an engine to allow electricity production. Assumptions were input for air/fuel ratio (7), stack height (10m), orifice diameter (1m), temperature (1,000^{o}C), methane and hydrogen destruction efficiency (each 99%) and gas collection system efficiency (%) of UNIFORM(85,95).

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Annex H: Cambridgeshire MBT Letsrecycle.com press article 04 October 2012

letsrecycle.com

October 4, 2012

MBT failure sees Cambridgeshire's waste landfilled

Waste Management

By Amy North

Thousands of tonnes of residual waste from households in Cambridgeshireare being sent to landfill following a mechanical failure at AmeyCespas mechanical biological plant at Waterbeach.

The facility, which has the capacity to process 200,000 tonnes of waste a year, is out of action following an incident on the evening of September 18, when the beam which holds the wheel used to turn the compost broke. Two staff members were one duty at the time, but no one was injured.

The beam which holds the compost turning wheel in place has broken

The firm is now working to get the plant up and running again, but no action can be taken until an investigation, which was undertaken by engineers, is complete.A report is expected to be finished by the end of October. AmeyCespa said that until it has received the results of the investigation, it cannot speculate on the reasons for the failure and the length of time operations will be suspended for.

This means that the 2,200 tonnes of residual waste sent to the plant each week by Cambridgeshire county council is being sent straight to landfill.It is going to asite operated by AmeyCespa which is also at Waterbeach.

Ordinarily, the MBT plant extracts recyclables from the residual using mechanical separation before breaking it down biologically. The process reduces the wastes mass by approximately 50%, with just the remaining compost like output sent to landfill.

In a statement issued earlier this week, the council said: AmeyCespa have made the council aware of a mechanical problem they have experienced at the MBT plant at Waterbeach. Engineers are currently on site and are investigating what has happened. We have a robust contract in place with AmeyCespa to ensure that, should situations like this occur, the services delivered to the communities of Cambridgeshire are protected and any additional costs to the tax payer are kept to an absolute minimum.

A spokesman for the council confirmed that the residual waste was being sent straight to landfill, but added that the council would be looking at other alternative options.

In May 2011 AmeyCespa revealed that it had to send more than 26,000 tonnes of Cambridgeshires residual waste to landfill following delays in the plants commissioning process (see letsrecycle.com story).

Failure

The composting hall in the MBT facility comprises of two lanes, each with separate giant wheels which turn the waste over a seven week period. Although one wheel remains unaffected by the mechanical failure, AmeyCespa said it will not run the other wheel until the expert report has been received.

A spokeswoman for the firm told *letsrecycle.com*: We have had experts in to investigate what happened. Because it is a complicated piece of machinery, until we get the reports back we are not operating the second wheel either. Until we know what caused it we cant be sure if it is safe to run both wheels.

Obviously the reason why we are not running the second wheel is we cant guarantee that the same problem is not going to happen again. Keeping our staff safe is our number one concern.

Meanwhile, the MBT plants sorting line, which removes recyclables from waste prior to the composting process, is also currently suspended, as the waste is automatically moved into the composting hall, and cannot operate as a stand-alone option. The firm said: As a matter of urgency, AmeyCespa is exploring the potential to install equipment which would allow these operations to recommence without diverting waste to the compost hall.

The machinery, which was manufactured by Kelag, was installed by contractor BAM Nutall. A spokesman for BAM Nuttall said: We acknowledge there is a problem and we are carrying out a thorough investigation as to the cause of any failure.

Facility

Related Links

AmeyCespa

Cambridgeshire county council

The MBT facility at Waterbeach was built as part of a 28-year, 731 million PFI contract between Cambridgeshire county council and Donarbon (later acquired by AmeyCespa) for waste treatment and disposal (see letsrecycle.com story).

The Waterbeach site also hosts an in-vessel composting (IVC) facility and a bulking up area for dry recyclables. AmeyCespa is in the process of building a materials recycling facility (MRF) which will eventually process the recyclables. The firm said that the rest of the site was operating as normal.

Annex I: Essex MBT Letsrecycle.com press article 24 October 2022

letsrecycle.com

October 24, 2022
by James Langley

Works set to start ahead of Tovi Eco Park removal

Councils

Vehicles & Plant

Essex county council says preliminary works ahead of the demolition of the Tovi Eco Park mechanical biological treatment (MBT) plant in Basildon are scheduled to get underway "shortly".

Essex is seeking a contractor to dispose of residual waste after the failure of the Tovi Eco Park (picture: UBB)

UBB Waste (Essex) Ltd, a partnership between waste management company Urbaser and infrastructure group Balfour Beatty, signed a PFI contract with Essex in 2012 to design, build, and operate the MBT facility across a 28-year period (see *letsrecycle.com* story).

However, the facility was plagued by significant issues and Essex announced in April it would be closed, cleaned and removed from the site, with UBB's contract cancelled (see *letsrecycle.com* story).

The work will include the removal of key items of machinery and equipment, much of which, Essex says, will be reused or recycled.

Cllr Malcolm Buckley, Essex's cabinet member for waste reduction and recycling, said: "It's really important that the facility's owners are able to repurpose and reuse as much of the equipment from the facility. Where items can't be used elsewhere, we hope they will be recycled wherever possible.

"In the meantime, UBB is looking to remove the facility as soon as possible and I am pleased these initial works will start soon."

The dismantling of the building itself is expected to start later in the autumn, Essex says. The works are scheduled to be completed around Easter 2024.

Residual waste

Meanwhile, Essex county council says it is continuing to work on a long-term strategy for residual waste management in Essex.

The council plans to launch a full public consultation on the future of household waste management in Essex "at a later date".

Essex formally launched a tender for an initial seven-year deal worth £62 million per year for the disposal of 350,000 tonnes of residual waste per annum in August (see *letsrecycle.com* story). However, the council unexpectedly pulled the procurement process on Friday (21 October).

The council currently sends residual waste to various landfill sites, including the Bellhouse Landfill in Colchester.

Essex has landfilled residual waste following the failure of the Tovi Eco Park and changes in the market for refuse derived fuel (see *letsrecycle.com* story).

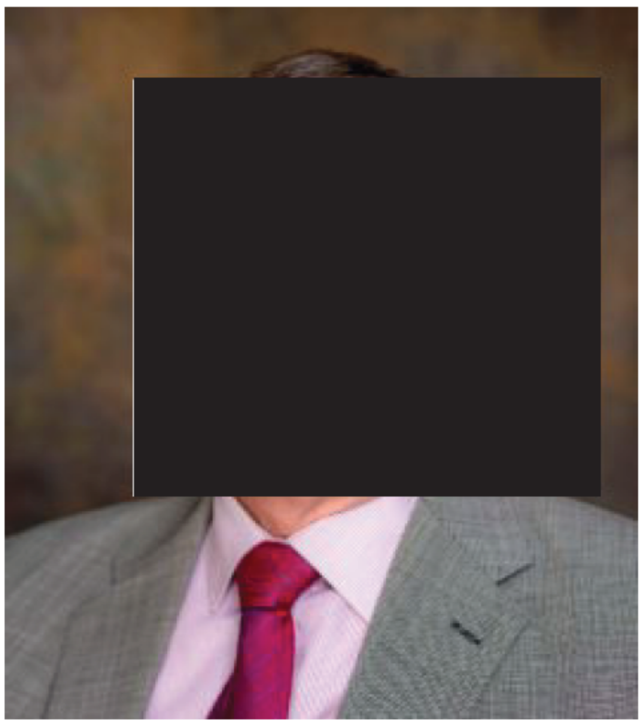
Essex

Cllr Buckley added: “We are working with the city, district and borough councils on options for a long-term solution for our waste treatment and disposal.

“Steps are already being taken to develop a new waste strategy and we will continue to progress the project as quickly as possible.

“However, we must also ensure we get it right so that we can encourage more sustainable and environmentally-friendly waste management in the long term.”

Representing an estimated population of more than 1.8 million, Essex county council had a household waste recycling rate of 49.8% in the 2020/21 financial year.



Cllr Malcolm Buckley, Essex county council cabinet member for waste reduction and recycling

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Annex J: Greater Manchester MBT Letsrecycle.com press article 24 August 2017

August 24, 2017
by Steve Eminton

Viridor Laing GM to be sold for £1

Councils

Waste Management

Closure arrangements for the giant Greater Manchester waste management contract, awarded in 2009 to Viridor Laing Greater Manchester (VLGM), were announced today (24 August).

The Greater Manchester Waste Disposal Authority, which is the client for the contract, said that since autumn 2015 it had been working "with all parties exploring a number of options to secure a reduction in costs and operational improvements to fulfil the required budget savings."

In April this year the Authority voted to end the waste and recycling private finance initiative (PFI) contract with VLGM and now legally binding "Heads of Terms" have been agreed, ahead of a conclusion planned for 29 September 2017.

One of the recycling facilities under the Viridor Laing contract

The Authority explained that contract and efficiency savings had been sought to help mitigate levy increases and next year the rise would be 7.6%. It also explained that until now levy increases had been softened by having to pay less to VLGM because of delays in the construction of facilities. The cost of the recycling and waste management services provided under the contract are £165 million per year.

The GMWDA said it will be exiting the contractual arrangements by "acquiring VLGM via a negotiated settlement for £1. As part of the arrangements GMWDA will be paying back outstanding bank loans at full value."

Difficulties

The contract has seen a number of difficulties on the construction/equipment front. Rather than opting for energy recovery by incineration within Greater Manchester, the authority opted for a contract which would see waste treated in an MBT process and then transported out of the area for incineration at Runcorn.

A vast number of facilities were built under an EPC contract awarded to Costain which in turn appointed a number of contractors to build different types of facilities. But, some of these ran into difficulties such as for composting plants built by TEG which ended up in dispute with Costain.

Apart from the technical problems, local authorities have in recent years started to review their PFI type contracts in the face of austerity and a changing legislative landscape where there is less pressure on councils to hit recycling targets and energy from waste is becoming more easy to access without preparation of material such as through MBT plants.

20	Household Waste Recycling Centres (HWRC) Note: 6 HWRCs have been closed in previous contract years.
5	Mechanical Biological Treatment Facilities (MBT) - 4 with Anaerobic Digestion (AD)
8	Transfer Loading Stations (TLS)
1	Thermal Recovery Facility (TRF)
1	Materials Recovery Facility (MRF)
4	In Vessel Composting (IVC)
2	Green Waste Shredding Facility's (GWS)
1	Energy Recovery Facility (ERF) Note: Refuse Derived Fuel (RDF) produced from the residual waste from Greater Manchester is used to generate heat and power at Runcorn 1 ERF through TPSCo (a joint venture between Viridor, John Laing Infrastructure and Inovyn), which has operated well since it came on line in 2015.

List of contract facilities (source: GMWDA)

Landfill diversion targets for the contract have been met but recycling is lagging behind.

Other local authorities reviewing their contracts include Sheffield with Veolia and Essex where the authority is involved in legal action with Urbaser Balfour Beatty over an MBT plant.

Heads of Terms

Pennon Group – parent company of Viridor – said today that "Viridor and its partners have been working with GMWDA to agree the principles of an exit. These principles have now been agreed and a heads of terms between GMWDA and Viridor Laing (Greater Manchester) Limited has been signed."

And, on the financial front, Pennon said that for the joint venture entities, "Viridor Laing (Greater Manchester) Holdings Limited and INEOS Runcorn (TPS) Holdings Limited, Pennon anticipates at this stage a net one-off nonmaterial impact to the income statement in 2017/18. This takes into account a reduction in the book value investment in joint ventures and an expected one-off gain on joint venture profit after tax."

Paul Boote, Pennon Group financial controller, told *letsrecycle.com* that the "non-material" side applied to the fact that "Pennon Group is a large top-end FTSE 100 company". He would not be drawn on the size of any losses as a result of the contract, explaining that heads of terms of agreement are to finalised by the end of September.

Savings

Greater Manchester Waste Disposal Authority said that "Immediately following the termination on the 29th September, refinancing arrangements will have been completed. This works on the same principles as a mortgage and the GMWDA has been able to secure significantly reduced rates. From this alone the savings are £20 million per year.

"In addition, modifications (which are yet to be fully determined) to the current suite of facilities are forecast to generate further savings in operational costs."

Future operation of HWRCs will be put out to tender

Under the proposed agreement, residual waste will continue to be treated at the Runcorn I Energy Recovery Facility which Viridor will continue to operate for the remainder of the original 25-year contract with no significant operational changes. And, it is expected that Viridor will continue to provide these services for a period of not less than 18 months. Viridor will also be eligible to bid for the new contract.

New contract to be let in the wake of Viridor's planned departure will include for operating residual processing sites and activities, plus any associated HWRC, TLS, and MRF based on those sites. Also included is the Bolton TRF and preparation and delivery of fuel to the Runcorn ERF by rail.

And, tenders will be invited to run civic amenity and bio-waste facilities.

Annex K: Merseyside MBT Letsrecycle.com press article 14 July 2011

letsrecycle.com

July 14, 2011

Orchid shuts formerly Defra-backed MHT plant

Waste Management

Orchid Environmentals 13 million mechanical heat treatment (MHT) facility in Huyton on Merseyside has shut, three years after opening with 5.6 million of funding from Defras New Technologies Demonstrator Programme.

The 13 million Huyton plant, which produces a fuel and recyclables, has had a throughput of up to 80,000 tonnes per year and operated for the past two years on a merchant basis. It opened in partnership with the Merseyside Waste Disposal Authority (MWDA) which had said it would help the Authority in the years before it appointed a waste treatment contractor.

Tanks for the Huyton plant prior to installation

In 2007, Carl Beer, director of Merseyside Waste Disposal Authority (MWDA), said: This technology will play a crucial role for Merseysides waste management in the period before we implement our new longer term contracts. If successful the Huyton project may be part of this solution.

Shotton and Bexley

The plant, which is understood to be the only one of its kind in the UK, has been closed by the Lancashire-based company as it focuses on developing two larger MHT facilities, at Shotton, in North Wales, and at Bexley, in South East London. Like the Huyton project, the proposed London facility has public sector support. The company has secured a 4 million loan from the London Waste and Recycling Board (see letsrecycle.com story) for development of the facility in Bexley. Planning permission for the Shotton plant was granted in 2008 and will be in an existing former Corus Steel building.

Orchid Environmental today acknowledged that it did not as yet have full funding finalised for either of the proposed new plants. Managing director, Steve Whatmore, told *letsrecycle.com*: Were very close to getting funding realised for the two 160,000 tonne-a-year capacity facilities.

Financial close

The company says it will achieve financial close on the entirely-privately financed Shotton facility in the near future, while funding for the Bexley plant was described as being close to fruition by Mr Whatmore. He explained that the nature of the funding for the Shotton project had impacted on the companys decision to close Huyton.

When you privately fund something, you want the money spent on exactly where youre looking to fund. Our focus is now on getting the build with Shotton, he said. The Shotton project was mooted as costing 20 million to develop when planning permission was secured in December 2008 (see letsrecycle.com story)

Funding support

The Huyton facility officially opened in June 2008 (see letsrecycle.com story), with Defras funding support for the project formally running out when the New Technologies Demonstrator Programme ended in March 2009. It uses a process that involves steam being used to separate out recyclables from the waste, leaving a fuel. As such, it is similar to autoclave, but does not involve pressure.

Mr Whatmore explained that, since the end of the Defra-programme, the plant had been p of residual household and commercial waste.But, he said that the company had achieve 50,000 and 80,000 tonnes-a-year of material depending on the type of waste feedstock b

As a research and development facility it achieved everything we set out to do in there, h to create robust supply chains both for feedstock for the plant and for the fuel and recyc

Related links

Orchid Environmental

While Orchid does not envisage the Shotton facility opening until the second quarter of 2012, Mr Whatmore was confident about the markets the company had in place. We have developed partnerships and relationships with offtake markets who are looking across five, six, seven or eight years, he said. The fuel goes to a variety of clients in the renewable electricity and heat sectors, theyre in much demand.

Annex L: Rotherham MBT Letsrecycle.com press article 02 October 2002

October 2, 2012

Waste Management

Sterecycle ceases operations after BDR ends contract

Autoclave specialist Sterecycle has ceased operations at its Rotherham-facility, after its main waste contract was terminated.

The Barnsley, Doncaster and Rotherham (BDR) Waste Partnership ended its waste treatment contract with Sterecycle after the firm entered administration on September 18 (see letsrecycle.com story).

Sterecycle has stopped processing waste at its Rotherham facility

Following the termination of the contract, the councils are sending the waste to Veolia ES' energy-from-waste plant in Sheffield.

In addition, 70 of Sterecycles 90 strong workforce have been made redundant.

The administrators are now looking to find a buyer for the business assets, which it hopes to have completed by the end of the week.

Talking to *letsrecycle.com*, Guy Hollander, one of the administrators from Mazars, said there had been over 40 expressions of interest in the site; however some of these are likely to fall away. Mr Hollander added that he had communicated with the interested parties and expected final bids in by close of play of today (October 2).

Discussing what happens next, he said: We just have to see what price we get, its a bit too early to say. The main thing we are concerned about is getting the business up and running and trying to preserve the workforce and maybe re-employ some of the others.

If they [the buyers] want to start operations again they can. The people we are talking to are looking at the on-going viability of the business, they are not looking to strip it out for metal.

BDR

BDR said it had to cancel the contract with Sterecycle as the terms and conditions were not being met.

Karl Battersby, strategic director for environment and development services at Rotherham borough council, said: Obviously it is always sad when any company gets into difficulties but it is particularly so when it is a local company offering such an innovative treatment of local household waste.

BDR has worked hard to support them throughout the term of the contract but unfortunately we had to cancel because the terms and conditions of the contract were not being met by Sterecycle and as a waste authority, our key duty is to our own customers – the public.

BDR added that it was now in discussions with the Environment Agency and the administrators to see how the site will be managed. In addition, it said it will work with other agencies to help find alternative employment for the Sterecycle staff.

Treatment

The 68,000 tonnes of BDRs residual waste that was treated by Sterecycle per annum is now being sent to Veolia ES energy recovery facility in Sheffield as well as to landfill.

Related Links

BDR

Sterecycle

Mr Battersby added: Last year the three authorities sent just under 68,000 tonnes of waste to the Templeborough autoclave facility as part of an interim contract. Fortunately, Sterecycle was one of several partner companies which deal with our waste and so we have been negotiating with them to ensure continuity in the disposal of the borough's waste on a temporary basis.

This is not the first time the councils have looked to Veolia for help. In early 2011 it treated the residual waste from Rotherham that would have been sent to Sterecycle, after an explosion at it's facility saw the site temporarily closed (see letsrecycle.com story).

The Yorkshire Police investigation into the explosion, in which one man was killed, is ongoing.

Annex M: Lancashire MBT Letsrecycle.com press article 06 August 2014

August 6, 2014

Councils

Global Renewables Lancashire contract terminated

Lancashire and Blackpool councils have cancelled a joint long term waste treatment contract with Global Renewables, just over three years after it began, writes Will Date.

The contract for waste treatment was awarded in 2007 to Global Renewables under a £2bn, 25-year agreement to process the household waste from 1.4 million people in Lancashire.

As part of the deal, the firm designed, built and operated two mechanical biological treatment (MBT) facilities in Farington and Thornton in the north-west, which commenced operations in early 2010. The plants took in municipal waste for sorting and treatment to allow the recovery of recyclable materials and the processing of much of the residues to a marketable compost product.

Global Renewables Farington MBT facility is now jointly owned by Lancashire and Blackpool councils

On Friday (August 1), the councils announced that they had taken over ownership and responsibility for running the two sites, after the 25-year contract with Global Renewables Lancashire was mutually terminated.

Termination

According to a spokesman for Lancashire council, the original terms of the PFI contract allowed for the facilities to be handed over to the council at the end of the 25-year deal or upon early termination of the deal.

> *"The facilities have made significant improvements in operations over the past 18 months and whilst it is always difficult to say previous issues have been fully resolved we are confident that the facilities can operate successfully and achieve high levels of diversion from landfill."* – **Lancashire council spokesman**

The local authorities have refused to reveal the financial terms of the cancellation of the contract, but have claimed that they will now be saving money as a result of renegotiating the terms of the PFI arrangement.

Lancashire and Blackpool claim that by restructuring the financing for the sites, they will jointly save more than 12 million pounds per year over what would have been the remaining 22 years of the contract.

The facilities had suffered teething problems since beginning operations, and in February 2013 it was revealed that around 75% of the waste which had been sent for treatment at the sites in 2011/12 had ended up in landfill (see letsrecycle.com). This was despite Global Renewables claiming that the sites could divert up to 75% of waste from landfill once fully operational.

Improvements

While improvements in the sites performance have been made, the councils have admitted that some issues are still unresolved. Work has been carried out on the Farington site to attempt to mitigate the odour released by the process for which Global Renewables was fined £150,000 by Preston Magistrates Court in April 2013. Mechanical failures have also seen the plants shut down for maintenance since opening.

The spokesman added: "As with any facilities of the scale and nature of our two waste recovery parks it takes a certain amount of time to fully understand and optimise operations. The facilities have made significant improvements in operations over the past 18 months and whilst it is always difficult to say previous issues have been fully resolved we are confident that the facilities can operate successfully and achieve high levels of diversion from landfill."

It is not yet clear what the cancellation of the deal will mean for the future of Global Renewables operations in the UK, as it currently operates no other facilities in the country. The firm declined to comment on the deal or its future in the UK market when contacted by *letsrecycle.com*

Related Links

Global Renewables

Lancashire council

Blackpool council

Annex N: Northwich MBT Letsrecycle.com press article 17 February 2023

letsrecycle.com

February 17, 2023
by Joshua Doherty

Waste Management

Councils

Ørsted seeks buyer for Northwich treatment plant

Ørsted has begun the search for a buyer for its Renescience project in Northwich, Cheshire, as it seeks to exit the waste treatment sector.

The plant is designed to treat unsorted residual waste using enzymes to create a 'bioliquid' and was referenced by Defra in the 2018 waste strategy (picture: Orsted.co.uk)

In its annual report for 2022 published on 1 February, the Danish energy company formerly known as DONG Energy explained that it has "initiated a process for identifying the right owner of our Renescience business, including our waste treatment facility in Northwich".

The 120,000 tonne "first of its kind" facility completed commissioning in October 2020 after four years of delays. It is designed to treat unsorted residual waste using enzymes to create a 'bioliquid' and solid recovered fuel, while also generating electricity.

This process also, the company claims, sees recyclable material separated out from the residual waste fraction. Waste for the facility is supplied by FCC Environment and sourced from the north of England and the midlands.

> Waste treatment is no longer part of our business model and strategic focus
>
> Ørsted

Losses

Ørsted says the facility has been accepting waste since going through commissioning, though the tonnages are unclear.

Last year, Ørsted said it was working on odours coming from the facility, after a string of complaints from local residents (see *letsrecycle.com story*).

Delays to the plant led to Ørsted taking a £50 million impairment charge. Ørsted Renescience Northwich also posted losses of £12 million and £10 million in 2020 and 2021 respectively.

The company now appears to be looking to cut its losses on the facility, though said the technology has “great potential”.

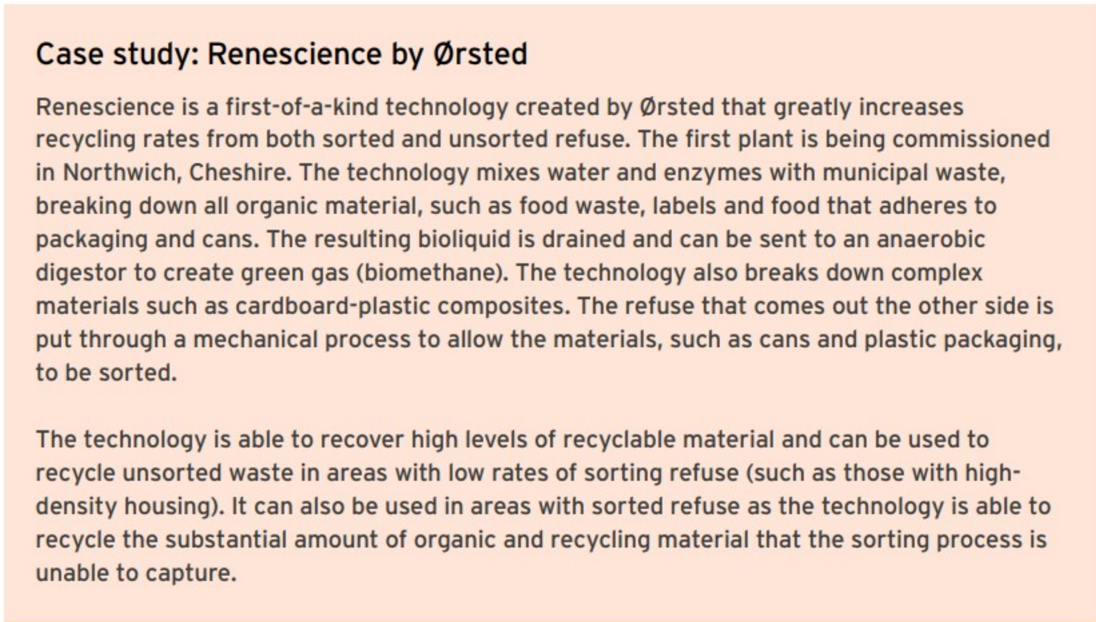
The report added: “The Renescience technology has great potential to help solve the increasing global waste challenge, and Ørsted has been a successful incubator for the technology. However, waste treatment is no longer part of our business model and strategic focus.”

Strategy

The plant was among those to be featured as a case study in the government’s Resources and Waste Strategy 2018.

According to the Strategy, the technology could be used to recycle unsorted waste in areas with low rates of sorting refuse – such as high-density housing.

The topic of sorting mixed waste was raised this week by Zero Waste Europe (see letsrecycle.com story).


Case study: Renescience by Ørsted

Renescience is a first-of-a-kind technology created by Ørsted that greatly increases recycling rates from both sorted and unsorted refuse. The first plant is being commissioned in Northwich, Cheshire. The technology mixes water and enzymes with municipal waste, breaking down all organic material, such as food waste, labels and food that adheres to packaging and cans. The resulting bioliquid is drained and can be sent to an anaerobic digestor to create green gas (biomethane). The technology also breaks down complex materials such as cardboard-plastic composites. The refuse that comes out the other side is put through a mechanical process to allow the materials, such as cans and plastic packaging, to be sorted.

The technology is able to recover high levels of recyclable material and can be used to recycle unsorted waste in areas with low rates of sorting refuse (such as those with high-density housing). It can also be used in areas with sorted refuse as the technology is able to recycle the substantial amount of organic and recycling material that the sorting process is unable to capture.

Defra mentioned the plant in its 2018 Resources and Waste Strategy (source: Defra)

Annex O: Renescience Project Site Visit, February 2023

Annex O: Renescience Project Site Visit, February 2023

Dr Swen Grossgebauer – Head of Innovation and Proposals

View of Renescience Project in Northwich

We inspire with energy.

Process description

Residual Waste is delivered and tipped into a waste bunker. An overhead crane is feeding the waste into one of the two reactors. The reactor is a long rotary tube where water and a mixture of enzymes is added. The rotary movement mixes the waste with the water and enzymes and allows for a continuous movement of the waste to the end of the reactor. The waste needs several hours to move through the reactor where most of the biogenic matter is dissolved into the liquid phase through the work of the added enzymes.

The liquid phase is pumped into the Anaerobic Digestion facility to generate biogas. The digestate of the Anaerobic Digestion facility will be dewatered and the process water is recirculated into the overall treatment process.

The solid material is conveyed into the adjacent sorting hall where mechanical treatment equipment separates the solid materials into the following fractions:

- Non-ferrous and ferrous metals
- 3D plastics which can be recycled
- 3D and 2D RDF which cannot be recycled

Advantages and Disadvantages

Based on the site visit the following assessment is made:

Advantages	Disadvantages
• The process allows for separation of the biogenic fraction in the residual waste and the conversion into biogas • Part of the solid material of the residual waste (metals and 3D plastic) will be separated and can be recycled • A proportion of the required process water will be recirculated	• More than 55% of the residual waste comes out as 3D and 2D RDF fraction and cannot be recycled and will be sent to an EfW facility • Highly complex process, especially the post-reactor mechanical sorting process • High energy and maintenance demand of the post-reactor mechanical treatment process • Lower availability than conventional EfW process • Overall higher treatment costs for residual waste • Site parasitic load is almost 40% of gross power generated

Conclusion

The Renescience process is a unique and patented process that allows for separation and liquification of the biogenic fraction in the residual waste which will then be used to generate biogas.

Some of the solid fraction of the residual waste is treated in this manner. However, more than 50% of the residual waste cannot be recycled and needs either to be landfilled or further treated in an EfW facility.

The post-reactor mechanical sorting process of the wet solid fraction is complex, energy and maintenance intensive.

Considering the relatively high existing and even higher targeted UK recycling rate through separation at source, especially with expected increase in separate food waste collection, the need for such a complex and costly residual waste treatment process with only a partial increase of the recycling output should be questioned.

The Renescience process might be more efficient to use in emerging markets where low recycling rates at source dominate and the biogenic fraction in the residual waste stream is much higher.

Annex P: Gateshead MBT/Autoclave Letsrecycle.com press article 12 August 2016

letsrecycle.com

August 12, 2016
by Tom Goulding

UK's largest autoclave plant to be resurrected

Waste Management

A defunct autoclave plant in Gateshead is to receive a new lease of life from October 2016, following a £2.2 million injection into the facility.

And, the site's new owner – Catfoss – has also been awarded planning consent to construct two gasification plants on the five-acre site.

Graphite Resources' Derwenthaugh EcoParc closed its doors in 2013 with a loss of 70 jobs.

One of three autoclaves arriving at the Graphite Resources Park 2009

The facility – which was aimed to be the largest steam-based autoclave plant of its kind in the UK – was capable of processing 320,000 tonnes of municipal and commercial solid waste when operations began in 2009 (see letsrecycle.com story).

Autoclave

Autoclaving is a process which involves heating the waste at high temperatures via pressurised steam, segregating recyclables and sterilising the waste fraction for use as refuse-derived fuel or biofuel.

The EcoParc is now set to be resurrected, after the site was sold to Humberside-based holding company Catfoss last year by Bilfinger GVA's Newcastle Industrial Agency on behalf of Graphite Resources. An environmental permit for the site was reissued by the Environment Agency in September 2015.

Catfoss, which holds a number of manufacturing and property development interests, will seek to resume operations and produce a turnover of £10 million per year.

Access

The company's aims have been made possible via a £2.2 million funding package provided by Leeds-based Access Commercial Finance. The package will be used to refinance the mothballed plant and buy the machinery required.

The plant could be fully operational by October 2016 with around 30 jobs created.

Going forward, Catfoss has also won planning consent to construct two pyrolysis treatment plants at the park – capable of producing up to 12MW of power for the National Grid.