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Discussion paper on the use of Mechanical Biological Treatment (MBT) to treat mixed putrescible waste

By order of Waste Authority

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Abbreviations

a	year
AOX	adsorbable organic halogens
AT_4	breathing activity over the course of four days
BOD_5	biochemical oxygen demand in five days
C:N ration	carbon to nitrogen ratio
CCHP	combined cooing, heating and power
CFCs	chlorofluorocarbons
CHP	combined heat and power
COD	chemical oxygen demand
DM	dry matter
DOC	dissolved organic carbon
el	electrical
EWC	European Waste Catalogue
g	gram
GF_{21}	gas formation rate over the course of 21 days
HCV	higher calorific value
kg	kilogram
kJ	kilojoule
kWh	kilowatt hour
L	litre
LCV	lower calorific value
m^3	cubic metre
max.	maximum
MBS plant	mechanical-biological waste stabilisation (drying) plant
MBT plant	mechanical-biological waste treatment plant
Mg	Megagram (ton)
mg	milligram
min	minimum

MPS plant	mechanical-physical stabilisation plant
MPT plant	mechanical-physical waste treatment/stabilisation (drying) plant
MT plant	mechanical waste treatment plant
N_{total}	total nitrogen
NF	non-ferrous
ng	nanogram
NIR	near-infrared (detection range for optical sensors used in sorting)
NMVOC	non-methane volatile organic carbons
OU	odour unit
RDF	refuse derived fuel
RTO	regenerative thermal oxidiser
Scm	standard cubic metre
SL	standard litre
SRF	secondary recovered fuel
TASi	German Technical Instructions on Municipal Waste
TMC	thermo-mechanical cell lysis
TN_b	total bound nitrogen
TOC	total organic carbon
VOC	volatile organic compounds
Wt%	per cent by weight
WTE	waste-to-energy plant

1 Project description and tasks

The following study describes and compares available MBT technologies.

Modern MBT technologies were mainly developed and are wide spread in central Europe, especially Germany. Hence, data sources in this paper often have German origin-

2 Historical background, description and treatment targets of MBT

2.1 What is MBT?

Mechanical-biological waste treatment (MBT technology) is a material-specific process. Mixed (residual) waste is separated into various fractions, each of which is treated and, if possible, recycled in a way that is customised to its properties. The core elements of MBT are mechanical or physical separation technologies and the biological treatment of biodegradable waste components unless they are diverted to recycling (e.g. paper). Most MBT plants divide their input into a fine fraction for biological treatment and a coarse high-calorific fraction that undergoes extended mechanical treatment.

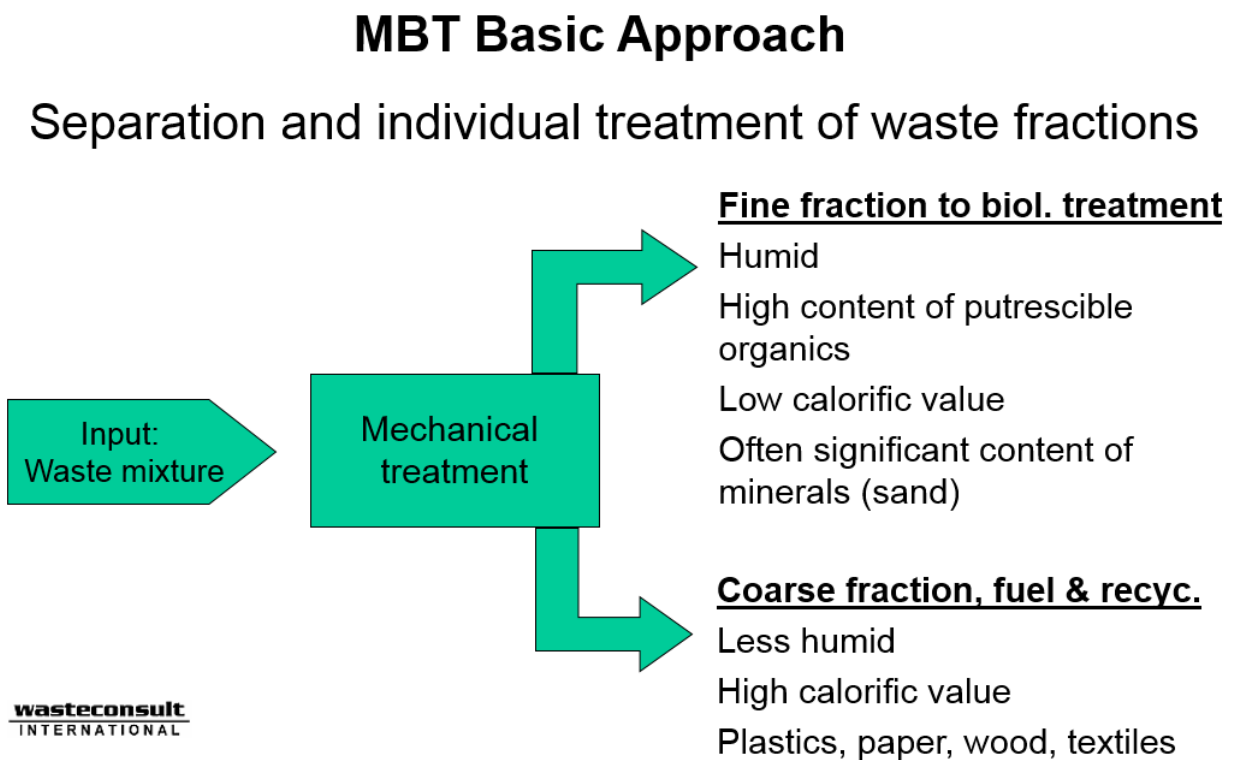

Figure 1 MBT basic approach

Mechanical-biological stabilisation plants (MBS) deviate from this concept as their entire input or the mechanically separated, high-calorific fraction undergoes biological drying.

2.2 Distinguishing between mechanical-biological treatment of residual waste and composting and anaerobic digestion of separately collected organic waste (biowaste)

The biological steps of the mechanical-biological residual waste treatment process are widely identical to those employed for the composting and anaerobic digestion of separately collected organic waste. MBT has tougher requirements with regards to mechanical treatment and some biological treatment machinery due to its broader input spectrum and more heterogeneous feedstock. MBT also necessitates more mechanical effort to extract a significant amount of material that does not endure biological treatment, for example the high-calorific coarse fraction and ferrous and non-ferrous metals. Where possible and useful, the coarse fraction should undergo additional processing and differentiation.

Residual waste also normally tends to have a much higher potential risk from spots of contamination and a significantly higher level of contaminants than separately collected organic waste. Consequently, biologically treated residual waste is not very suitable for agricultural application and should preferably be excluded from agricultural application due to potential contamination that can not be monitored. Besides of a higher level of hazardous substances, MBT compost usually has a higher level of visible impurities than compost from separately collected organic waste.

Mechanical-biological treatment of residual waste and the treatment of separately collected organic waste differ because of their differing input and treatment targets.

2.3 Current treatment targets

The objectives of mechanical-biological waste treatment vary depending on the location, waste flows, legal and economical situation, and they can thus be weighted differently:

- minimising climate-relevant methane emissions from landfills
- decreasing landfill leachate contamination
- reducing landfill void consumption
- filling existing landfill volume capacities
- minimising thermal waste treatment
- separating recyclable materials
- producing a high-calorific secondary fuel

2.4 Historical background

Drivers of the development of MBT as well as for improvement in waste management and waste legislation were

- Producing cheap fuel from waste (late 1970s)
    - Non successful first attempts of mechanical treatment for RDF production (accidents and no economical viability)
- Producing a fertilizing compost and avoiding Landfilling (began in the 1970s)
    - Has been widespread in Poland, Austria, France and other countries, still in practice for example in Australia, France and Spain
- Groundwater and soil protection (1980s and 1990s)
    - Basic MBT technologies reduced leachate contamination and gas production significantly (only voluntarily applied at a few locations)
- „Exploding“ waste amounts and shortage of sanitary landfill space (late 80s and early 90s)
    - Basic MBT technologies reduced landfilled waste volume (only voluntarily applied at a few locations)
- Climate protection (since 90s)
- Increasing prices and expected shortage of resources (90s and now)

In Europe, the EU Landfill Directive prescribes that the amount of biodegradable municipal waste going to landfill must be reduced to

75 % of 1995 levels by 2006;

50 % of 1995 levels by 2009;

35 % of 1995 levels by 2016.

This leads to widespread introduction of sophisticated waste treatment processes, especially incineration and MBT. Countries that landfilled more than 80 % of their municipal waste in 1995 could apply for a prolongation up to 4 years. Most East European countries, Greece and UK did.

The real kick-off for the development and widespread application were legal regulations and landfill levies.

2.5 Benefits of MBT over competing technologies

2.5.1 Benefits of MBT over bioreactor landfill

Bioreactor landfills are sometimes considered as viable and competitive alternatives to MBT, but MBT offers significant advantages over bioreactor landfills:

- Full control and prevention of gaseous emissions in enclosed systems
- Industrial process in which the total waste is involved. No dry (not affected) zones such as in a landfill
- Leaves more stabilized material in the landfill (Aerobic degradation is more effective on poorly biodegradable substances than the anaerobic processes in the landfill)
- Higher gas yield and capture (intensive treatment and no loss of open installation areas or leaks in a landfill)
- Valuable resources (metals, wood, plastics, paper ...) are recycled and not lost in the landfill
- Producing a high calorific solid fuel
- Less land consumption and avoidance of burden for future generations

2.5.2 Benefits of MBT over solid waste incineration

Mass burning MSW is a widespread and approved waste treatment option. Adding MBT to the waste management strategy has major advantages compared to waste management plans that rely on incineration only:

- Mostly cost effective (capital and operating costs), especially at lower requirements than in central Europe / Germany
- Economic operation of smaller units is possible
- Much less sensitive to fluctuations in waste composition and waste production, thereby significantly lower economic risk
- Option to extract recyclables
- No burning of water and stones. Only appropriate, high calorific value waste going into the energy recovery

- Less potential of highly toxic emissions, as the high temperature thermal processes can be avoided (except for the combustion of the RDF)
- Usually less resistance in the population

3 Types of mechanical-biological waste treatment

3.1 Overview

Mechanical-biological waste treatment plants are grouped into the following types based upon the main technology used in the biological stage:

- Conventional MBT with a humid fine and a coarse high calorific output fraction
    - Aerobic processing ("composting" technologies)
    - MBT with „dry" anaerobic treatment (65-70% of water in the fermenter)
    - MBT with „wet" anaerobic treatment (85-96% of water in the fermenter)
- MBT (MBS) with biological drying for solid recovered fuel (SRF/RDF) production
    - Short aerobic drying process (BD) and efficient material separation after drying for combustion and recycling
- Mechanical-physical drying plant (MPS). Similar to MBS, but drying with fossile energy and no biological step

Anaerobic technologies yield both solid output streams and biogas (methane) that can be used as a source of energy. Anaerobic stages are always followed by an aerobic treatment phase. Installations with anaerobic digestion stages can operate as full-stream or partial-stream fermenters (in relation to the input to biological treatment).

A special kind of anaerobic MBT plants are percolator plants. In these plants the putrescible organic matter is washed out of the waste and the organic matter enrich liquid is anaerobically digested.

The choice of MBT machinery is based upon the following factors:

- the treatment objective
- the type and composition of waste
- the requirements for subsequent biological treatment
- the requirements for energy recovery

Usually, MBTs consist of the following basic elements:

- Input control /selection
- Extraction of material with high energy content (high calorific value) by sieving (diameter >60-150mm / ~3-6´´) or other technologies
- Magnetic metal (Fe) separation
    - Magnetic separator for ferrous metals (always available)
    - Eddy current separator for non-ferrous met. (many plants)
- Biological treatment of fine fraction
- If necessary, further mechanical treatment of biologically treated group for the withdrawal calorific constituents by sieving or air classification
- If necessary, further processing of the calorific fraction

In biological drying plants, usually the total input is shredded and fed to the biological drying process. Separation can be done better after the drying.

The following pictures and drawings show some basic MBT elements

Figure 2 MBT waste receival hall

Figure 3 **Sieving drum**

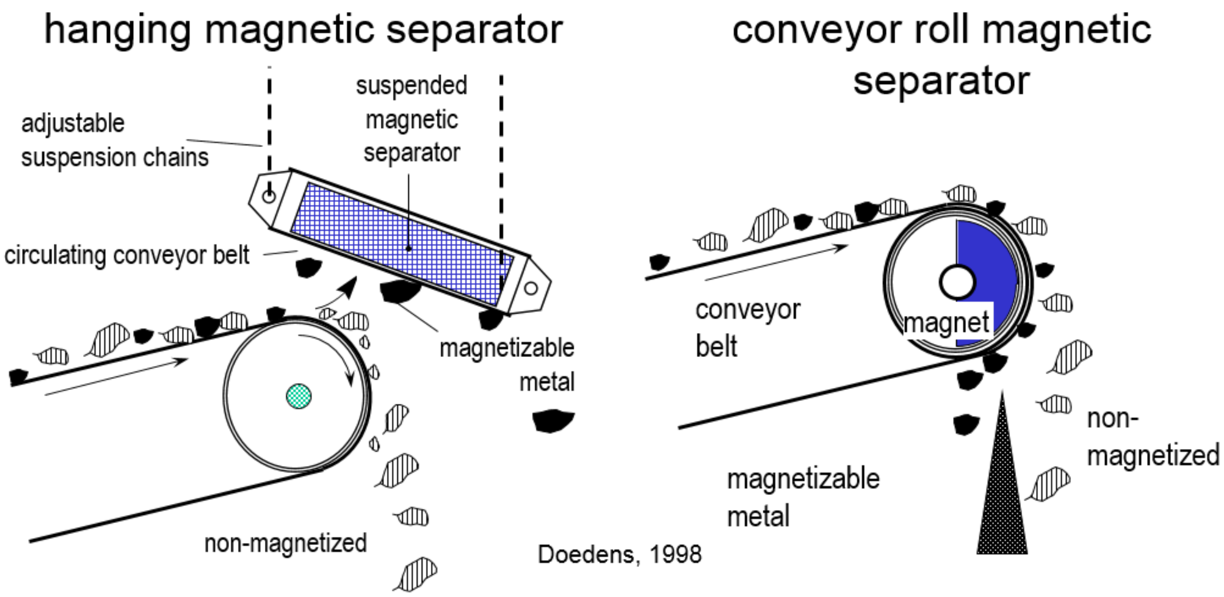

Figure 4 **Metal separation**

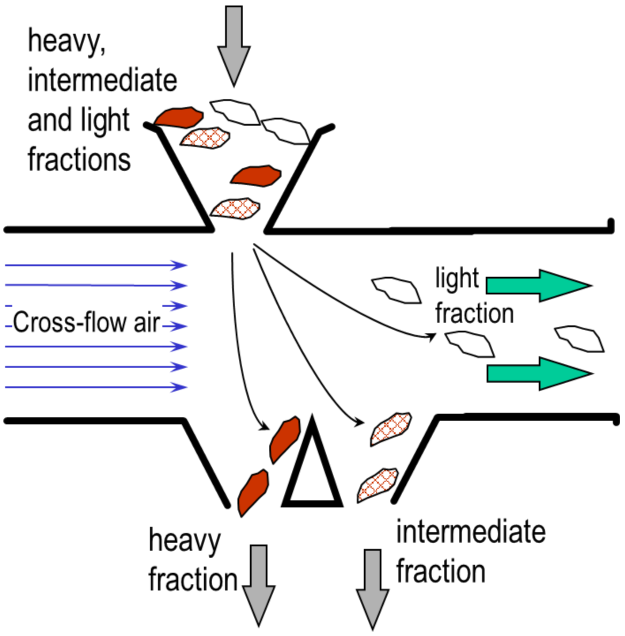

Figure 5 **Air classifier**

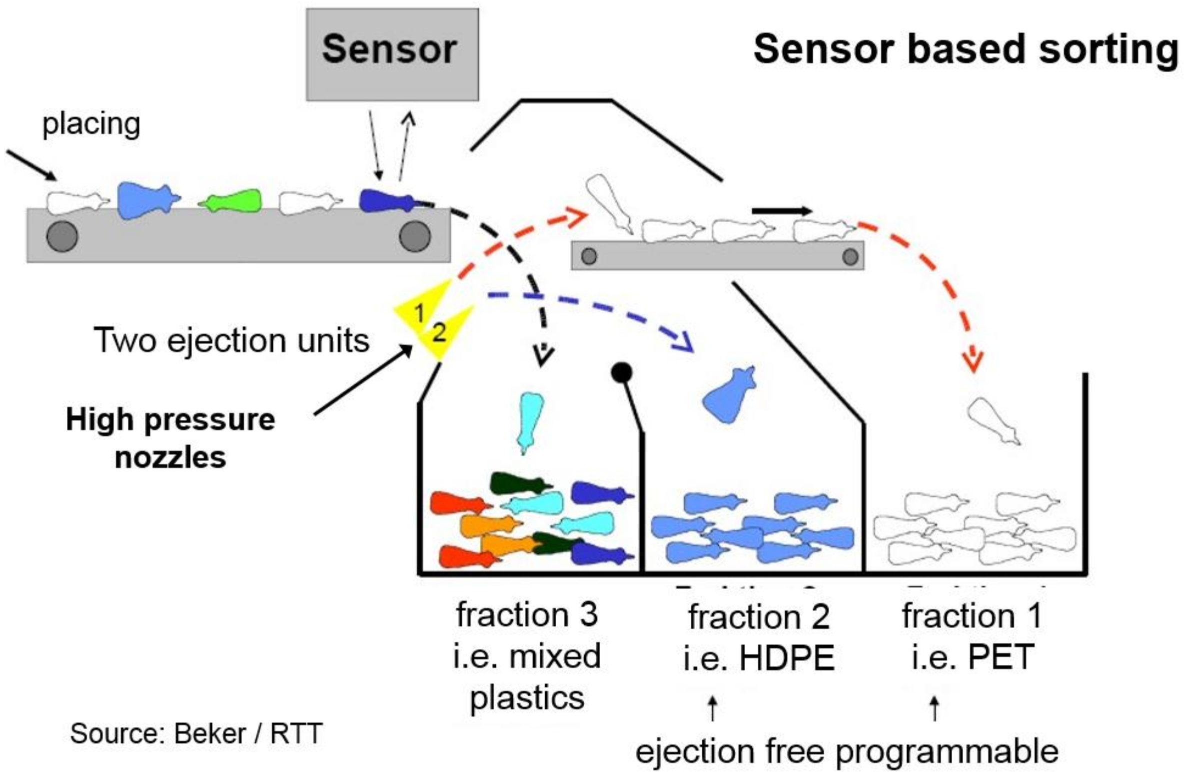

Figure 6 **Sensor based sorting**

3.2 Description of the process groups

3.2.1 Conventional MBT with a humid fine and a coarse high calorific output fraction

Conventional MBTs split their input into a fine fraction for biological treatment and a coarse high-calorific fraction that undergoes extended mechanical treatment. The fine fraction is either handled as a stabilised landfill input fraction or in some countries also used as low grade compost.

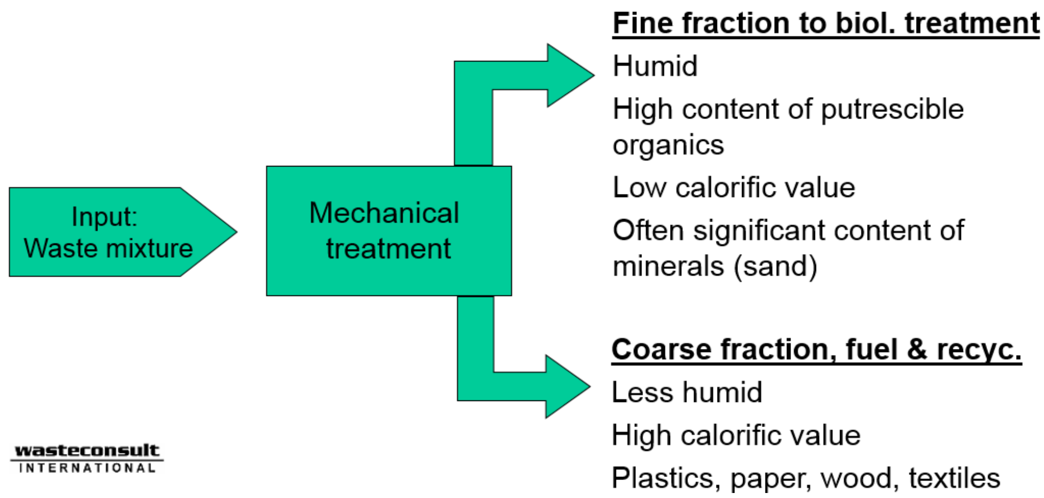

Figure 7 Input splitting in a conventional MBT

The oldest and most widespread process are aerobic MBTs. The process is similar to composting plants for organic waste, but the heterogeneous MSW sets higher and different demands on the machinery. The duration of the biological treatment depends on the treatment target (degree of stabilisation of the output) and legal requirement. The top flow chart in Figure 8 shows the process steps of an aerobic MBT.

In anaerobic MBTs the whole or a part of the biologically treated fraction first undergoes treatment in anaerobic digester (fermenter). There are many different processes for anaerobic digestion (AD). They differ in the number of steps, temperature and the kind of digestion vessel for example. The benefit of AD is the yield of Methane gas (biogas). The AD step is followed by an aerobic process that stops the methane production (and possible emissions from the digester output), reduces odour and further stabilises the output biologically.

While aerobic MBTs often can be operated without producing wastewater (percolated water from the bottom of the windrows can be recirculated to the windrow), anaerobic MBTs usually produce wastewater. The concept of partial flow AD, like it is shown in the second flow chart in Figure 8, uses the wastewater to compensate the water demand of the aerobic process step. This works in case of moderate waste moisture content and requires a sufficient amount of fresh waste in the aerobic step. The applied AD process is so called dry, which still means a water content of 70% or more in the fermenter.

Full flow AD is often operated as wet fermentation and in that case also the aerobic treatment can be done in the liquid phase. The output of the biological step is mechanically and thermally dried.

A special kind of wet anaerobic MBT plants are percolator plants. In these plants the putrescible organic matter is washed out of the waste and the organic matter enrich liquid is anaerobically digested. Garage / concrete box fermenters make use of percolation too.

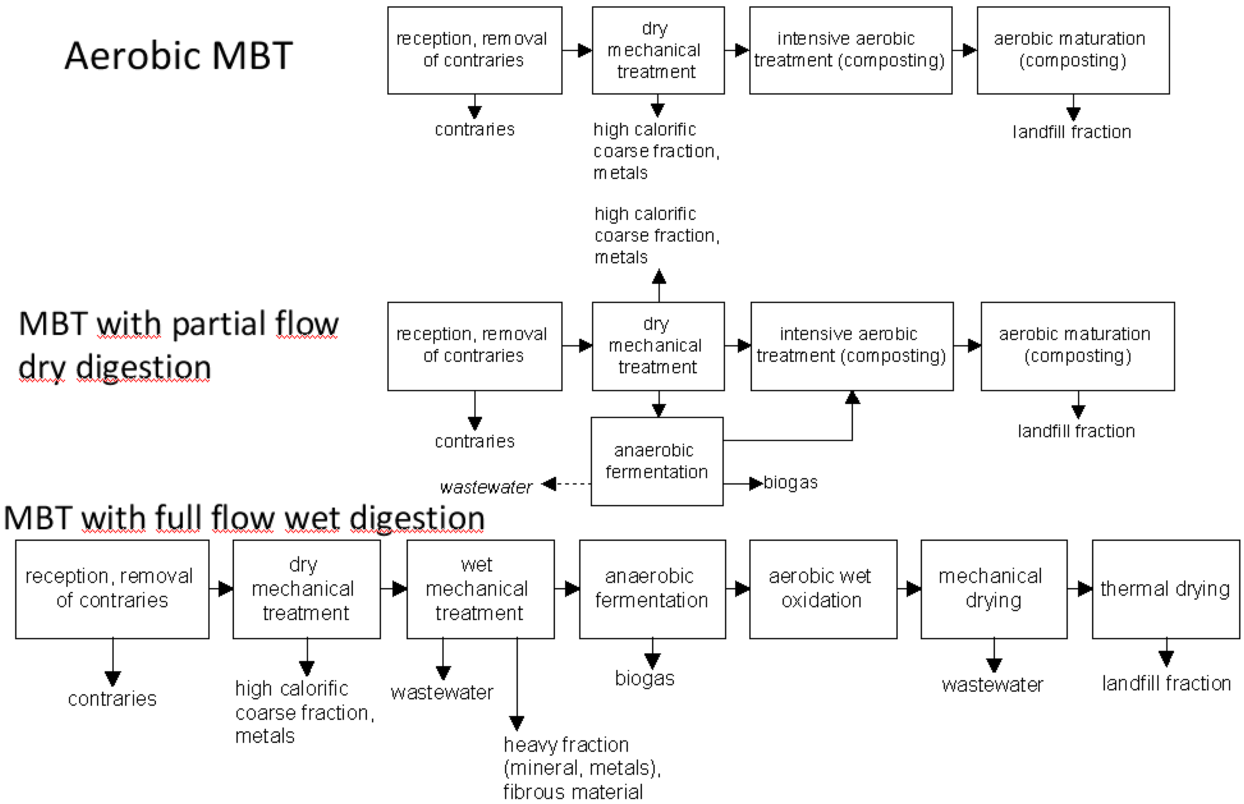

Figure 8 Simplified process chart of conventional MBT processes

3.2.2 • MBT (MBS) and MPS with drying process for solid recovered fuel (SRF/RDF) production

Mechanical biological drying plants (MBS; mechanical biological stabilisation) are aerobic MBTs. After removal of contraries, the whole input is shredded and without splitting up in various fractions completely fed to the aerobic biological treatment. The process is short and hot. The heat comes from the bacteria in the biological degradation. Humidity leaves the waste via the warm exhaust air. Afterwards, both the coarse and the fine waste particles have a low moisture content and an increased calorific value. This way, also the wet putrescible waste fraction is turned to a refuse derived fuel.

After the drying, the different waste fractions are much easier to sort. Mineral components (sand, stones …) and other unwanted fuel components can be easily removed. The drying also enhances the applicability of sensor based and other sorting processes to pick out recyclables.

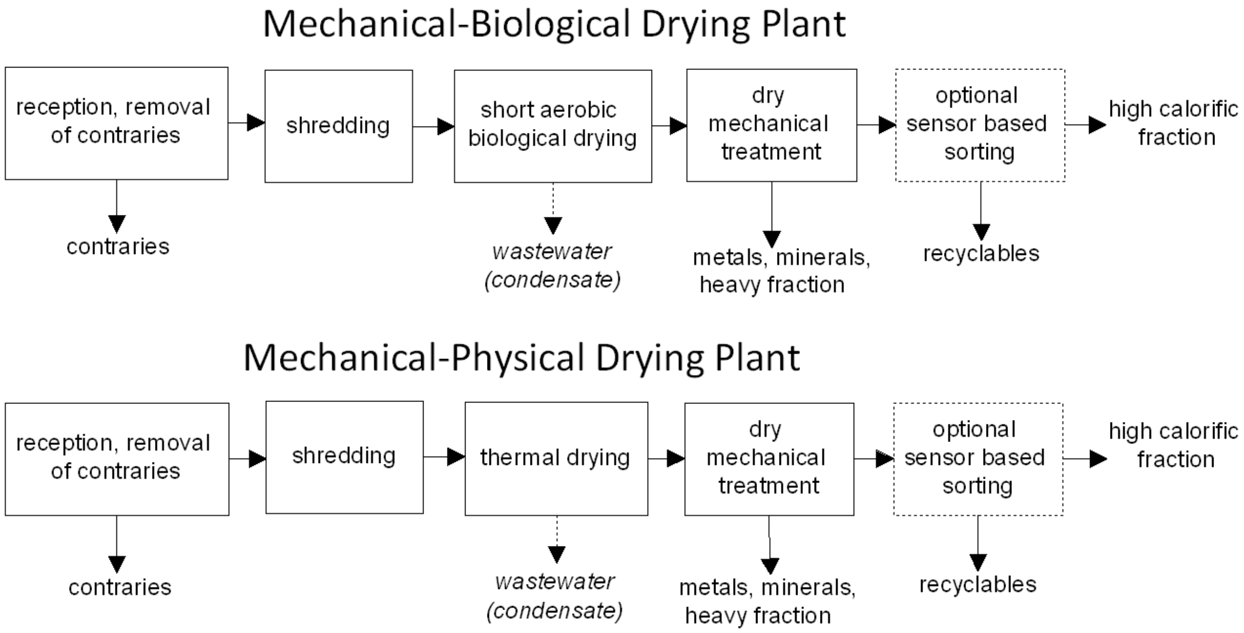

Figure 9 Simplified process chart of biological and physical drying plants

Mechanical physical drying plants are similar to mechanical biological drying plants, but the drying is done in gas heated drum driers.

4 Main material flows

4.1 Input materials

Input material of MBT plants usually consists mainly of the mixed residual fraction left over after source-separated waste collections unseparated, mixed household and household like commercial waste. Besides household waste and commercial waste with similar properties, these facilities also process a small amount of commercial waste, bulky waste, sorting residues, sewage sludge and grit chamber residues.

4.2 MBT output

Table 4-1 shows as an example the average breakdown of solid material flows at German MBT plants handling residual waste. A distinction is made between MBT (upstream of a landfill) and MBS (primary objective: producing alternative fuels, biological drying) technology.

Table 4-1 Solid output streams by fraction (wt.%) in terms of overall output (excluding rotting and drying losses) for different types of plants, showing the average and range of German installations (Kühle-Weidemeier, M. et. al. 2007) and supplements

Fraction	Percentage by weight	
	MBS	MBT
FE metals	4.2 (2.6-7.0)	3 (0.3-4.8)
NF metals	0.4 (0-0.9)	0.1 (0-0.7)
Impurities	1.3 (0-8.7)	2 (0-12)
Other	6.4 (0-33)	5 (0-22)
Landfill fraction	12 (0-26)	41 (19-64)
Other low-calorific material	8.9 (0-39)	3 (0-21)
High-calorific fraction	67 (28-97)	46 (29-77)

*A few MBT plants have now been retrofitted to add NF separators, which were not installed at the time when these measurements were taken. The NF material stream should thus have increased.

Figure 4-1 shows the cumulated mass flow of all German MBT plants. The values represent the annual average. Of course, depending on technology and treatment targets the mass flow in individual plants will be different.

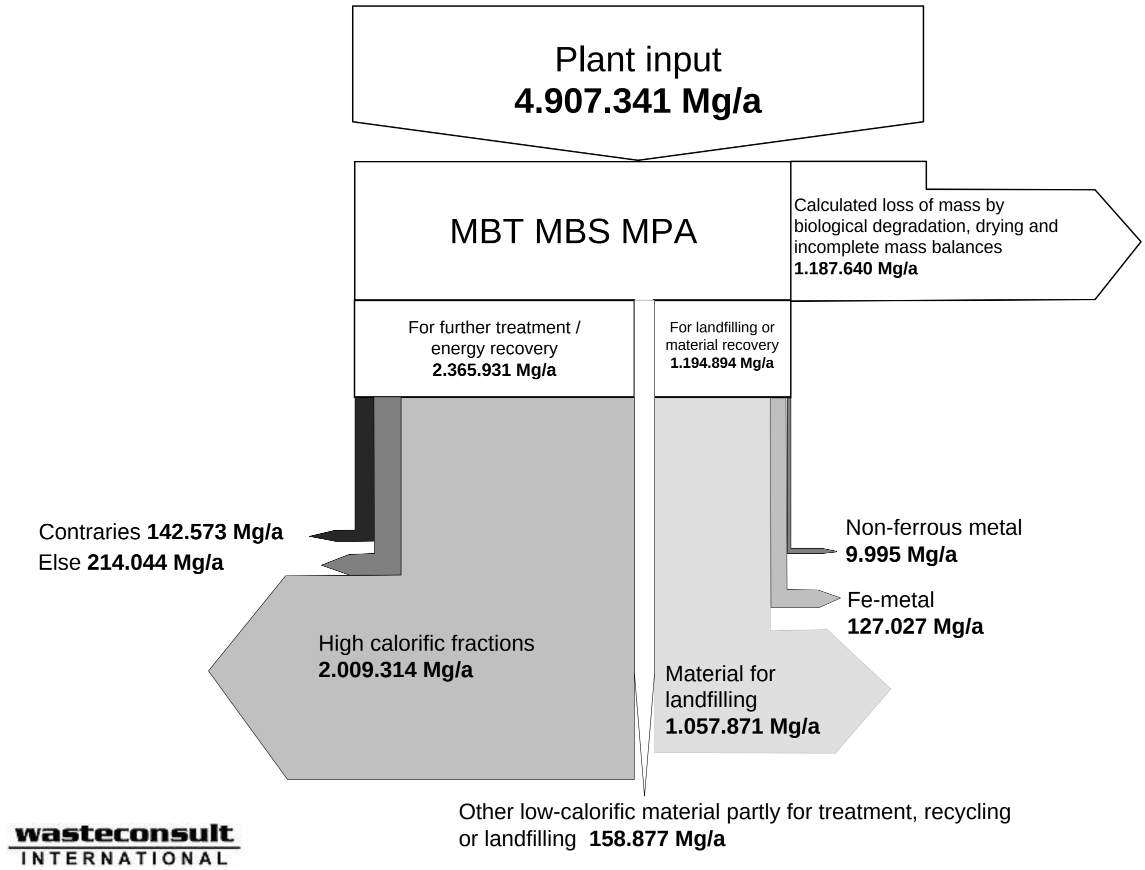

Figure 4-1 Mass flow of the total of Germany's MBT plants (various technologies), (Kühle-Weidemeier, 2007)

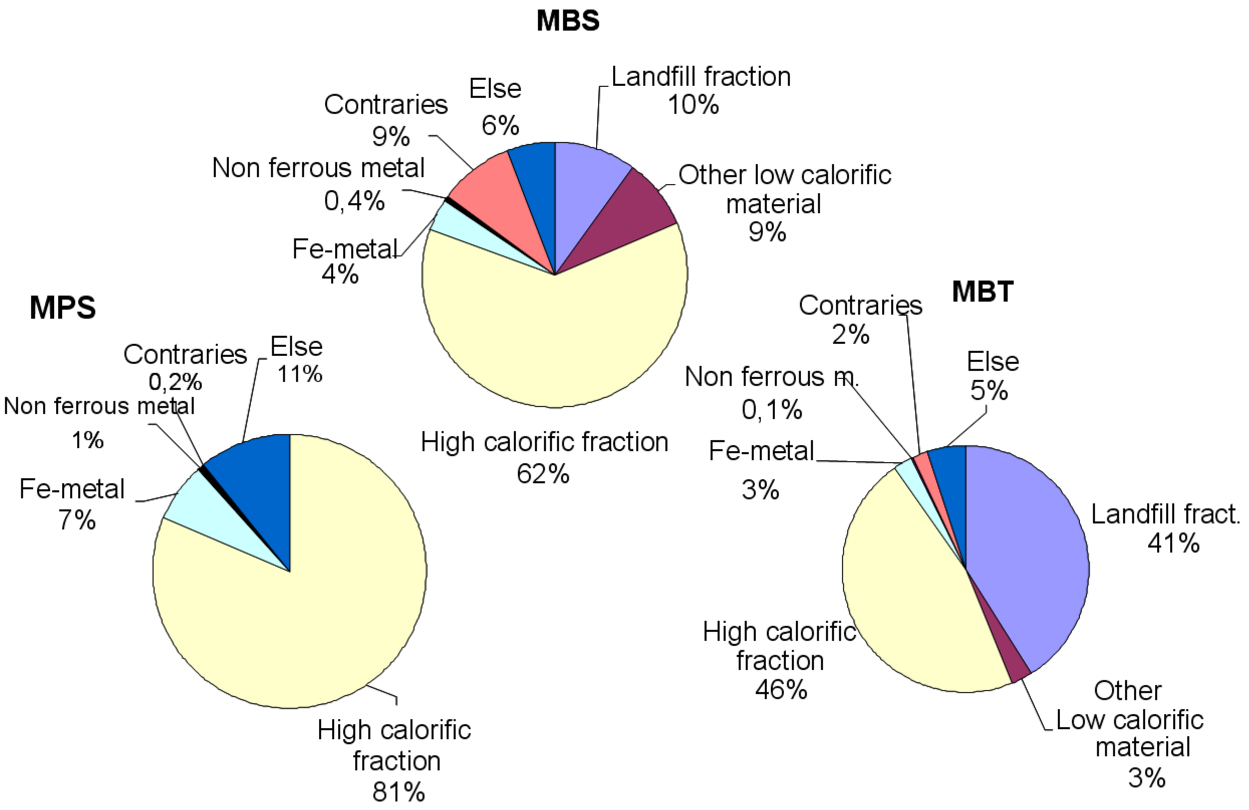

Figure 4-2 Share of the various fractions of the total solid output of the total of German MBTs in dependence of the kind of technology (Kühle-Weidemeier, 2007)*

* It has to be noted that the MPS data is based on only 3 plants and the high content of RDF output is influenced by input composition.

All data shown about mass flows are meant as an illustrating example. Waste composition in many countries is much different from waste composition in Germany and will lead to different output composition.

5 Process steps and machinery

5.1 Suitable processes and machinery

Heterogeneous MSW is a challenge for machinery and processes. Although common types of machines (shredders, sieves, conveyors …) and processes are used, these need to be tailor-made for this application. MBT has other requirements than mining, agriculture or biological treatment of separately collected organic waste.

5.2 Manual sorting and removal of impurities

Improperly sorted items and large impurities are first removed by hand or using grippers before mechanical treatment truly begins. This step prevents damage to technological systems and avoids introducing hazardous substances or items that might stop technology from working properly.

5.3 Mechanical treatment

5.3.1 Functions of mechanical treatment

Mechanical processing prepares waste for subsequent treatment. The degree of processing is determined mainly by the application for the high-calorific coarse fraction and the biological treatment process for the fine fraction.

Mechanical treatment has the following functions:

- ejecting and/or processing (e.g. shredding) impurities
- screening out a fine fraction with a high level of degradable organic components for biological treatment (not at MBS plants)
- sorting, shredding or customising high-calorific waste fractions for energy recovery (in the MBT plant’s main stream before or after biological treatment)
- ejecting heavy fractions
- separating groups of materials for recycling (e.g. metals)
- breaking down and homogenising waste components for biological treatment
- customising high-calorific output material

5.3.2 Shredding and homogenisation

In the first stage of mechanical processing, waste is prepared for subsequent treatment, pre-shredded to the necessary size and thereby also homogenised for the first time. The shredding process also opens containers and bags etc, and increases the surface area of the waste components, improving the breakdown of degradable organic elements for biological treatment.

The decision whether to pre-shred material depends upon the waste’s properties. The machinery used in this phase varies in terms of its shredding effect and depends on the type of waste to be treated. Plants frequently use breaking (e.g. single or multi-shaft breakers), cutting (rotary shear or cutting mill) or shearing (screw mill) machinery. One alternative is high-pressure compactors, which combine shredding and sorting of fractions that will undergo biological treatment.

Some MBTs apply a very slowly rotating steel drum to homogenise the mixture initially. The turning motion shreds and homogenises the material to a certain amount, improving bioavailability and also helping to aerate the mixture in a closed environment. Integrated nozzles can inject moisture, if needed. The residence time is one to seven days. These drums are a combination of mechanical and biological treatment. Rotating drums have been popular in some places in the past but they are rarely used in modern MBTs in Europe, because of their high cost of operation and only minor process improvement.

5.3.3 Sorting coarse and fine fractions

The sorting of high-calorific coarse waste fractions and the fine fraction destined for biological treatment is largely performed using screening (drum, vibrating and star screens) with screen cuts between 40 mm and 150 mm. Air-classifiers are occasionally used as well / additionally. A few plants also utilise ballistic separators.

High-pressure compactors (e.g. VM Press) are used in some plants to separate the wet organic fraction from the dry fractions.

5.3.4 Separating FE and NF metals

Magnets remove ferrous metals; non-ferrous (NF) metals are extracted using eddy current separation systems.

5.3.5 Processing the high-calorific fraction

The resulting high-calorific fraction sometimes must undergo additional processing prior to energy recovery, if necessary, depending on the customer’s specifications. Apart from additional shredding, other steps include further removal of metals and other impurities, such as rocks or other inert, non-combustible materials.

5.3.6 Ejection of impurities and recyclables using sensors

A few plants also utilise sensor-based sorting technologies (optical NIR sensors) in order to remove PVC, for instance, from the high-calorific fraction. The PVC's high chlorine level would lower fuel quality. A few sensor-based sorting solutions remove paper and wood even from the fine fraction.

5.3.7 Wet mechanical sorting technologies

Wet digestion plants use pulpers after the dry mechanical stage to homogenise substrate and better bring it into suspension through defibration. The pulper can eject both non-digestible floating solids and inert suspended solids, but this step may also be performed in other stages (e.g. the grit chamber). The pulper is followed by other wet sorting stages to remove floating and suspended solids (the grit chamber). Hydrocyclones are also used for this purpose.

The objective is to remove impurities, such as leftover metal, glass, sand, rocks and gravel, through sedimentation and plastic through a floating action to the aqueous phase. The degradable organic fraction that will be sent for anaerobic biological treatment is left.

5.4 Biological treatment

5.4.1 Aerobic treatment

5.4.1.1 Intensive decomposition (degradation)

The stages of biodegradation follow first-order kinetics, corresponding to a curve that first falls steeply before showing an asymptotic motion. Most decomposition by mass occurs when the degradation curve is very steep during a period that typically lasts two to three weeks. This phase is known as intensive decomposition because of the significant break-down of material (which is simultaneously accompanied by the most intense phase of emission activity).

Aerobic degradation releases carbon dioxide, water, ammonia and heat as the main (gaseous) products of metabolism. The temperature typically stands at 50-60°C in the intensive decomposition phase, and is even higher in MBS plants. The water content, aeration and temperature are the key process and control parameters in composting.

Enclosing or encapsulating the intensive decomposition stage is a core element of efforts to minimise emissions and is an essential requirement for German MBT plants.

At MBS plants, the overall biological degradation process is restricted to a hot (intensive) decomposition (drying) phase lasting 7 to 14 days, during which moisture is expelled from the waste via the exhaust air and is not replaced.

5.4.1.2 Maturation

Substances that are tough to decompose and unusable decomposition and transformation products release humic substances during the maturation phase. Maturation takes ca. 4 to 8 weeks depending on the process and feedstock and legal requirements for the output quality.

5.4.1.3 Shape and encapsulation of windrows

5.4.1.3.1 Box, container and tunnel windrows

In this method, waste rots in actively aerated concrete tunnels or containers that can be closed securely. This enclosed system permits comparatively accurate control of the composting process by measuring and regulating temperature and oxygen levels in the exhaust air. Process conditions can be tailored exactly to the stage of decomposition as each tunnel contains material of the exact same age. The material is turned upon entry and removal. The rotting time is short as the parameters can easily be controlled.

A new kind of encapsulation for of aerobic processes are semi-permeable membrane covers (for example GOREtex®). They are a hybrid form of tunnel or in-vessel composting on the one hand, and covered windrow composting on the other. The semi-permeable membrane cover, which is water-resistant but also permeable to gas and steam, protects against water logging. The cover and the active aeration it provides should create process conditions under which odours, VOCs and other emissions are largely contained.

The main advantages and disadvantages of the membrane covered windrows are

+ No (bio) filter required for exhaust air

+ Less waste water

+ Lower costs for operation and construction

- Less durable (e.g. replacement of membranes)

- Higher risk of leakages

Figure 3 Membrane Tunnels with hydraulic roofs

5.4.1.3.2 Linear windrows

This technique composts material in fortified open-air composting lines (which may also be covered by a roof or enclosed) that are actively aerated on an individual basis. Special turning machinery turns the windrows line by line.

5.4.1.3.3 Table windrows

Table windrows are over-sized windrows that are typically set up throughout almost entire halls and equipped with automatic turning machinery (bucket wheel or screw system). A ventilation floor provides active aeration. The aeration floor is divided into segments, allowing aeration intensity to be adjusted based upon how well the material is decomposing.

5.4.1.3.4 Triangular windrows

Triangular windrows are laid out in elongated lines in a hall or in a space covered by a roof structure. Material is stacked by a wheel loader, for instance, and turned by a wheel loader or a windrow turner. Triangular windrows mostly employ passive aeration and are mainly used for maturation when the demand for oxygen is no longer quite as high.

5.4.1.3.5 Composting and homogenisation drums

A few installations begin biological treatment in a steel drum that rotates very slowly to homogenise the mixture (in other words, using mechanical treatment). The turning motion shreds and homogenises the material even more, improving bioavailability and also helping to aerate the mixture. Integrated nozzles can inject moisture, if needed. The residence time is one to seven days. Material then undergoes conventional rotting. Composting drums are rarely used because of their high cost of operation and only minor process improvement.

5.4.2 Anaerobic treatment (digestion)

5.4.2.1 Fermenter

5.4.2.1.1 Fermenter operation

There are two ways of operating fermenters: (almost) continuously (complete mix fermenters and plug-flow fermenters) and in batches (box fermenters). Substrate typically stays in the fermenter for around three weeks. Currently, batch systems are only applied for separately collected organic waste.

5.4.2.1.2 Water content in the fermenter

Wet and dry digestion differ by virtue of the level of dry solids (DS) in the fermenter. The DS content stands at around 4% to 15% in wet processes. This level is generally reached by adding liquids, preferably in the form of industrial water or water from digestate processing. Salinity limits the ability to recirculate water without adding a treatment step. The DS level in dry processes ranges between 30% and 35%. So dry digestion is by no means dry. It is a wet process too.

5.4.2.1.3 Process temperature in the fermenter

Mechanical-biological treatment plants digest material in a mesophilic (ca. 33 - 42°C) or thermophilic (55 - 60°C) range. Wet digestion installations mostly operate in the mesophilic range. Thermophilic digestion potentially yields more gas, but this has to be offset by higher energy consumption.

5.4.2.1.4 Process stages

Installations with multiple stages (typically wet digestion plants) feature a separate hydrolysis tank prior to the fermenter (methanogenesis) in order to create an optimal environment for both phases and their microorganisms (especially the pH level). Methane is often already released in the hydrolysis container. Material stays in the hydrolysis tank for around 4-7 days.

Dry digestion is generally a single-stage technique.

When single-stage techniques are used, all phases of decomposition take place in the fermenter. Single-stage techniques always represent a compromise as microorganisms have different requirements regarding their environment. In practice, there are no conclusively documented differences between the yield from single-stage and two-stage techniques (in the case of comparable input materials).

5.4.2.1.5 Types of fermenters

In practice, the main types of fermenters are as follows:

- vertical fermenters with an agitator (typical in wet digestion facilities)
- vertical fermenter using plug-flow technology (dry digestion)
- horizontal fermenters with a slow transport agitator using plug-flow technology (dry digestion)
- tunnel fermenter (discontinuous dry digestion)

5.4.2.2 Maturation

All plants follow the anaerobic stage(s) with an aerobic stage. This phase helps to end methane production (aeration) and prevent odorous emissions as well as continue biological degradation, especially of substances that are hard to break down in the anaerobic phase. At dry digestion plants, this stage is designed as a composting phase. The heat generated in the pile allows significant amounts of moisture to be expelled with the exhaust air, which permits at least partial-stream digestion plants to run without generating wastewater at favourable waste compositions and climate conditions.

Maturation occurs in boxes or tunnels with forced aeration systems, at least in the first few days.

5.4.2.3 Wet oxidation

Wet digestion plants aerate material in aerated containers during the liquid phase using a wet oxidation process. The typical residence time lasts 7-11 days.

5.4.2.4 Drying

The output from partial-stream digestion plants is mixed with untreated feedstock entering composting, thereby also providing the necessary moisture for decomposition. Excess moisture is discharged in warm, water-saturated exhaust air.

Full-stream digestion plants usually require separate drying stages, especially when performing wet digestion. First, mechanical dehydration takes place using decanters or centrifuges and auger presses, for instance. Flocculants can assist the dehydration process. If necessary, and it often is, this phase is followed by thermal drying in band or drum dryers heated with waste heat from the CHP plant and biogas.

5.4.2.5 Biogas

5.4.2.5.1 Gas storage

Biogas can be stored in the fermenter itself and/or separately in tanks.

5.4.2.5.2 Gas purification and treatment

Unwanted components often have to be removed from raw biogas to avoid damage (corrosion, abrasion or deposits) to gas upgrading infrastructure. These components may be particles or trace gases (e.g. hydrogen sulphide). Hydrogen sulphide levels might also have to be reduced to prevent sulphur dioxide emissions. These techniques are geared towards the actual composition and chosen method of utilising biogas. The level of undesired substances in biogas depends primarily on the composition of feedstock entering the plant. A large variety of processes to remove unwanted gas component. They differ significantly in cost for construction and operation.

5.5 Wastewater treatment

Unless a plant is wastewater-free, wastewater that is not recirculated is treated prior to discharge. This step typically takes place in landfill leachate treatment units or the wastewater is sent to the local sewage treatment plant through the sewer network. Wastewater treatment is thus not typically part of the mechanical-biological treatment plant itself.

5.6 Waste gas (exhaust air) treatment

5.6.1 Machinery

A combination of a gas scrubber (not required for wet digestion plants) and at least one downstream process are generally used to treat waste gas generated by MBT plants. The downstream process is usually a biofilter and in Germany a regenerative thermal oxidation (RTO). RTO achieves the highest level of exhaust gas purification but consumes lots of energy, especially at aerobic MBT plants.

5.6.2 Acidic scrubber

The main function of an acidic scrubber is to remove nitrogen compounds that would lead to the release of nitrogen oxide (NO_x) and nitrous oxide (N_2O) from waste gas. Any ammonium nitrogen in the waste gas stream is transferred into the scrubbing liquid (generally diluted sulphuric acid). In addition, the scrubbing process captures dust and humidifies dry waste gas from mechanical treatment before it enters the biofilter.

5.6.3 Biofilter

In the biofilter, the waste gas flows extensively through a bundle of organic material (often root wood) whose surface is teeming with microorganisms.

Biofilter functionality "*is based upon the degradable organic substances and odours from the waste air being dissolved in a liquid phase (generally water), thereby allowing microorganisms to foster biologically oxidative degradation. Conditions must be put in place to facilitate microorganism growth in order to achieve the necessary degradation efficiency (from the BREF for large-scale shredders).* In particular, these conditions include having consistent and suitable temperature and moisture conditions, a suitable pH level and adequate surface area contamination for degradation, i.e. not too large (degradable material per m² and hour).

5.6.4 Regenerative thermal oxidisers

Regenerative thermal oxidisation is a flameless oxidation technique that involves a heated bed of ceramic material. The function of an RTO is to reduce greenhouse gas emissions (e.g. methane) and to dispose of other organic substances that have an impact on the environment and human health.

Non-catalytic regenerative thermal oxidisers can essentially be broken down into the following systems:

- *RTO systems with a combustion chamber (largely three chamber systems)*
- *RTO systems without a combustion chamber (largely one chamber systems)*

RTO systems consist of an oxidation zone and heat exchange elements before and after the oxidation zone. Crude gas is preheated to the oxidation temperature of ca. 800°C to 1,000°C in the upstream heat exchange element. (Stockinger, 2004).

The RTO can source some of its operating energy and temperature from the oxidation of organic waste gas components, apart from in the start-up phase. For the rest a supply of biogas or fossile gas is required.

5.6.5 Waste gas combustion

Three German plants do not treat waste gas in an RTO, but send it to an incineration plant for waste or secondary fuel where it is used as supply air. These plants have a backup RTO that is used when the incinerators are under maintenance. Feeding the exhaust gas to the incinerator requires special corrosion protection measures in the incinerator. This way of treatment is interesting, when a biofilter is not appropriate for exhaust gas treatment and otherwise a RTO would be required.

6 Current use of the various MBT technologies

6.1 Relevance of the main processes

As an example for the relevance of the various processes, Table 6-1 shows existing mechanical-biological treatment facilities for residual waste by plant type in Germany. These 45 plants have a total treatment capacity of 5.3 million t/a. Twelve of these facilities have an anaerobic stage to generate biogas and another twelve plants are MBS units.

Almost all plants were rebuilt or substantially remodelled between 2001 and 2005 in order to comply with legal requirements that have applied to MBT plants since 1 June 2005.

Table 6-1 Mechanical-biological waste treatment plants in Germany 2007 / 2010 (MBS) (Data: ASA, 2010; Kühle-Weidemeier et al., 2007)

Type of biogas treatment technology:	**Full-stream digestion**	**Partial-stream digestion**	**Aerobic treatment**	**Aerobic biological drying (MBS)**	**Total**
Total capacity in [1,000 t/a]	888	432	2,006	1,984	5,310
Number of installations	8	4	19	14	45

6.2 Destination of MBT output streams

6.2.1 Biologically treated fine fraction

Residual waste normally tends to have a much higher potential risk from spots of contamination and a significantly higher level of contaminants than separately collected organic waste. Consequently, biologically treated residual waste is not very suitable for agricultural application and should preferably be excluded from agricultural application due to potential contamination that can not be monitored. Besides of a higher level of hazardous substances, MBT compost usually has a higher level of visible impurities than compost from separately collected organic waste. Visible impurities may have a bigger influence on the public acceptance of the product than chemical analysis that is only understandable for experts. The preferred destination of the MBT fine fraction should be a landfill.

Anyway, under feasible framework MBT can be able to produce MSW compost with acceptable quality. If MBT output should be used on land, an excellent (and accepted) separation of hazardous waste is required, especially in case of pure aerobic treatment or at dry fermentation plants. Wet fermentation MBTs have a higher potential to produce a cleaner organic fraction. Also the mechanical treatment should be designed in a way that avoids carryover of contaminants into the organic fraction.

MBT Lantic (France) benefits from a very good hazardous waste collection, careful mechanical treatment (no shredding, no hammer mill) and its location in a rural area and produces exceptionally good MSW compost. Morvan (2005) concludes about MBT Lantic: *The best technology used for MSW composting consists on the following sequence: separate disposal of special waste, mainly batteries and WEEE (waste electrical and electronic equipment); rotary drum during four days; sieving at 30 mm; double selective conveyor; second sieving at 10 mm; maturation.*

Table 6-1 Contaminants in organic MBT output fractions (compost like output)

Remark: European notation, dot and comma in reverse use to Anglo-Saxon notation

		Analysis					Boundary values			
		MBT Lantic (1)	German wet fermen-tation MBT (2)	MBT Tel Aviv methano-genic reactor(3)	MBT Eastern Creek (3)	Mean of biowaste composts in France (1)	*Australian compost standards*	**German biowaste ordinance application per hectare (10000m²)**		UK PAS 100 compost standard (3)
Parameter	Quantity / Unit	Mean	1	?	?	Mean		<20t/3a	<30t/3a	
Lead	mg/kg TS	59	**171**	58	150	119,0	***200***	**150,0**	100,0	**200,0**
Cadmium	mg/kg TS	0,8	**2,2**	**2,0**	**3,0**	0,7	***3,0***	**1,5**	1,0	1,5
Chromium	mg/kg TS	42	95	**140**	100	39,0	***400***	**100,0**	70,0	100,0
Copper	mg/kg TS	66	***207***	**182**	**200**	71,0	***200***	**100,0**	70,0	**200,0**
Nickel	mg/kg TS	23	***69***	24	50	19,0	***60***	**50,0**	35,0	50,0
Mercury	mg/kg TS	0,3	***1,1***	***4,0***	1,0	0,2	*1,0*	**1,0**	0,7	1,0
Zink	mg/kg TS	235	***715***	***1022***	*400*	235,0	*250*	***400,0***	*300,0*	*400,0*

Italic values: Exceeds Australian standard; **bold values:** exceeds German standard <20t/3a

Data source: (1) Morvan, 2005; (2) Wasteconsult data; (3) Archer, 2005

Table 6-1 compares the contamination of the compost / degradable organic fractions from different MBTs. Only MBT Lantic complies with all standards and can compete with the mean quality of French biowaste composts. Only the values of Lantic seem to be based on a sufficient number of samples. But are these values truly comparable? The contamination of the output is strongly influenced by the contamination of the input that certainly will be different at all locations. Furthermore, the compost of the aerobic plant will contain more inert mineral substance than the digestate from the German and the ArrowBio plant because in those plants the sand is removed by the (liquid) mechanical treatment. The German plant is not designed to produce compost like output. Hence, no special measures were taken to produce a low contaminated output.

For producing compost with low contamination from mixed / residual waste Usually a combination of some of the following measures is necessary:

- Excellent collection of hazardous waste
- Avoiding to shred the MBT input -> using drums or high pressure presses (VM Press) instead
- Efficient metal separation in the plant
- Wet separation steps

6.2.2 High calorific fraction

The high calorific, coarse fraction has the largest share of the mass flow out of modern type MBTs. It is a valuable solid fuel (SRF/RDF) and the recovery of this energy is highly desirable. There are various possible destinations for the RDF from MBTs.

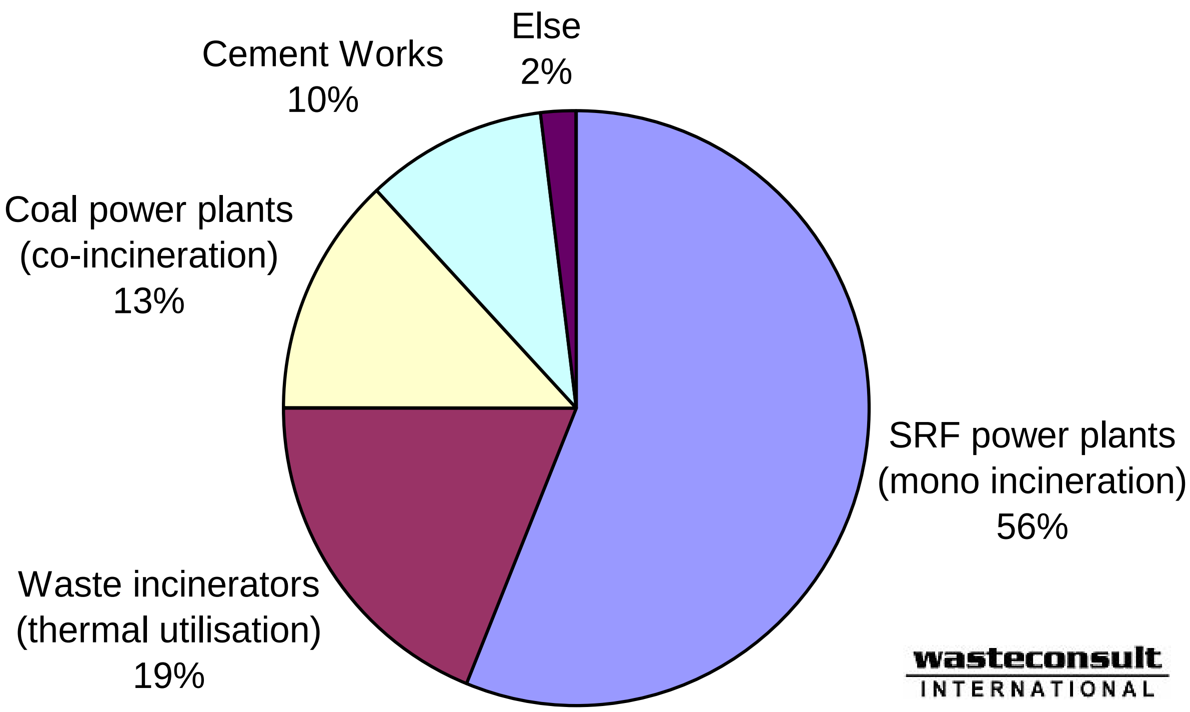

Figure 4 Destination of the high calorific MBT fractions in Germany 2012

In Germany, special SRF / RDF power plants have become the most important destination for RDF from MBTs, These plants are usually parts of industrial facilities and produce process heat in most cases. Figure 5 shows the development of the RDF market in Germany over the last 20 years. Not all RDF in that diagram comes from MBT.

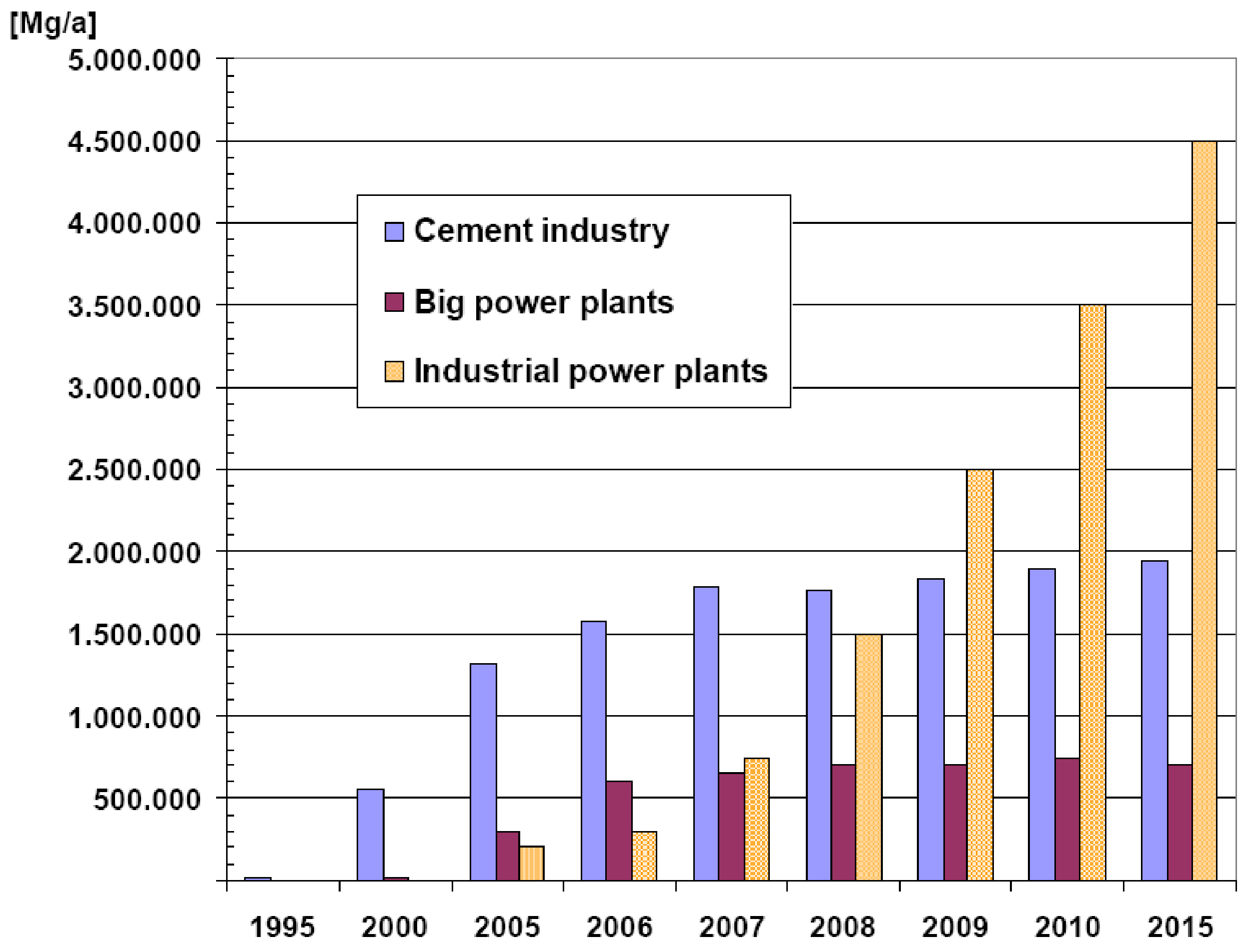

Figure 5 RDF-market development in Germany (Input from MBT and other sources)

Source: Glorious, 2011

With increasing prices for secondary raw materials, sorting and recycling of some RDF components may become more attractive than energy recovery. Sorting is also an option to facilitate the application of energy conversion technologies with higher public acceptance. Possible destinations for sorted RDF materials are:

Wood -> Biomass power plants

Paper -> Recycling or power plant

Plastics -> Pyrolysis, liquidizing or recycling

6.2.3 Recyclables

Recycled fraction from MBT are usually dirty and hard to market for true recycling with the exception of ferrous and non ferrous metals.

7 Evaluation and selection of MBT processes

7.1 Evaluation / pros and cons of the process types

7.1.1 Aerobic MBT

Due to it’s simpleness, low capital costs and reliable and robust biological process, aerobic MBT is very widespread. The comparatively low amount of machinery required facilitates economical operation of small units. The advantages and disadvantages can be summarised as follows:

+ Lowest investment costs of modern type MBT

+ Even small units make sense

+ Still a simple and the most reliable MBT process

+ 50% and more landfill diversion in spite of the simple technique

- No biogas production, pure energy consumer

7.1.2 MBTs with anaerobic digestion

Anaerobic MBTs are more complex and need more machinery than aerobic MBTs. The biological process is more sensitive and harder to revitalise after problems in the biological step. As a rule of a thumb one can say, the more water is in the process the higher is the risk of potential problems. This requires a thorough selection of the design team and the suppliers. Investment costs are higher than those of aerobic MBTs but bigger units can be more economic in operation than aerobic MBTs. The advantages and disadvantages can be summarised as follows:

+ Biogas production that can exceed the energy demand of the MBT by far

- Higher investment costs

- MBTs with anaerobic stages are more complex than aerobic MBTs

- The anaerobic process is more sensitive than the aerobic

- Operation requires higher skills of the operational personnel

- In the first years of operation, German anaerobic MBTs have shown more problems than aerobic plants

MBTs with anaerobic digestion are attractive due to their energy balance. For evaluating their feasibility, they were subdivided in dry and wet anaerobic processes. Dry digesters are smaller (less volume of water), usually have a simple pipe system with robust elements such as concrete pumps, the digesters (a plug flow system) are usually built in a way that sedimentation in the one stage fermenter rarely is a serious problem. Less volume also means less water to heat. This facilitates the operation at thermophilic temperatures which often results in higher gas yields than mesophilic processes.

Wet anaerobic systems have lots of pumps and pipes and sedimentation of sand or other heavier substances happen easier in the pipes, pumps or fermenters or hydrolysis tanks. Also fibrous materials can cause blockages of the system. Hence, a complex wet mechanical pre-treatment is required that keeps sand, heavy materials and fibrous materials out of the biological treatment steps.

Due to the higher water content, wet anaerobic systems are usually operated a mesophilic temperatures. The digestion process in wet anaerobic MBTs is normally implemented as a two stage process. In theory, this creates a better environment for the microorganisms and hence a higher gas yield. In practice this could not always be achieved, even the opposite happened.

The advantages and disadvantages of dry and wet fermentation can be summarised as follows:

Dry fermentation (65-70% of water in the fermenter)

+ Less complex because of missing wet separation steps

+ Lower investment costs

+ Less problems in the first years of operation in Germany

- Higher emission potential (especially odour) in case of operational flaws

Wet fermentation (85-96% of water in the fermenter)

+ High potential of material and energy recovery (not always achieved in practice)

+ In combination with wet oxidation nearly completely closed and in case of the right supplier lowest odour risk

+ Clean mineral fractions can be separated

- Complex and sensitive process has a higher potential of problems and requires well educated personnel

- Very few capable suppliers and very thorough selection of the supplier required

- Significant effort to dry the landfill fraction of the output

- High amount of wastewater

Wet anaerobic treatment has the disadvantages of high drying effort for the landfill fraction, the quantity of wastewater and complex handling in practice.

7.1.3 Aerobic MBT (MBS) with biological drying (BD)

Biological drying is a simple and approved aerobic process that converts most waste components to a high calorific dry fuel (RDF). Thus, biological drying plants only make sense, when a demand for the produced RDF exists or definitely is expected. The advantages and disadvantages can be summarised as follows:

+ Reliable aerobic process

+ Tunnel / box system with good emission control

+ Dried material allows enhanced sorting and material recovery

+ High yield of high calorific secondary fuel (RDF)

+ 65-90% landfill diversion

- Increased risk of fires (very dry material)

- No biogas production (but huge amount of refuse derived fuel RDF with high calorific value)

7.1.4 Mechanical-physical stabilization (MPS)

MPS is like MBS but has high fossil energy consumption.

7.2 Costs and selection of the right process

7.2.1 Costs

Cost depend on local prices, treatment targets, waste properties and many more varying factors. Each MBT is an individual case. These factors often have more influence on the costs than the chosen technology. Hence, only a very broad and non technology specific range of costs can be given here. Costs need to be calculated for each individual location and it's local conditions.

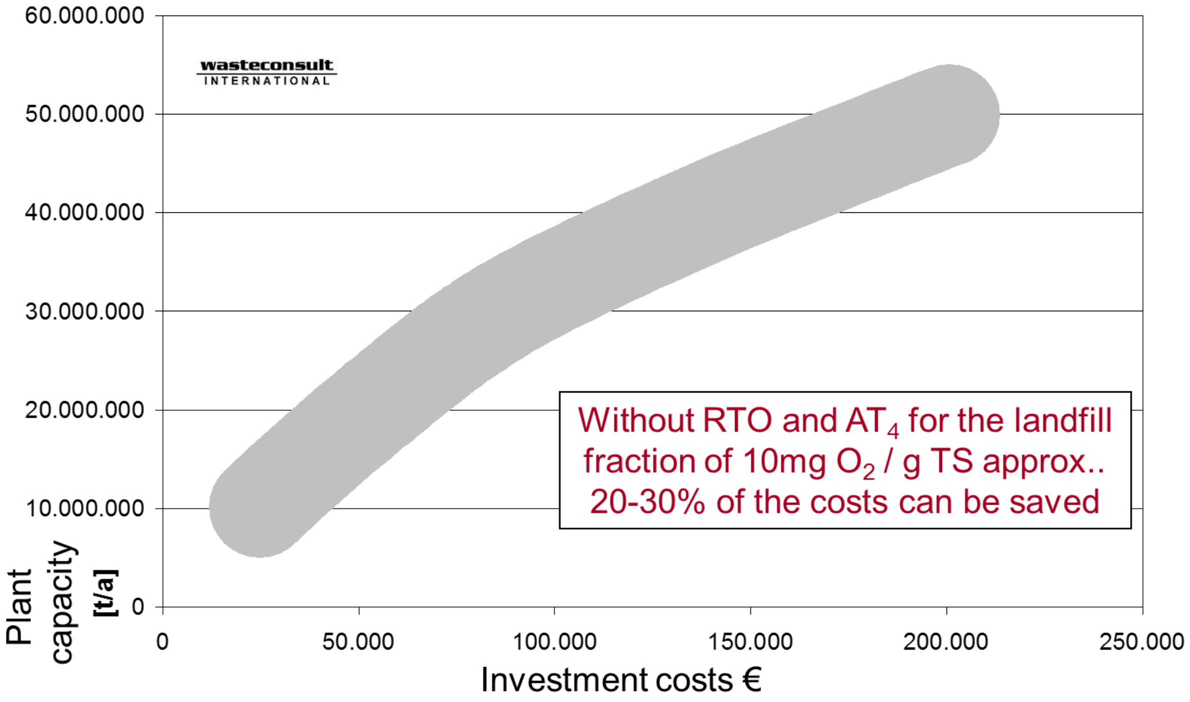

Figure 6 **Approximate investment costs for a MBT compliant to German standards**

Treatment costs:

10 – 30 Euro / t for low technical standard

40 – 60 Euro/ t medium standard

50 – 90 Euro / t for high technical standards (e.g. compliant to German regulations)

Total costs are significantly influenced by the costs for landfilling of the fine fraction and for the combustion of the high calorific fraction

7.2.2 Selection of MBT Technology

7.2.2.1 Plant capacity and appropriate process

The right technology depends on local conditions, There is not the one perfect technology. Depending on the treatment capacity of the MBT, the following rough evaluation of the economic viability of the different processes can be given:

For plants to 50,000 t / a, normally aerobic systems are economically the best solution, in anaerobic systems the specific investment costs are too high.

Plants with partial flow (dry) digestion make sense from about 75,000 tons / year

Plants with full-flow wet digestion are reasonable up from 100,000 tons / a.

The more complex / extensive the anaerobic stage and the higher the water content, the greater are the expected operational problems and the requirements for the qualification of the staff.

7.2.2.2 Adoption to local waste properties

MBT needs to be adopted to local waste composition! Variations require changes in machinery, machine dimensioning and process control! It is necessary to consider at least

- Different moisture content
- Different waste compositon
    - Level of soil, sand and other mineral contents
    - Plastic content
    - Wet organics content
    - …
- Different level of salt content

7.2.2.3 Key Considerations for Technology Selection

The following headwords summarize the most important facts that should be known as input for a thorough feasibility study and technology selection. An early decision for one favourite technology should be avoided.

- Composition and amount of input including monthly variation
  Influences dimensioning and selection of machinery. Important to find out if there is enough feedstock to run a desired process in a reasonable size

- Input moisture content
  Influences mechanical treatment and especially the water balance of the biological step. Can change technologies from effluent free to demanding water management and purification. Influences duration of biological or physical drying processes.

- Legal and own treatment targets
  Is a very high degree of biological stabilisation of the fine fraction required that demands longer aerobic process steps? Will an output fraction be used as compost and hence a gentle mechanical treatment might be favourable? Does biogas from AD get an increased feed in remuneration? Is producing RDF a major target?

- Is there a market for the output fractions
  Revenues and costs for utilizing or disposing the MBT output fractions are a major cost factor in MBT operation. If not already existent, markets have to be created. Producing a high calorific fraction / RDF makes no sense when there is no destination for it

- Who will take the output fractions and for which price (extensive, creative market research and negotiations with local industries required)
  - Technology influences amount and share of the fractions

- Which output qualities are required
  This influences treatment times and machine selection. Are sorting steps required? Is a technology required, that avoids contamination of the fine fraction?

- Amount, handling and discharge of waste water
  A challenge for anaerobic and especially wet anaerobic processes. Also important for waste drying processes in case that the humidity in not completely steamed out with the exhaust air.

- Supply with water in case of wet digestion
  Most processes (sometimes with exception of drying processes) require addition of water, especially wet AD.

- Feed in remuneration for electricity from biogas
  Very important and sometimes essential for a cost effective operation of AD.

- Alternative destinations for biogas
  If electricity and heat from biogas CHPs can’t be utilized to a major amount, AD may not be the best solution or a different destination for the biogas needs to be found (e.g. liquid fuel or upgrading for the gas grid).

- How to use the thermal energy (from CHP plants)
  Important for the energy efficiency and carbon footprint of MBT with AD.
- How flexible is the technology to adopt to changing quality, quantity and composition of the input
  Pure aerobic processes are less demanding and more flexible here.
- Choosing the right process is not enough
  Coosing the right, experienced and successful supplier is very important too.

7.2.2.4 Technology trends

Markets change and development of technologies goes forward. In central Europe the following trends in mechanical biological treatment can be watched:

Organic waste:

- Anaerobic digestion steps become more and more important

MBT for mixed / residual waste:

- Aerobic plants with a major landfill fraction or producing compost (that often nobody wants to have) are loosing importance
- Conventional aerobic plants are converted to biological drying plants
- Anaerobic plants are highly requested but not always the economically most attractive option
- Cheap incineration can be a challenging competitor
- Due to a lack of input, some MBTs in Germany are splitting their lines and run a part of the plant with separately collected organic waste.

7.2.2.5 Recommendations for implementation of MBT

- Introduction of source separated collection of organic waste is a key element to handle organic waste in urban areas and to produce a compost with high quality and acceptance. In urban areas bring only the residual waste to MBT
- Find a competent, experienced consultant with proven MBT references for your waste management conception
- Before tendering, make sure you exactly know where you can bring the output fractions and what price it will have, pre-contracts can help.

- Make use of the experience that was gathered in Europe in the last years
- Design the machinery and the buildings as flexible as possible. Changes in waste management and waste policy are often hard to predict.
- Keep sufficient distance between the plant and the next housings
- Don‘t save some thousand Dollars for a qualified consultant and end with a non working multi million ruin
- Visit a full scale reference plant and talk under four eyes with the operator
- To avoid disappointments, calculate minimum 6 months or more (depending on technology) for the commissioning phase.
- Before operation starts, send members of the future team for a practice at an already existing MBT with the same or similar technology.
- Keep yourself informed and up-to-date. There is a conference specialised on MBT and MRF: www.waste-to-resources.eu

8 Examples of full scale MBT plants

8.1 MBT with aerobic biological treatment

8.1.1 MBT Großefehn: Aerobic residual waste treatment

8.1.1.1 Plant data

Plant capacity: 47,000 Mg/a

Commissioning date: 2004

Specific technology name: Tunnel composting plant

8.1.1.2 Input materials

Table 8-1 Plant input (actual throughput in 2009)

Input fraction	Wt%
Household waste	30
Fine fraction from external treatment or similar plants	55
Bulky waste	14
Wood	1

8.1.1.3 Mechanical stage

Waste is shredded after unloading. After passing through a FE separator, waste is split into a > 40 mm high-calorific coarse fraction and a < 40 mm biodegradable organic fine fraction using a screen. The fine fraction ends up in a biological treatment plant. The coarse fraction is loaded on to container transporters.

8.1.1.4 Biological stage

The biological treatment stage was designed to have input of 24,000 Mg/a of < 40 mm organic fine fraction. Composting takes place in 30 tunnels and lasts a total of 6-8 weeks. Conveyor belt systems transport material that will undergo biological treatment from the preparation hall to the automatic system that feeds material into the composting hall. It is removed using a wheel-loader.

8.1.1.5 Exhaust air treatment

Hall exhaust air (exhaust gas) with low levels of contamination is treated using biofilter modules. More contaminated waste gas is treated by a dual-line regenerative thermal oxidiser (RTO) with an upstream acidic scrubber. The total volume of waste gas stands at ca. 50,000 m³/h.

8.1.1.6 Wastewater management

The plant does not generate any wastewater.

8.1.1.7 Material streams and recovery

According to the operator, 719 Mg/a of ferrous metals were recycled in 2009. Some 4,531 Mg/a of wood were incinerated to generate energy. A high-calorific fraction totalling 17,336 Mg/a was disposed of at a waste incineration plant. The landfill volume stood at 20,167 Mg/a.

8.1.1.8 Process flow chart

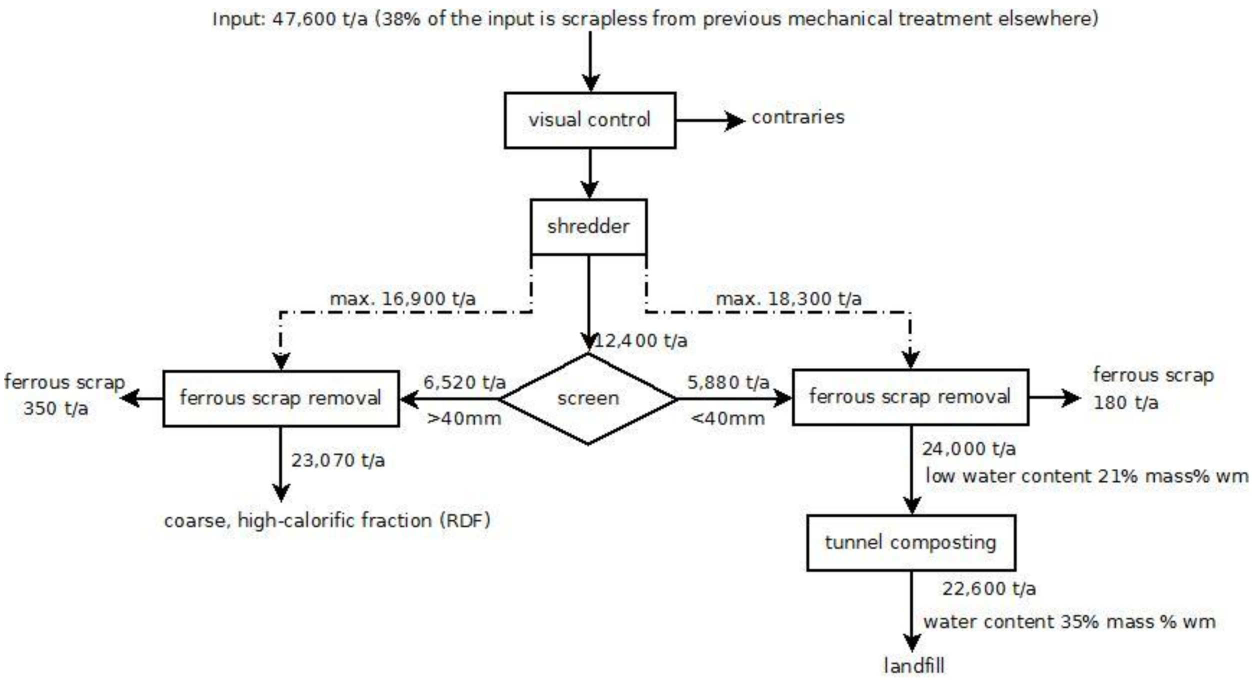

Figure 7 Process flow chart MBT Großefehn

8.1.2 MBS Nuthe-Spree: Mechanical-biological stabilisation (biological drying)

8.1.2.1 Plant data

Plant capacity:	135,000 Mg/a
Commissioning date:	2006
Specific process name:	Herhof Trockenstabilat® technology

The plant description is based upon the operator's website.

8.1.2.2 Input materials

Table 8-2 Plant input (actual throughput in 2009)

Input fraction	Wt%
Household waste and mixed municipal waste	82
Bulky waste	12
Waste from a mechanical treatment facility	1.7
Mixed construction and demolition waste	1.5
Sludge from industrial wastewater treatment	1.0
Other	1.1

8.1.2.3 First mechanical stage

Damp waste (household waste, mixed municipal waste, other wet wastes and sludges) are placed in an underground bunker and preshredded and dried without being sorted beforehand. Bulky waste and other dry wastes are pre-sorted and pre-shredded in a flat bunker. Some of this pre-shredded waste is then added to the wet waste in the underground bunker and runs through the entire process together.

8.1.2.4 Biological stage

Material is split into nine composting boxes after preshredding. Waste spends seven days undergoing biologically drying and stabilisation in composting boxes by virtue of the heat generated by microorganisms.

8.1.2.5 Second mechanical stage

The material is sorted mechanically after biological drying. The facility has a disc screen, a star screen and two vibrating screens to sort material by size, and pneumatic tables and air-classifiers to sort by density. The heavy fraction and > 35 mm lightweight fraction undergo additional shredding. Ferrous and non-ferrous metals are removed from the different spectra of grain sizes.

8.1.2.6 Exhaust air treatment

Waste air generated during drying is first fed through a heat exchanger to remove moisture. It is then treated in an RTO.

8.1.2.7 Wastewater management

Condensate generated in the heat exchanger (ca. 30,000 m³/a) is processed at the plant with the goal of reducing ammonium, COD and BOD levels. Some of the treated wastewater is recirculated and evaporated in the cooling circuit using evaporative air coolers. In the winter, excess water is discharged into the sewage system for additional treatment.

8.1.2.8 Material streams and recovery

In 2009, 3,380 Mg of ferrous metals and 395 Mg of non-ferrous metals were recycled. The energy recovery stream consisted of wood (3,325 Mg/a), secondary fuels (57,900 Mg/a with an LCV of 14,000 kJ/kg), which were co-incinerated in lignite-fired power plants and cement kilns, with refuse-derived fuel (6,010 Mg/a with an LCV of 12,600 kJ/kg) combusted in a power plant run on alternative fuels. A total of 8,070 Mg of mineral waste components were generated, some 4,550 Mg of which were disposed of and 3,520 Mg of which were recovered. Figure 8shows the material streams in graphic form.

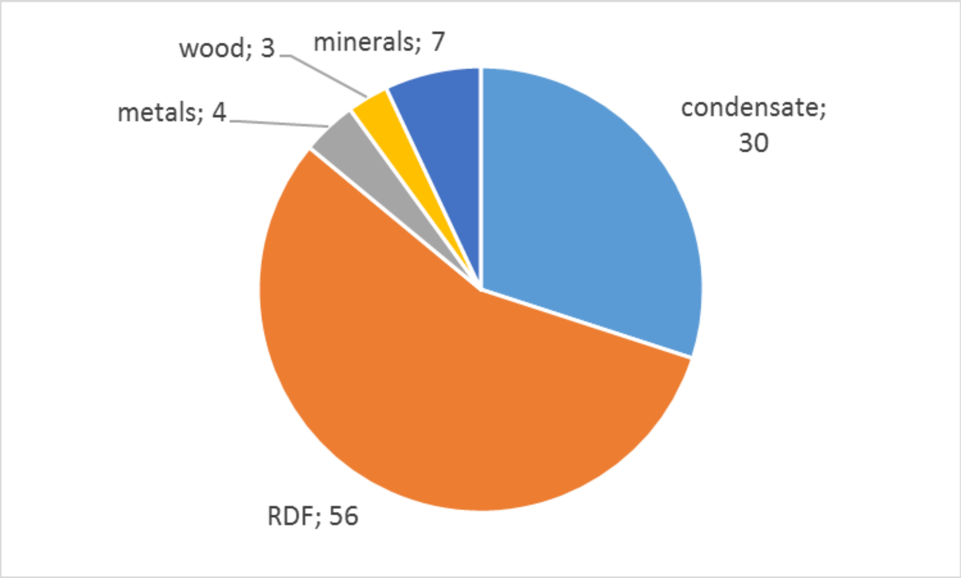

Figure 8 **Percentage of liquid and solid flows of MBT (MBS) Nuthe-Spree**

The production condensate depends on the kind of exhaust air (also called exhaust gas) treatment. This plant is located in Germany and German law indirectly requires thermal treatment of the MBT exhaust gas. To minimise energy consumption of the exhaust gas treatment, a major part of the air is recirculated. To prevent overheating, the recirculated, water saturated air needs to be cooled. This cooling process produces the condensate. MBS using only biofilter or membrane covers can usually avoid this problem.

8.1.2.9 Process flow chart

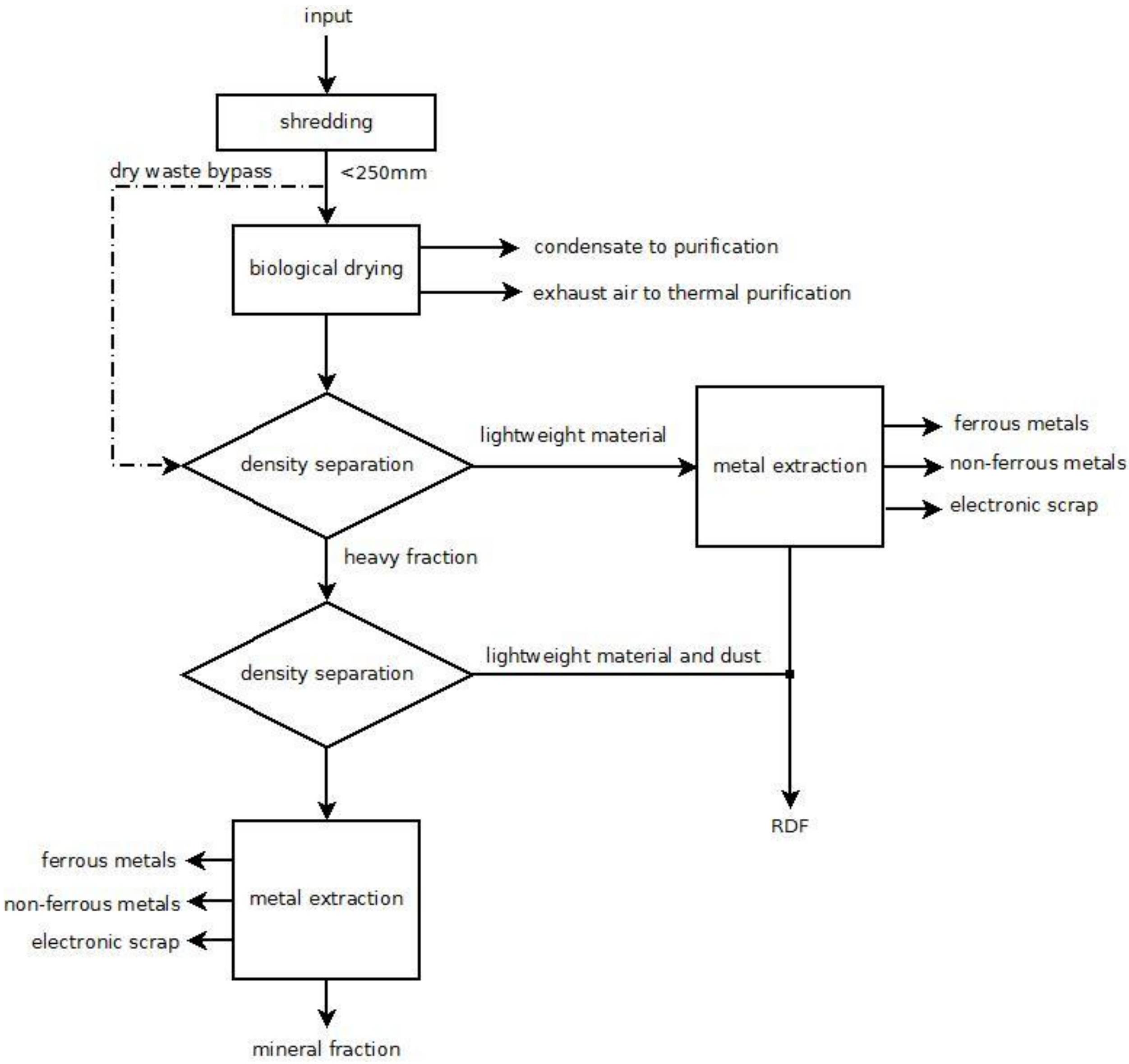

Figure 9 Process flow chart of the mechanical-biological stabilisation plant (MBS)

8.2 MBT with anaerobic treatment steps

8.2.1 MBT Pohlsche Heide: Partial-stream digestion

8.2.1.1 Plant data

Plant capacity: 115,000 Mg/a

Commissioning date: 2005

Specific technology name: Partial-stream digestion and tunnel composting

8.2.1.2 Composition of input material (actual throughput in 2009)

Input fraction	Wt%
Household waste	52
Commercial waste	35
Sludges and viscous wastes	13

8.2.1.3 Mechanical stage

Waste is shredded in the mechanical section of the plant. Waste is then screened and metal is removed. Material smaller than 60 mm is transported straight to the biological treatment area. Organic adhesions and mineral components are removed from wastes larger than 60 mm. Screen overflow (> 300 mm) is reshredded.

8.2.1.4 Biological stage

Almost two-thirds of the < 60 mm fraction spends 21 days undergoing “dry” fermentation in a mesophilic fermenter and is then mixed with unfermented waste in composting tunnels. Aerobic treatment takes place in 32 actively aerated tunnels. Material is added using a conveyor belt system, with a wheel loader removing material after 7 weeks.

8.2.1.5 Exhaust air treatment

An acidic scrubber, an RTO and a biofilter treat exhaust air.

8.2.1.6 Wastewater management

The plant is designed to operate without generating wastewater.

8.2.1.7 Material streams and recovery

Organic components are fermented; the resulting methane is fed into a combined heat and power plant. According to information from the survey on which this report is based, some 1,799 Mg/a of ferrous metal and 231 Mg/a of non-ferrous metals were recycled. A thermal power plant generated energy from 40,000 Mg/a of <150 mm secondary recovered fuel with an LCV of 15,000 kJ/kg. Some 25,000 Mg/a was consigned to landfill.

8.2.1.8 Process flow chart

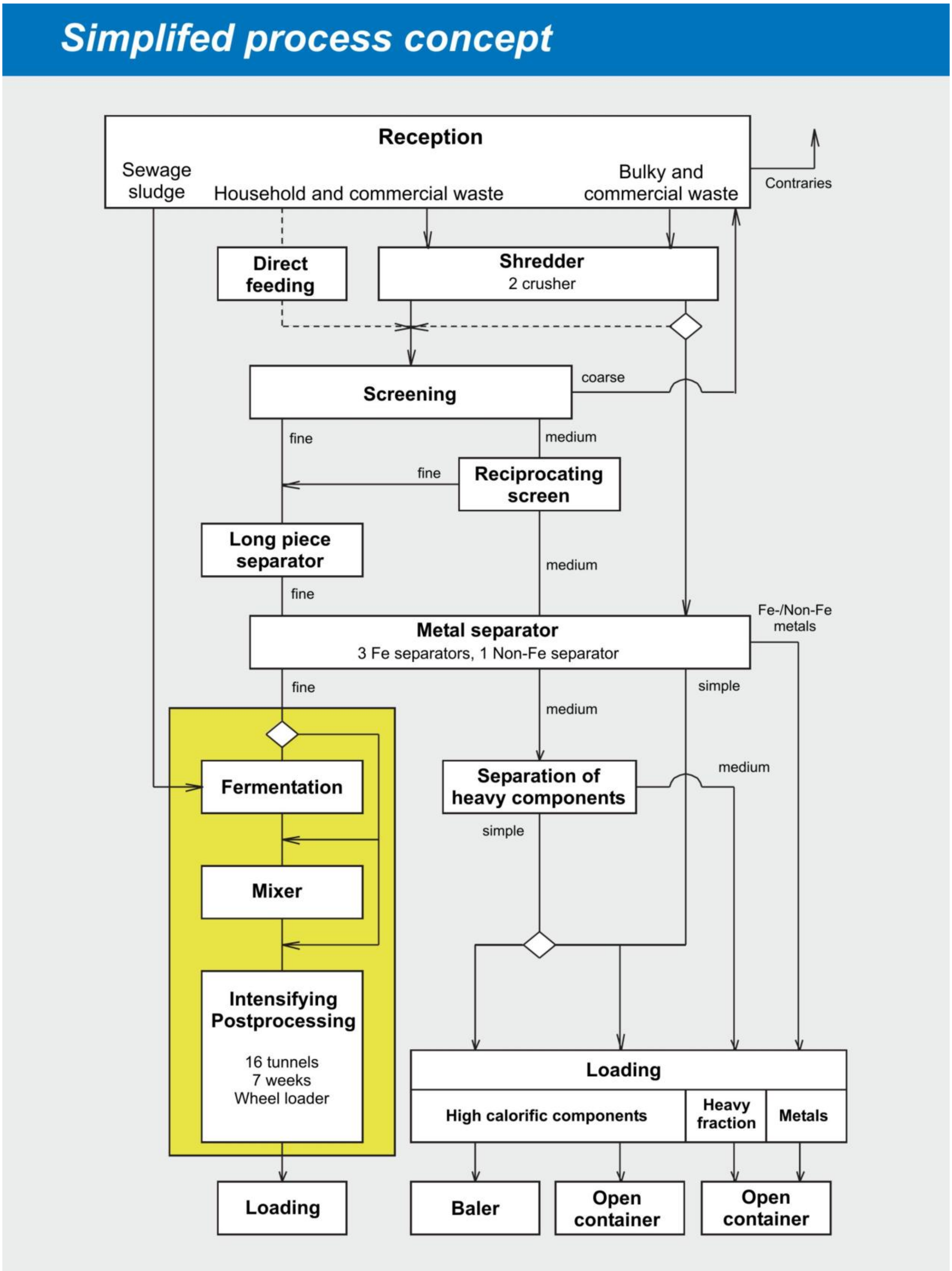

Figure 10 Process flow chart MBT Pohlsche Heide

8.2.2 MBT Suedniedersachsen: Full-stream wet anaerobic digestion

The following description of this plant is based on Fricke et al. (2010) and is supplemented by data from our own research.

8.2.2.1 Plant data

Plant capacity: 133,000 Mg/a

Commissioning date: 2008

Specific process name: Two-stage, mesophilic full-stream digestion with subsequent wet oxidation

8.2.2.2 Input materials

Table 8-3 Composition of feedstock (actual throughput in 2009)

Input fraction	Wt%
Household waste	79
Bulky waste	13
Commercial waste	7

8.2.2.3 Mechanical stage

Waste is first shredded and screened. The > 60 mm fraction is sent for energy recovery once metals have been removed (high-calorific fraction). The <60 mm fraction undergoes biological treatment after recyclable metals have been removed and following additional screening. Biogas that can be used to generate energy is produced during this stage. Oversize material is sent for a second round of shredding. **Error! Reference source not found.** shows the mechanical treatment process in detail.

8.2.2.4 Biological and wet mechanical stage

8.2.2.4.1 Mixers and pulpers

Pulpers turn the fine fraction into a pumpable suspension by adding water at a rate of ca. 1:4. In addition, the technology shreds organic components again, dissolves dissolvable components and ejects heavy materials. The mixer is designed to handle 51,600 Mg/a of fine fraction and around 206,000 Mg/a of process water at throughput of 110 Mg/h based on an average of number of operating hours.

8.2.2.4.2 Grit chamber

The grit chamber serves to remove both lightweight materials (e.g. plastic and wood) and heavy materials (inert material). The injection of air makes the substrate less dense and thus increases the degree of sedimentation. At the same time, the resulting water flow helps to rinse out sediment on the flat wall of the grit chamber.

8.2.2.4.3 Hydrolysis

Hydrolysis or acidogenesis is performed in a separate container before the fermenter. The container is fully mixed to prevent the formation of floating matter and sedimentation, a step that also helps to homogenise substrate. The hydrolysis container serves simultaneously as a balancing tank. It is constantly emptied, but filled only discontinuously, in other words the level rises during the week, but falls on the weekends. The maximum fill volume stands at roughly 4,800 m³. Daily throughput amounts to ca. 700 Mg/d. The substrate's average residence time lasts ca. 7 days. Other functions or properties of the balancing tank are:

- to offset the discontinuous addition of nutrients in order to even out the feeding of the biology with nutrients;
- to have an operating temperature of ca. 30°C with a pH level of around 5;
- to add FeCl to precipitate iron sulphide in order to minimise H_2S levels in biogas."

The sulphide precipitation system was to be replaced by biological desulphurisation technology for biogas in 2011.

8.2.2.4.4 Fermentation

The hydrolysis unit is *"followed by two 4,800 m³ fermenters. They have top-entry agitators and are thus fully mixed. The substrate stays in the fermenter for around 14 days, with the fermenter running at a temperature of around 37 °C. The pH level is neutral (around pH 7)..."*

8.2.2.4.5 Aeration

Aeration takes the form of wet oxidation in two aerated, complete mix lines, each equipped with three agitators. *"Air (ca. 2,400 m³/h) is injected below each agitator, with air bubbles being distributed by a turbine-like agitator at the bottom of the basin. Each line has a theoretical fill volume of 40x9x8 m (LxHxT) = 2,880 m³. The substrate has a residence time of 5-7 days. Annual throughput stands at ca. 234,000 Mg due to the low dry matter level of 2-3% DM and the aforementioned short theoretical residence time*." Defoaming oil can be added, if needed, to prevent foam formation.

8.2.2.4.6 Dehydration

"After aeration, solid/liquid separation is performed with the help of three decanters using flocculants to provide further customisation. The liquid phase (process water) is recirculated and cycled back to the entire process. Throughput varies between 15 and 25 m³/h depending on the configuration. This results in a maximum sediment volume of 1.2 Mg DM/h at an average dry matter level of 30-35%."

8.2.2.4.7 Mechanical and thermal drying

A band dryer dries output from digestion. Thermal drying in a band dryer aims to ensure that residual material achieves a suitable water level for insertion in landfill. Waste heat from the CHP plant meets 65% of the dryer's energy needs.

8.2.2.5 Exhaust air cleaning

Controlling ventilation in the aeration stage prevents the formation of nitrous oxide. An RTO with an efficiency of over 95% oxidises carbon in the exhaust air. An acidic scrubber treats NH_3 contamination in the MBT plant's exhaust air.

8.2.2.6 Wastewater management

Each year, the plant generates some 22,000 m³ of wastewater that is not treated at the plant itself, but rather by a percolate water treatment plant and a municipal sewage sludge treatment facility.

8.2.2.7 Material streams and recovery

According to the operator, 3,688 Mg/a of FE and NF metals were recycled in 2009. Refuse-derived fuel (60,153 Mg/a) with an LCV of 12,266 kJ/kg was used to generate energy. Some 1,344 Mg/a of impurities were disposed of at a waste incineration plant. The landfill fraction stood at 23,587 Mg/a.

8.2.2.7.1 Biogas

Biogas passes through a dual-line activated carbon filter before being used at a CHP plant. Biogas is then converted into heat and electricity by two gas-engine combined heat and power plants. The CHP plants have a capacity of 2 x 634 $kW_{heat}$and 2 x 658 kW_{el}.

8.2.2.8 Process flow chart

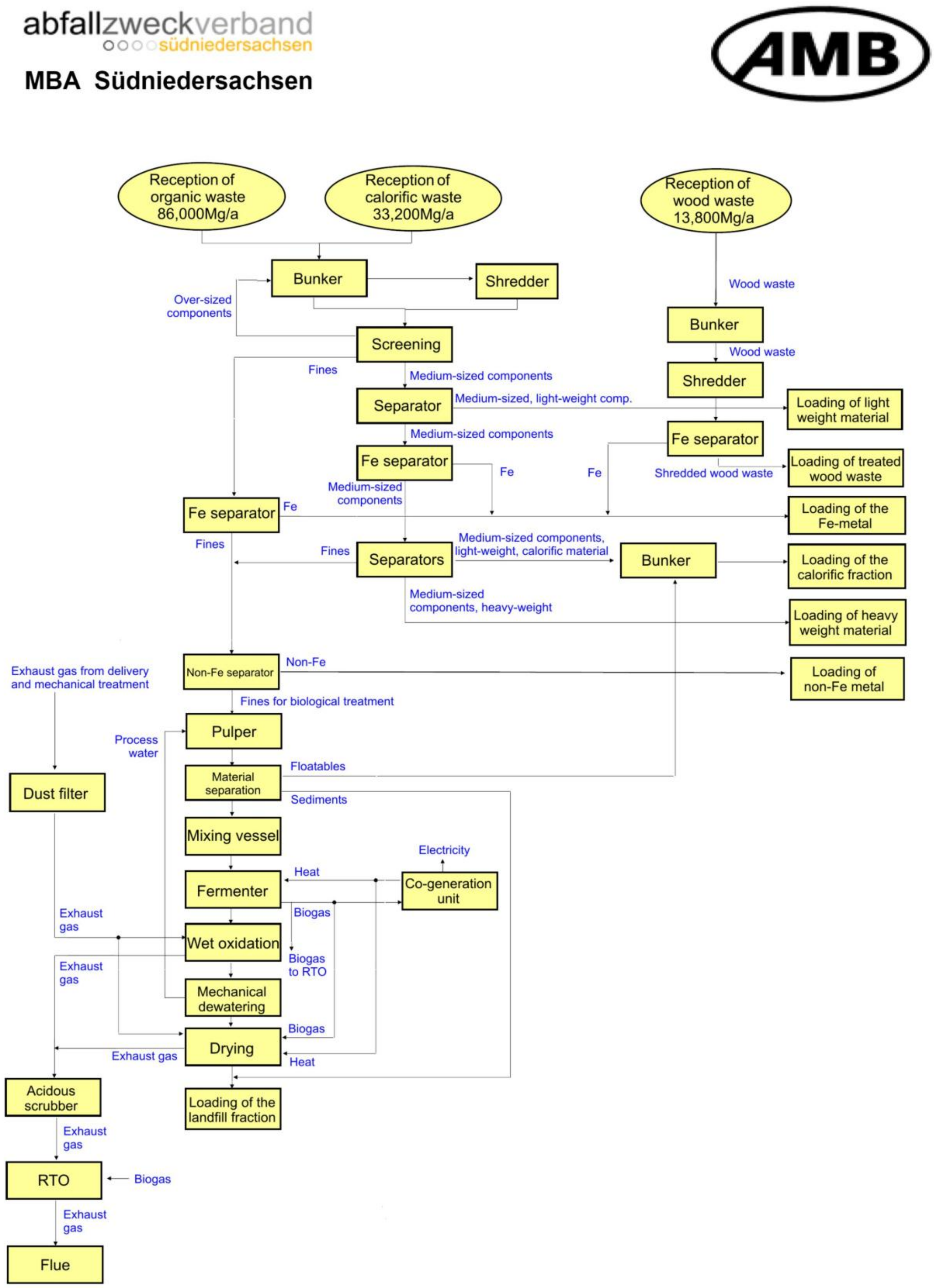

Figure 11 Process flow chart for the sample full-stream digestion plant

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