

# Chapter 5

## POTENTIAL TECHNOLOGIES MEDIUM TERM




# 5.1 Overview

The possible technologies **appropriate for diverting waste from landfill in South Africa in the medium term**[8] are described in this section. They are as follows, and discussed in this chapter:

- Incineration (with energy recovery)
- Mechanical biological treatment
- Anaerobic digestion
- In-vessel composting

# 5.2 Incineration (with energy recovery)

**Incineration (also often referred to as energy from waste (EfW), waste to energy (WtE) or energy recovery facilities (ERF)** [9] is a thermal waste treatment technology which combusts waste in an atmospheric oxygen environment to produce heat which in turn can be used to generate heat and electricity through a steam circuit system.

## 5.2.1 Incineration process

**Incineration is the direct combustion of materials,** and differs in this respect from gasification and pyrolysis technologies which thermally treat a material to produce secondary products. The combustion process directly releases energy in the waste, **which can be recovered as heat; heat and electricity; or electricity only.** Typically, incineration plant combustion **temperatures are in excess of 850$^{0}$C and the waste is converted into carbon dioxide and water, with a wide variety of trace gases and ash residue.** Any non-combustible materials (e.g. metals, glass) remain as a solid, known as **Bottom Ash**, which contains a small amount of residual carbon. **Incineration with energy recovery is a well-established technique** for municipal waste treatment globally, with a substantial concentration of plant in Europe and China.

### 5.2.2 Combustion process

There are four combustion technologies that can be employed to burn either MSW or RDF. A brief overview of the main combustion technologies is presented in the Technical Glossary, Table 19. All of the combustion technologies presented are designed for processing MSW, however will not be able to handle large 'bulky' items of waste which will not fully combust.

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[8] Some of the technologies described in this section have been developed in parts of South Africa under specific circumstances. These are concentrated on large metropolitan areas with the most developed collection and treatment infrastructures. Although, the technologies may be suitable for a larger proportion of municipalities, they are often developed in large metropolitan areas in the first instance.

[9] Energy from waste can also be used to describe gasification, pyrolysis and anaerobic digestion technologies which recover gas, heat or electricity from processing a waste derived feedstock.

### 5.2.3 Energy recovery process

**The standard approach for the recovery of energy from the incineration of MSW is to utilise the combustion heat through a boiler to generate steam.** Of the total available energy in the waste up to **80% can be retrieved in the boiler to produce steam.** The steam can be used for the generation of power through a steam turbine and/or used for heating. An energy recovery plant that produces both heat and power is commonly referred to as a combined heat and power (CHP) Plant and this is the most efficient option for utilising recovered energy from waste via a steam boiler.

**An Incinerator producing exclusively heat can have a thermal generating efficiency of approximately 80-90%**; this heat may be used to raise steam for electrical generation at approximately 17-30% gross efficiency[10]. Net electrical efficiencies (taking account of the parasitic load of the plant) are often cited up to **~27% for Incinerators recovering electricity only,** although some facilities have reported exceeding this many do not achieve these levels and can show recovery efficiencies of 20 – 25%. The need for a steam turbine generator set to produce electricity limits the upper efficiency based on acceptable boiler temperatures. For an incinerator that produces combined heat and power (CHP plant), the electrical and thermal generating efficiencies will vary depending on the split between the two forms of energy (heat and power).

In contrast incinerators perform poorly when compared to the electrical efficiencies of coal fired power stations (33-38% efficiency) and combined cycle gas turbine (CCGT) power stations (50%+ efficiency). This is due to a combination of technical issues and the much larger scale of coal and gas fired facilities. Where the energy recovered from an incinerator is used to generate steam for heating, **the efficiency is comparable with a boiler fired with natural gas or oil**. It is possible that in the future the efficiency of electricity generation using incineration will increase given the trend in other solid fuel applications of more severe operating conditions at higher temperature.

## *5.2.4 Incineration plant configurations*

Here, the incineration process is summarised by way of example configurations of the various technology components. **Incineration is a much more established technology, globally, than gasification and pyrolysis**, and is therefore considered a standard waste treatment solution in many parts of the world, for example Europe and North America. A typical process flow diagram for waste incineration is shown in Figure 12.

*Table 7: Key characteristics of incineration*

| | |
|---|---|
| **Waste streams accepted** | Residual waste, C&I waste, certain fractions of C&D waste, RDF |
| **Input capacity ranges** | 10k – 500k tonnes per annum |
| **Typical outputs** | Electricity, heat, incinerator bottom ash, air pollution control residues |
| **Purpose** | To recover energy from non-recyclable mixed waste streams |
| **Indicative capital cost** | c. R 1,395m – R 1,860m for 100ktpa facility |

## 5.2.5 Preliminary treatment / volume reduction stage

The incinerator requires a relatively homogenised waste stream or RDF. **If the facility is planned to accept untreated waste it is essential that some waste preparation activities are carried out in order to remove unsuitable materials.** This will remove unwanted items (i.e. oversized components like wood and bulky household items) from the waste feedstock and also allows the recovery of valuable materials (for example, ferrous and non-ferrous metals) although this later process isn't necessary. Typically, a bag splitter will be used to split bagged waste and a simple form of treatment (hammer/ball mill, crushers and/or shredders) will be utilised in order to prepare the waste into a treatable, consistent and uniform nature.

## 5.2.6 Mechanical sorting stage

A variety of mechanical treatments exist suitable for MSW pre-treatment prior to incineration. These can be designed to extract recyclable fractions from a mixed waste stream. Most commonly ferrous and non-ferrous metals will be recovered for recycling using magnets and eddy current respectively, although similar treatment of the Incinerator Bottom Ash (IBA) **post incineration is a more common alternative for metal recovery** from an incineration process. It is possible, although not widely practised, that a more advanced pre-treatment process can be designed to remove other valuable target materials. This should be done with care so that the **waste CV is maintained at a level suitable for the incineration technology** chosen.

## 5.2.7 Thermal treatment stage

The waste feedstock will be fed into the incineration chamber(s) on a continuous basis where it will be heated in a furnace at temperatures in excess of 850$^{o}$C. **The waste will transform into an ash and waste heat**, with the heat rising and ash falling through grates at the bottom of the incineration chamber. The heat will flow into a boiler chamber where it is converted into steam which in turn can be fed through a steam circuit to produce heat and electricity. Part of the generated heat and electricity will be used to power the facility, with the rest available for export.

## 5.2.8 Emissions control stage

The major emission from a plant with energy recovery is the release of flue gases from the combustion process. The use of an air filtration system to remove particulate matter from the flue gases results in a fine, dusty waste stream referred to as air pollution control residues (APCr) (or in some cases Flue Gas Treatment residues). **This waste stream must be disposed of appropriately to a controlled landfill.** Emissions of many parameters need to be monitored continuously to comply with operation permits. Some substances, including dioxins, furans and some metals, cannot be measured continuously or it may be prohibitively expensive to do so. Some substances such as dioxins and furans can be continuously sampled, with analysis carried out periodically to give the average amount emitted over a longer period. Emissions of substances which cannot be measured continuously are normally measured periodically. Routine day-to-day control is achieved by ensuring that surrogate indicators such as combustion temperature, particulate emissions and hydrogen chloride emissions are within the permitted limits.

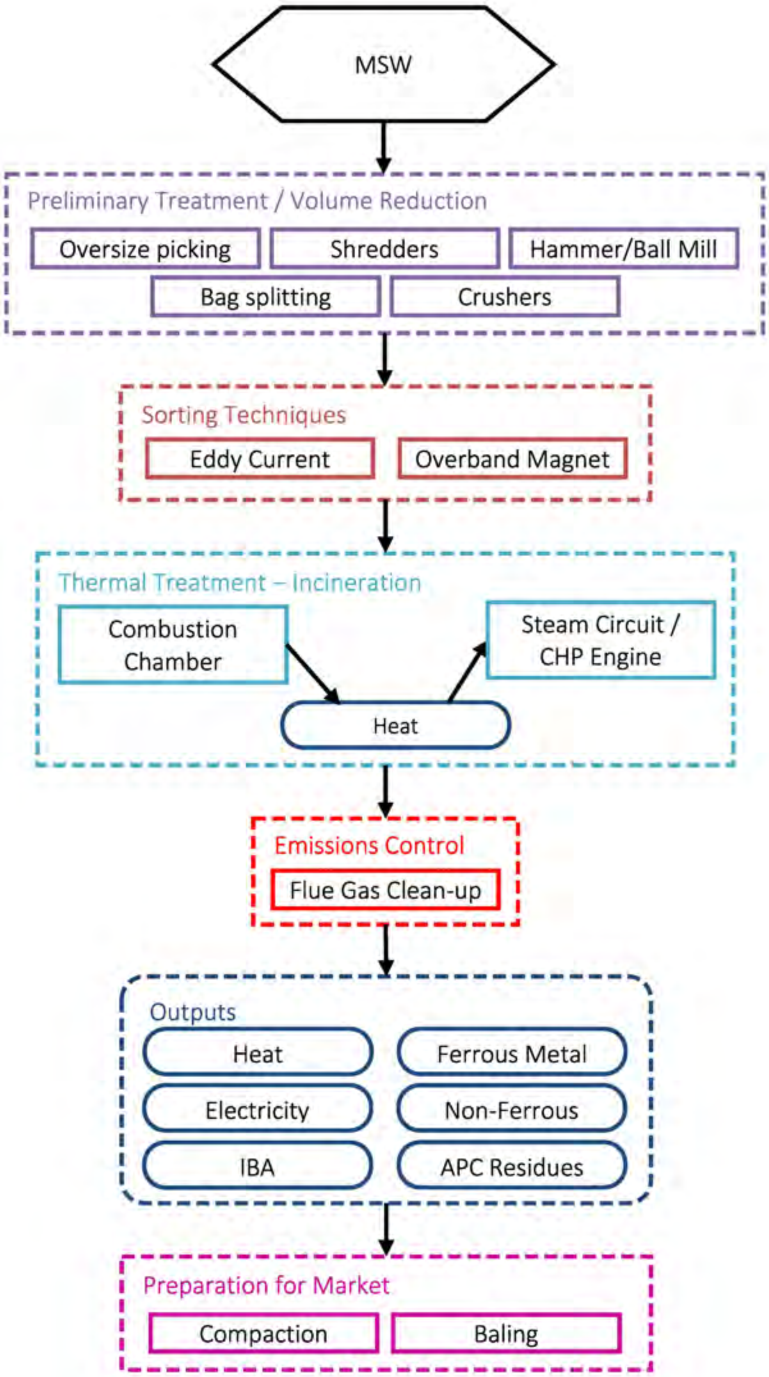


*Figure 12: Typical incineration process flow diagram*

## 5.2.9 Product polishing / quality refining stage

The bottom ash produced by incineration will likely contain ferrous and non-ferrous metals, unless these have been previously removed from the waste stream. **The metals recovered will be of a lower quality than source separated materials of MRF outputs**, however will still be of financial benefit.

## 5.2.10 Process outputs

Heat and electricity derived from the combustion can be exported to the local grid or nearby users as the market dictates. Whereas electricity will be readily in demand, and can be fed into the grid where there is a suitable connection, heat requires an adjacent user and therefore its use may be problematic. Heat can be used to supply a district heating network for either nearby businesses or homes. The heat will be pumped through pipes to the end user and can be used for heating purposes or for hot water. Metals (and other recyclate) extracted at the front and back ends of the incineration process are suitable for sale into the relevant local commodities market. Inert material from the front end of the process (if applicable), and ash (non-APCr) from the back end of the incineration process can be used as aggregate materials if local standards allow. A common use for ash from incineration processes is as a component of cement as a substitute for natural aggregate. **APC residues will need to be disposed of in controlled landfill sites as a hazardous waste.**

## 5.2.11 Preparation for market

Aggregates and ash will require bulking ready for onward transportation. Any raw recyclate which is recovered will similarly require baling in preparation for its end market.

Due to the high capital costs involved, the shortage of suitably qualified and experienced personnel needed to operate thermal treatment plants as well as the environmental concern for properly managing flue emissions, has resulted in South African companies and municipalities rather considering lower-technology waste treatment solutions. Advanced thermal treatment solutions may well become viable as municipalities, after having dealt with the less costly treatment and disposal of waste streams such as builders' wastes, recyclables and garden wastes, focus more on diverting residual wastes (such as mixed organic wastes) from landfill.

## 5.2.12 Concluding comments

Incineration is a common waste treatment process in numerous countries across the world. It is **an established technology** than can be used to treat a variety of waste streams. It is **capital intensive**, however revenue from both gate fees and energy generation has made the technology competitive in other countries, especially in instances where there is a lack of alternative fuel source or a high price is paid for traditional fuel sources (e.g. coal or natural gas). There have been **major changes in the environmental controls** applied to waste incineration plant due to concerns over health impacts. The EU regulates these processes under the Industrial Emissions Directive (IED) which specifies stringent limits for emissions from waste incineration processes (these also apply to Advanced Thermal Treatment, see chapter 6).

# 5.3 Anaerobic digestion

**Anaerobic digestion (AD) has been used by civilisations for thousands of years for the treatment of waste.** In modern times, it is an established technology for treating agricultural wastes and sewage sludge. Over the past 5-10 years, AD has gained in popularity as a treatment technology for source segregated organic wastes, in particular those including food waste. Most facilities accepting food waste tend to blend the food waste with other waste streams including garden waste, cattle wastes, maize etc. This approach may offer advantages both in terms of stabilising the process and gas yield optimisation.

## 5.3.1 Anaerobic digestion process

Anaerobic digestion of organic waste centres on the **biological degradation of biodegradable wastes by microbes under strictly controlled conditions.** The microbes use the biodegradable wastes as food for growth and multiplication. In AD, **the process operates in the absence of oxygen**, in other words, under anaerobic conditions.

During the process, **biodegradable material is converted into methane ($CH_4$) and carbon dioxide** (which together comprise a combustible energy source known as biogas), leaving a partially stabilised wet organic mixture consisting of a wet solid or liquid suspension of non-biodegradable materials; undigested organics; microbes; and decomposition by-products. This partially stabilised wet mixture is known as 'digestate'. This digestion process also requires additional heat which may be applied to maintain optimal temperatures; however assuming the biogas is appropriately recovered the process is still **a net producer of energy**. A simplified mass balance of the AD process is shown in Figure 13 below.

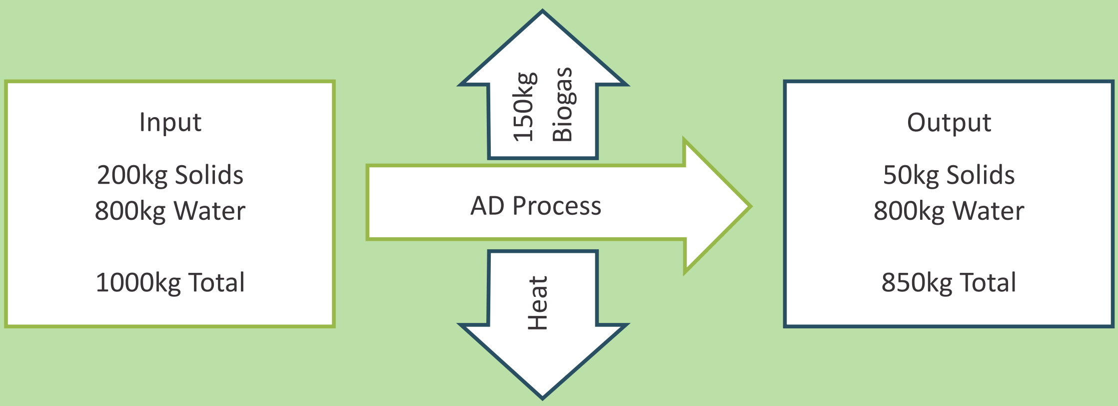


*Figure 13: Example anaerobic digestion mass balance*

The digestion process consists of a chain of four steps, illustrated in Figure 14. The outputs from the AD process are discussed in more detail subsequently.

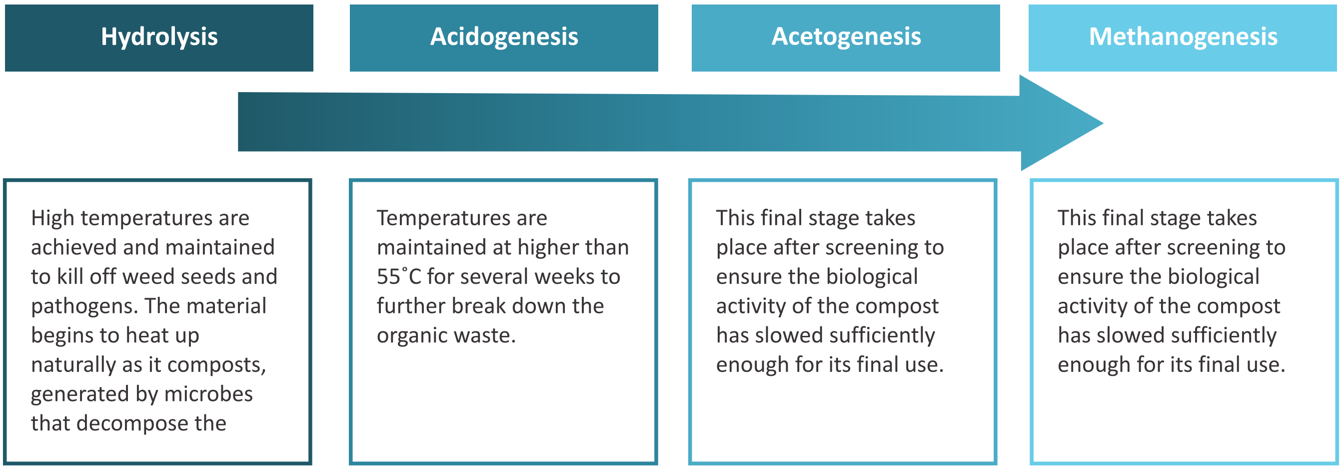


*Figure 14: Anaerobic digestion process steps*

### 5.3.1.2 Anaerobic digestion

**Is suitable for materials with low solids content and moisture contents ranging from 60 to 95%.** Commercially, 'wet' AD operates at solids contents less than 15% and 'dry' processes operate at solids contents more than 20%.

Wet AD systems have a long established track record in the wastewater industry. The wet AD process is most suitable for the treatment of source segregated food waste. For municipal waste, **food wastes are suitable input materials for AD**. Biodegradable food waste can be treated alongside other non-municipal wastes, such as agricultural slurries and industrial food wastes to optimise the process. Other biodegradable material, such as green waste, can be treated; however the 'dry' AD technology is more appropriate for this waste stream, although **there is less of a commercial track record for 'dry' AD than 'wet' AD.**

Dry AD systems use plug flow reactor designs, which involves adding fresh waste and/or partially fermented waste into one end of the reactor while fully digested residue is extracted from the other. Typical waste feedstocks for a dry AD process include garden waste and energy crops with greater 'structure'. Dry AD technologies can comprise vertical or horizontal tanks. Vertical tanks rely on gravity to move material through the system, whereas horizontal systems use specialised augers or baffles.

AD technologies are, by their nature, enclosed, using specifically designed vessels, interconnecting pipe-work, mixers, macerators and pumps. AD processes for food waste may include a de-packaging stage to remove unwanted plastics, metal, paper and card contamination.

Waste feedstock is mixed and macerated with a large proportion of recirculated process effluent and/or fresh water to prepare the waste as a dilute 'wet' or thick 'dry' slurry to be fed into the digester tank. This also provides a useful decontamination stage to remove heavy and light contaminants through gravimetric separation. **The digestion process takes place in sealed tanks (digesters) that are usually continuously mixed to maximise contact between microbes and waste.** Mixing can be achieved using mechanical stirring, or by recirculating biogas or waste through the digestion tank.

The process can be operated at moderate (mesophilic 30-40°C) temperatures or high (thermophilic 50-60°C) temperatures. In mesophilic systems, a pasteurisation unit is used to heat the material before or after digestion to achieve sanitisation by killing potentially pathogenic organisms. 'Dry' AD processes are better suited to thermophilic conditions, while 'wet' processes can be either mesophilic or thermophilic. The differences between the two process operating temperature conditions are summarised as follows.

*Table 8: Comparison of mesophilic and thermophilic anaerobic digestion technologies*

| Operating parameter | Mesophilic | Thermophilic |
|---|---|---|
| **Temperature** | 30-40 C | 50-60 C |
| **Digester residence time** | 15-30 days | 10-20 days |
| **Advantages** | More robust and tolerant process.<br>Less energy input required. | Higher gas production.<br>Faster throughput (lower residence time).<br>Separate sanitisation stage may not be required. |
| **Disadvantages** | Lower gas production rate.<br>Requires larger digestion tanks.<br>Requires a separate sanitisation stage. | Greater energy input required.<br>More sensitive to environmental variables.<br>Needs effective control. |

The AD process **can be a single step where all the waste is placed into a single digester vessel, or a multiple step process using a series of vessels** to optimise different stages of the process. Multiple step processes employ a separate hydrolysis stage, which is either aerobic or anaerobic, to optimise the breakdown of complex organic material into soluble compounds. This is followed by high-rate anaerobic digestion for biogas production. Multiple stage processes normally take place in two vessels in series: one for hydrolysis, the second for digestion.

### 5.3.1.3 Digestate

The digestate from AD can have high moisture content as a result of the low solids content of the feedstock and the breakdown of solids during the process. The resulting material can either be spread as 'slurry' or can be mechanically dewatered with the **digestate used on land as a soil conditioner or composted** providing it meets the appropriate regulatory standards. The liquid effluent from dewatering of digestate may be recycled back to the AD process, used directly as a liquid fertiliser if it meets the appropriate regulatory standards, or used in subsequent aerobic composting of the dewatered digestate.

The amount of digestate produced will depend on the process design and the nature of the feedstock. **Around 0.8 tonnes of wet digestate can be expected per tonne of delivered food waste.**

### 5.3.1.4 Biogas

Biogas produced during anaerobic digestion comprises mainly methane (typically ranging between 50-75%) and carbon dioxide, as well as smaller quantities of other gases including hydrogen sulphide. Biogas is also saturated with water.

The amount of biogas produced using AD will vary depending on the process design and the nature of the feedstock. **For source separated food waste, between 120 and 150m$^3$ of biogas may be produced per tonne of delivered feedstock**; the biogas production for mixed residual waste will be lower.

Biogas is stored in large vessels prior to its use on or off site. Biogas can be used in a number of ways. Often it is combusted (after removal of water and corrosive gases) **to produce heat and electricity using some form of CHP generator.** There will be a parasitic load required to power the plant, typically around 10% of the electricity produced.

Excess electricity can be exported and sold to the grid. **Electricity generated from biogas is renewable energy** and in many countries financial incentives may apply. There may be opportunities locally for use of excess heat from the CHP, such as district heating or an industrial or commercial heat sink, with a portion often also used in the AD process itself.

The biogas could also be **cleaned to produce for either injection into a gas grid or for use as a vehicle fuel.** For these applications, the removal of hydrogen sulphide, moisture, carbon dioxide and other trace gases are required to increase the methane content to over 95%, as well as compression of the resulting 'biomethane'. There are a number of technologies available to clean up the biogas, with gas scrubbing with water being the most common. **The capital outlay for infrastructure to upgrade biogas can be significant** (7-10% of total Capex).

**Gas networks are not commonplace in South Africa** and those that exist are usually small private networks within industrial properties. Some micro-utility gas networks have been set up by private residential housing developers using LPG. The largest CNG gas network is run by eGoli Gas that supplies approximately 7,500 industrial, commercial and domestic users in the Johannesburg area with a 1,200km gas network.

**There is potential for biogas to be fed into some of these smaller private networks**, with success most likely in the industrial sector. However, consideration needs to be given to the constraints and processes required by the Municipal Finance Management Act and the Municipal Systems Act with regard to the sale of such gas to a private entity.

**Upgrading the biogas and injecting it to a gas network is one of the most efficient uses of the biogas**, and this is a growth area in Europe. If the biomethane is to be used in this way, it will need **to be compressed to suit the local gas main pressure**. In addition to cleaning up, the biogas may need to be mixed with a small quantity of propane to increase its calorific value comparable to natural gas. **Once in the gas network, the biomethane will be used alongside regular natural gas** – no modifications to equipment or appliances will be required. Where biogas is upgraded for injection to the grid, additional site area is required as a result of the additional safe zone needed around the bulk propane storage, typically 35x38m, or 0.13 hectares.

**Biomethane can be used as a fuel for vehicles as an alternative to compressed natural gas (CNG)** with the same engine and vehicle configuration as natural gas. The biomethane would need to be compressed to over 200 bar for this application, to reduce the storage volume and increase its energy density. If the biomethane is to be transported as fuel in a tanker, it would typically be liquefied as LNG; the cost of doing this may be prohibitive on a small scale. If the AD facility and biogas upgrading plant is local to the gas fuelling station, the biogas can be connected directly to a compressor for fuelling. If the biogas upgrading plant is not able to be connected to the gas fuelling station, the biogas will need to be injected into the gas grid (see above) with a take-off point for refuelling.

**The use of biogas as a vehicle fuel is reported to being piloted in Johannesburg by Novo Energy,** the success of which is unknown at present. However, the use of biogas as vehicle fuel has been adopted successfully internationally, for example in India. Due to the generally large distances between towns and the limited range of a biogas fuelled vehicle, the use **of biogas as a vehicle fuel is better suited to fleets of vehicles that operate within the inner city,** for example taxis or waste collection vehicles that operate in predefined routes. A CNG fuel station was opened in Johannesburg in early 2014 with the aim of supplying the taxi and logistics industry. The success of this project along with that by Novo Energy would be a good indicator of the potential for biogas fuel in South Africa.

# 5.3.2 Anaerobic digestion plant configurations

Anaerobic digestion is a microbiological fermentation process which occurs in an air-starved environment, used to stabilise organic waste and derive a biogas for energy recovery. Here, the AD process is summarised by way of example configurations of the various technology components.

*Table 9: Key characteristics of anaerobic digestion*

| | |
|---|---|
| **Waste streams accepted** | Putrescible / organic waste, garden / food waste collections, slurries, energy crops |
| **Input capacity ranges** | 5k – 150k tonnes per annum |
| **Typical outputs** | Biomethane, heat and electricity, nutrient rich digestate |
| **Purpose** | To recycle biodegradable waste into a digestate for land application / soil improvement and recover energy as either gas or heat and power |
| **Indicative capital cost** | c. R 124m – R 217m for a 25ktpa wet AD process |

*Figure 15: (clockwise from top left) Anaerobic digestion tanks (image courtesy of WRAP); biogas CHP engine and cleaning equipment (image courtesy of WolfeWare Ltd); digestate spreading (image courtesy of Agrivert)*

**A typical AD process flow diagram is presented in** Figure 16. Each of the process stages is summarised subsequently.

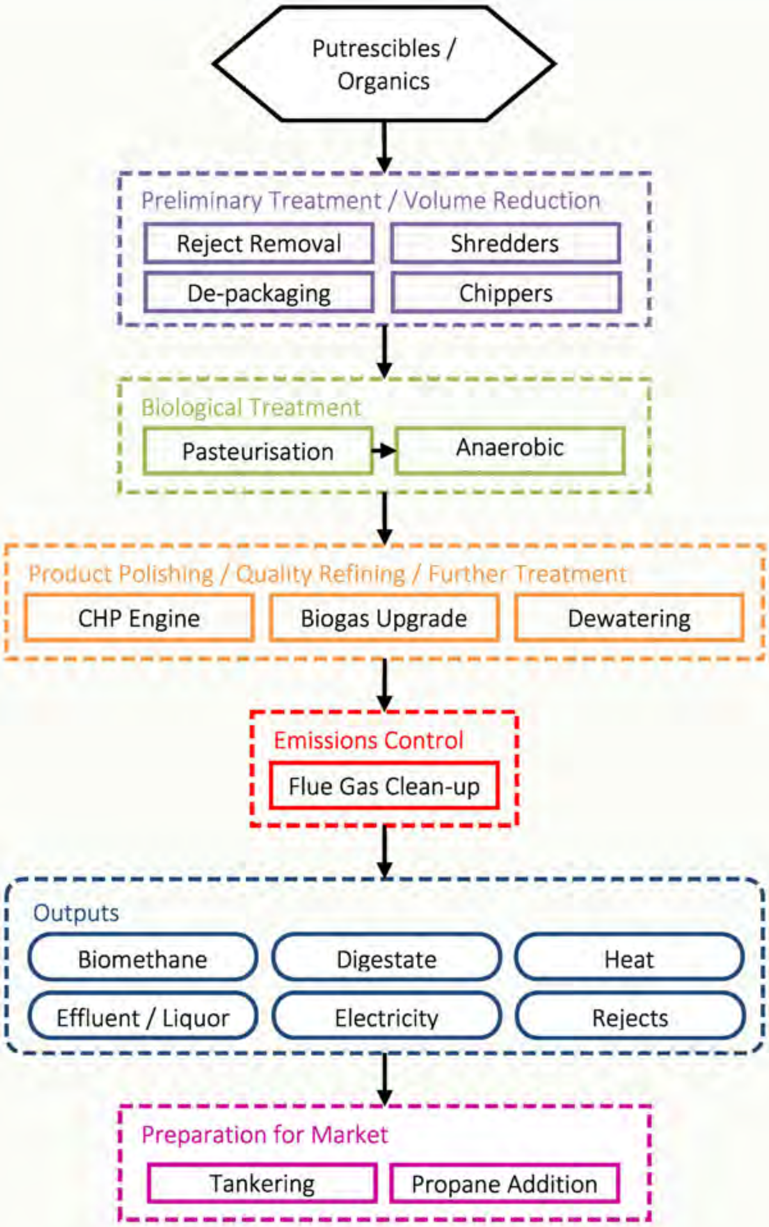


*Figure 16: Typical anaerobic digestion process flow diagram*

## 5.3.3 Preliminary treatment / volume reduction stage

**Food and garden waste delivered to an anaerobic digestion facility will often require pre-treatment prior to biological processing**. Food waste, from some sources, may still be in a packaged form and will therefore require de-packaging. Some recyclable materials can be recovered from the de-packaging process, for example plastics, metals (e.g. cutlery, foil) and glass aggregate. Garden waste feedstocks are likely to contain large objects which are not suitable for anaerobic digestion without size reduction by chipping or shredding. Large food waste items will similarly require maceration. These processes will enable the digestion and pasteurisation processes to occur quickly and efficiently reducing the required retention time of waste in the facility. **Pre-treatment is also necessary to remove contaminants which cannot be accepted by an anaerobic digestion process**, for example dry recyclates and hazardous wastes.

**AD is an appropriate technology for processing a wide range of organic derived feedstock and waste streams.** Examples range from agricultural energy crops or slurries through to abattoir wastes and sewage sludge. Most AD processes blend input streams in order to optimise the gas yield from the process and the stability of the operation.

## 5.3.4 Biological treatment stage

Biological treatment consists of two stages; a pasteurisation stage to stabilise, sanitise and kill pathogens in the waste; and a digestion stage where microbes convert waste into biogas, digestate and water. **If pasteurisation is required it will occur in a separate tank to the digestion process, and should achieve at least a 70$^{o}$C temperature for one hour duration, or 57$^{o}$C for a five hour duration.** Following pasteurisation, waste will be fed into a digestion tank where it will reside for a minimum of two weeks prior to digestate and water being fed out of the back end of the process. The residence time may be optimised to a point where biogas yields of the remaining feedstock are insufficient to warrant further biological degradation. Biogas will continuously rise through the feedstock and out of pipes from the top of the digestion tanks from the moment that waste is fed into the process. Pasteurisation may also be undertaken after the digestion stage; however operational experience of this is more limited. Dry AD systems which maintain an adequately high temperature (thermophilic stage) for a prolonged time period may not require pasteurisation, however it is still recommended in some instances in order to eliminate hazards in the waste.

**It should be noted that digestion is a sensitive process and requires active and on-going monitoring and managing to ensure that the operation proceeds in a stable manner.** This is often achieved by careful blending of feedstock materials, operating conditions and in some cases through the addition of supplements (e.g. trace elements) to ensure a stable environment for the bacteria.

A liquor that arises from the process (or via dewatering of digestate) may be recirculated through the digestion processes in some systems or discharged to sewer (with appropriate consents) where of a sufficient quality to do so.

## 5.3.5 Product polishing / quality refining / Further treatment stage

Further processing of the digestate is required to ensure that the material is fully decomposed after the digestion stage. As a rule of thumb this will be done for a further 18 days. It is usual that this aerobic composting stage is done in a further set of tanks, however if local conditions are suitable, it is possible for this maturation to occur outside (e.g. in windrows). If a local use for the nitrogen rich digestate isn't available it may be necessary to dewater the digestate to produce liquor and solid digestate. These can then be easily transported for use further afield. The dewatered, and further matured solid digestate can be used in the same way as compost of a similar nature, and the liquor (subject to quality considerations) may be spread to land as a natural fertiliser.

The biogas produced by the anaerobic digestion process is transferred to a storage tank before further processing. This processing can be in one of two forms. Most commonly, and cheaply, the biogas can be burnt in its current state in an engine to produce electricity and/or heat if desired. Typical electrical generation from anaerobic digestion is 75-225kWh per tonne of feedstock (dependent on the type of feedstock and the AD process conditions). Where biogas is used for onsite electricity generation, a generator similar to that used in landfill gas applications can be used, as these generators are designed to combust moist gas containing some hydrogen sulphide.

**Roughly 10-15% of the electricity generated will be required as parasitic load to operate the anaerobic digester and associated equipment.** An alternative use of the biogas is as a fuel for use on site or input into the local natural gas network. This requires upgrading of the biogas into biomethane possible through a variety of gas scrubbing technologies. The available technologies for upgrading biogas are more limited in size than CHP engines, and therefore a facility will need to be suitably designed to fit with the nearest upgrade equipment size available.

## 5.3.6 Emissions control stage

When biogas is used on-site for electricity and/or heat generation the flue gases from the combustion process will require clean-up prior to release. The biogas is typically high in sulphide content and therefore requires the removal to reduce associated environmental impacts.

## 5.3.7 Product outputs

Anaerobic digestion produces biogas which can be used to generate renewable heat and/or electricity or upgraded to biomethane for use as a replacement of natural gas or fuel. When biomethane is input into a grid network it is likely to require further upgrading so that the Calorific Value matches the CV of the gas in the wider distribution network. This is done through the addition of propane, although **this process can be expensive especially if a large amount of propane is required.**

Matured digestate from the process can generally be used directly at a nearby location or dewatered with the liquor being used further afield as a natural fertiliser and the further matured solid digestate used as renewable compost for soil improvement. Alternatively, if no market can be found for the product or the waste stream is contaminated with hazardous substances, it is possible to dry the digestate output for use as an RDF in energy recovery facilities, however **when additional process steps are added there is always an additional cost implication.**

Rejects and contaminants from the early processing stage will be sent for disposal or treatment as local existing facilities dictate.

## 5.3.8 Preparation for market

Dewatered (solid) digestate material will require bulking for transport off site, whereas liquor will require tankering ready for transportation off site. If upgrade to biomethane treatment is employed, with final input into the gas grid, propane addition is likely to be required. Addition of other propane and other additives may be required for vehicle/appliance fuel dependent on the upgraded biomethane properties, which will be dictated by the characteristics of the waste (and other feedstocks) treated.

**There are many examples in South Africa of anaerobic digestion treatment.** Larger-scale anaerobic digestion plants have mainly been used for the treatment of sewage sludge, with a number of smaller-scale plants being used for general organic solid wastes such as food and agricultural wastes. There is a growing awareness in South Africa of the benefits of anaerobic digestion treatment and it is expected that significant growth in the use of this technology will take place in the near future.

A number of anaerobic digestion plants have been installed in South Africa receiving animal waste/manure and the gas has been used for heating and electricity generation. These installations range in size from very small scale installations to plants in excess of 10 tonnes/day.

The sort of technology required to recover energy from biogas has also been utilised on landfill sites for the recovery of landfill gas through funding from the World Bank as illustrated by the case study overleaf.

## 5.3.9 Conclusion comments

Anaerobic Digestion has some potential for application in treating a range of organic waste streams in South Africa, and it is a growing technology internationally. Careful consideration is required for correctly matching the waste stream with an AD technology type and choice of outlet for both digestate and biogas products. The management of these outputs is key to economic viability. Feedstock into AD processes is also a key consideration for economic viability. In the Netherlands numerous facilities have been forced into closure through lack of control over feedstock supply meaning it was unaffordable to fully stock the facilities. Similarly, it is important that key feedstock characteristics are maintained throughout the life of a plant, as a facility designed to accept a specific feedstock (e.g. food waste) will not easily adapt to accepting a different feedstock (e.g. energy crops). It is therefore important to not build facilities which are overly reliant on a feedstock, the availability of which is subject to change. **An Anaerobic Digestion process is a sensitive technology that requires on-going management and monitoring to ensure than optimum conditions are preserved** and that the process does not become unstable.

As both an energy and a waste treatment process, a variety of skills and health and safety issues can arise at AD plants and therefore good practice methods should always be employed. The management of digestate (including maturation or dewatering), **can give rise to significant odour** issues, appropriate environmental controls and management systems should be in place to address such issues.

## *Case study: Landfill gas capture and electricity generation, Durban, Kwazulu-Natal*

### Background

In 2002 the World Bank approached the South African Government with a view to implementing a Clean Development Mechanism (CDM) renewable energy project in South Africa. Through the University of Kwa-Zulu Natal (UKZN), Durban Solid Waste (DSW) was approached to initiate the technology development in July 2003 and subsequently the first landfill gas to electricity project in Africa was developed. The project was split into two components; part 1 was a 1MWe installation at the Mariannhill Landfill site; and, part 2 a larger 6.5MWe installation at Bisasar Road Landfill site.

### Mariannhill landfill site

The project is a collaboration with the World Bank's Proto Carbon Fund who purchase all Carbon Emission Reductions (CERs) that are generated. A total of 180,864 CERs have been issued, with the plant generating 24,911 MWh of electricity saving the eThekwini Municipality R 10,400m.

### Bisasar road landfill site

An Emissions Reductions Purchase Agreement (ERPA) is currently not in place and is accumulating CER's produced from landfill gas capture at Bisasar Road. This is due to the very depressed price of CER's at present. To date 815,344 CER's have been issued, and sold to Nedbank. The plant has generated 239,638 MWh of electricity therefore saving the municipality R 95,300m.

### General

When the project first commenced there was no expertise in the country to guide or assist in decision making. Therefore the decision taken was to own the project outright and to tender out for the expertise required. Several of the projects that have followed have in fact sold the rights to the gas to private enterprises and merely receive a royalty percentage of the profits. Should carbon tax become a reality in South Africa then these projects could become extremely profitable and a source of revenue income for municipalities.

As this is a substantial investment for the municipality a dedicated project manager has been appointed to manage the project. As the work is specialised, the municipal use a quality based approach to the tenders where the companies tendering first have to show that they have the expertise and has to obtain a minimum score before the issue of price is considered. In order to run a successful project many skills are required; therefore, seven separate contractors have been appointed on the project. The appointed contractors' activities includes construction and pipe laying, engine maintenance and repair, gas field management, air quality monitoring, data management for CDM, electrical maintenance and then equipment and spares suppliers.

### Source

Personal Communications, John Parkin, eThekwini Municipality (2014)

# 5.4 In-vessel composting

**In-vessel composting (IVC) is a relatively new technology, used to accelerate and closely control the composting process.** It is a variation on traditional composting processes (see Chapter 4.2 **Open window composting)** whereby the composting process is undertaken in a controlled, contained environment. IVC is suitable for source-separated organic waste and for mixed residual waste as part of mechanical biological treatment (see Chapter 5.5).

## 5.4.1 In-vessel composting process

For IVC systems, the composting process takes place under controlled conditions in an enclosed environment, either within buildings (bays, beds) or in composting vessels (tunnels, drums, towers). **Mechanical agitation and forced aeration are methods used to control oxygen supply, temperature and moisture loss.** As with open windrow composting, material is shredded prior to composting.

**IVC requires a net input of energy,** predominantly in order to apply the oxygen necessary to increase microbial activity and ensure adequate application of heat. **Typically, temperatures between 60°C and 70°C are achieved by IVC processes**. High temperatures have the advantage of killing potentially pathogenic organisms in the waste (sanitisation), and can also be used to dry material. The retention time of materials in an IVC facility is dictated by the end use, and necessary degree of decomposition, sanitisation and stabilisation required for this end use. Outputs which are dried for use in a subsequent treatment process may require shorter retention periods than those designed for agricultural or horticultural applications.

The partially composted waste after the IVC process is often composted in the open air (as a secondary composting phase) to fully stabilise the waste when intended for use in agricultural or horticultural applications. This second phase of composting is usually termed 'maturation' and often occurs in windows for 2 weeks or more.

In some countries (such as those in the EU) there is a **requirement to monitor the conditions within an IVC system to ensure that temperatures are appropriate for the destruction of pathogens associated with animal by-products** (e.g. wastes containing meat). Temperature probes are employed within the vessel to measure, record and demonstrate these temperatures.

All in-vessel composting systems need to manage and control odour from the process exhaust gases. This is typically achieved by passing exhaust air through water and/or chemical scrubbers, biofilters (e.g. layers of woodchip or similar media) or thermal or ozone oxidising units.

### 5.4.1.2 IVC technologies

Four main different in-vessel composting systems as discussed:

- **Tunnels** are large-scale rectangular vessels using forced (fan assisted) aeration. There is a high degree of flexibility in the design of tunnel composting systems, depending on budget and the level of automation required. They can be permanent concrete or steel structures, or more temporary structures with concrete push walls. They may be single or double IVC technologies ended for material loading and unloading, and may be fitted with retractable roofs to assist with moving the material. Tunnel composting may be either batch or continuous, and moving floors may be used to move the material. They can be filled manually by loading vehicles or by loading conveyors.

The waste may be aerated by various means: blowing or sucking air through a slatted floor, perforated pipe-work or special aeration channels. By adjusting the amount of cool air entering, the level of air recirculation and the rate of air flow the conditions within the process (e.g. oxygen levels and temperature) may be controlled. Moisture may be controlled by pumping leachate or water onto the composting mass through a spray bar in the roof.

- **Vertical towers** and silos operate by the material being fed into the top of the sealed vessel on a continuous basis. It is composted as it moves down through the tower. These systems may consist of several vessels each with a single compartment, or single larger vessels with several compartments. The rate at which the material moves down through the system, and therefore its residence time, is governed by the rate of removal of processed material at the bottom. Material is removed by augers or scraping arms, which creates space for material to move down the vessel under gravity.

- **Rotating drum** composting is a continuous process where material is fed into a large rotating drum. The material is agitated and aerated as it moves along the drum, allowing the composting process to proceed. Mixing, aeration and agitation is achieved by means of baffles and plates on the walls of the drum.

- **Bays & Beds** are in-building composting systems. The material is placed in long concrete-walled bays or extended beds, with aeration and mixing achieved by specialist turning machines. During the turning process, material is moved along the length of the bay in a continuous flow. The floor of the processing building may be fitted with a forced aeration system, often under negative pressure to prevent odours escaping.

The Technical Glossary, Table 20, summarises the similarities and differences between the various technology options for in-vessel composting.

#### 5.4.1.3 Bio-drying

The in-vessel composting technologies described here can be used to rapidly 'dry' the waste, usually as part of a pre-treatment process for mixed residual waste, for example in mechanical biological treatment (see Chapter 5.5). **In this 'bio-drying' technique, naturally occurring heat from biological processes evaporates moisture and dries the waste. This is supplemented by forced aeration which helps distribute the heat and oxygen throughout the materials, and therefore helps to quicken the process. Bio-drying is used to reduce the mass and partially degrade organic components of the waste.** Bio-drying makes the waste more amenable to mechanical separation and gives it a higher calorific value if used as a fuel.

**Compost and stabilised bio-waste-**The quality of the output from the composter will depend on the type of waste feedstock and the operation of the composting process. **High quality compost from green garden waste and / or food waste treatment can be used as soil improver, mulch, topsoil, turf dressing and growing medium** providing it meets the required standard.

**Stabilised bio-waste from mixed residual waste treatment (e.g. MBT) will have a much lower quality than the product from source-separated waste,** and is unlikely to be suitable for purposes other than as a soil conditioner or land remediation medium.

The compost or stabilised bio-waste must meet the required regulatory standards for application to land. All composts to be used as fertilisers must be registered with the Department of Agriculture, Forestry and Fisheries, and meet all the necessary requirements set out in the Regulations Regarding Fertilisers (GNR 732).

**Summary of biological treatment systems-** Table 21 in the Technical Glossary summarises the various biological treatment systems and their key components, as have been discussed in Chapters 4.2 (open-windrow composting), 5.3 (anaerobic digestions) and 5.4 (in-vessel composting).

## 5.4.2 In-vessel composting plant configurations

In-vessel composting is a way of accelerating the composting process, within an enclosed environment. Here, the in-vessel composting process is summarised by way of example configurations of the various technology components.

| | |
|---|---|
| **Waste streams accepted** | Putrescible / organic waste, garden / food waste collections |
| **Input capacity ranges** | 10k – 150k tonnes per annum |
| **Typical outputs** | Compost |
| **Purpose** | To recycle biodegradable waste into a compost for land application / soil improvement |
| **Indicative capital cost** | c. R 62m – R 93m for a 30kpta facility |

*Table 10: Key characteristics of in-vessel composting*

*Figure 17: Inside a tunnel method IVC facility (image courtesy of Viridor); IVC compost (image courtesy of Sita)*

A typical windrow composting process flow diagram is presented in Table 18. Each of the process stages is summarised subsequently.

## 5.4.3 Preliminary treatment / volume reduction stage

Source segregated organic wastes will often require a limited amount of treatment prior to composting. Firstly waste will be screened and any oversize items, or obvious contaminants, removed, for example tree branches or large inert materials. Following this the **waste will be either shredded or chipped to increase the surface area and reduce the average material size in order to speed up the biological composting process,** and negate the potential of blockages in the IVC machinery.

# 5.4.4 Biological treatment stage

There are four methods of treating the organic solid waste feedstock by IVC:

- In-vessel composting tunnels
- Silos or towers
- Rotating drum
- Forced agitation

They are all enclosed, either in buildings and/or specifically designed vessels (e.g. tunnels, drums, or towers). The techniques used to control the supply of oxygen required by the process are the mechanical agitation of waste (turning) and/or blowing or sucking air through the waste (forced aeration) offering differing levels of process control and automation. **The processes can either be operated on a batch or continuous basis** depending upon the technology type and supplier.

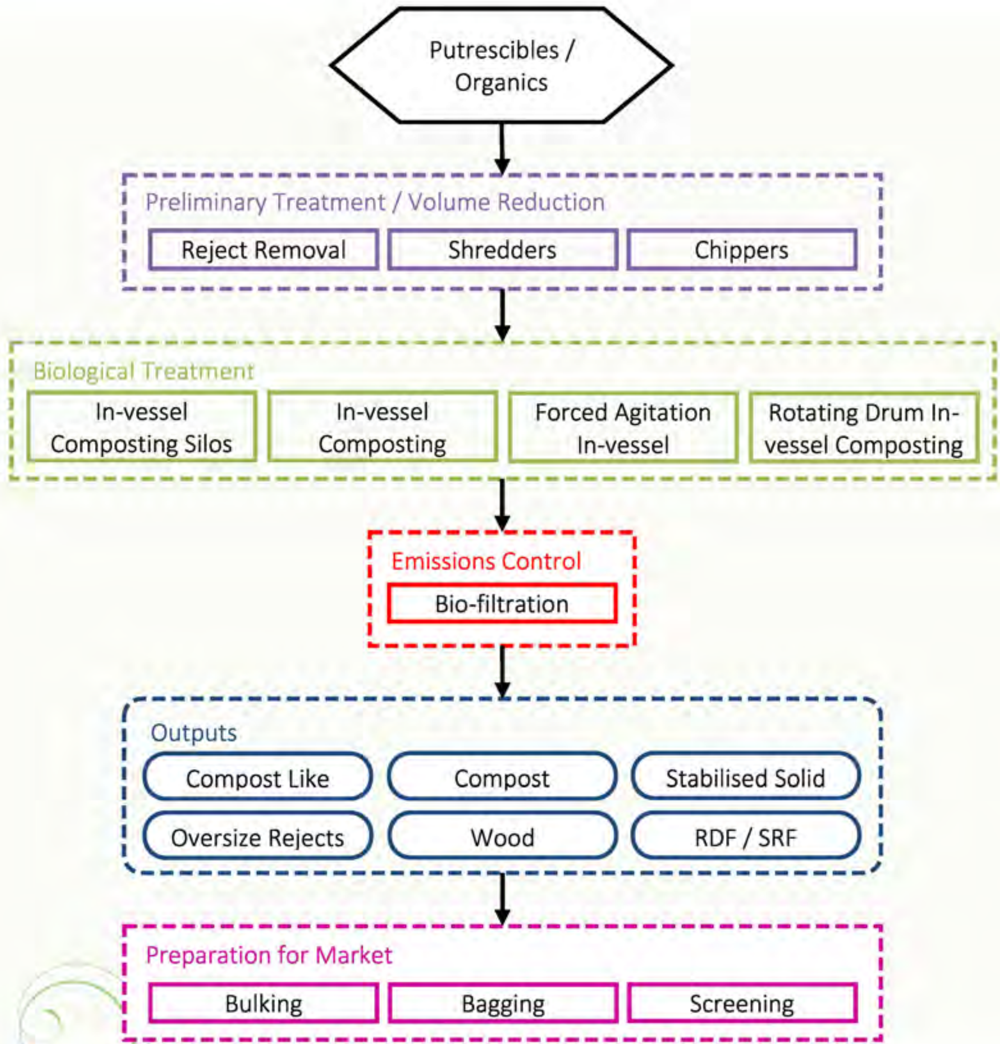


*Figure 18: Typical in-vessel composting process flow diagram*

## *5.4.5 Emissions control stage*

Odorous gases are controlled by passing exhaust air through water and/or chemical air scrubbers, bio-filters, and thermal or ozone based oxidising units. **It is common that in-vessel composting buildings operate under negative pressure** therefore eliminating the release of nuisance smells to the immediate environment and local receptors.

## *5.4.6 Process outputs*

Dependent upon the feedstock of an IVC facility the majority output will be compost, or compost like output in the case of mixed municipal wastes. The composting process will reduce the moisture content of feedstock and therefore the quantity of compost produced will be lower than the quantity of feedstock provided. The compost is suitable for use as a soil improver for horticultural and agricultural purposes, or for large scale remediation / landscaping works. Compost like output can be used for capping landfill sites or remediation where permitted. A dried output from IVC is alternatively suitable as use as a Refuse Derived Fuel (RDF) for energy recovery facilities. Rejects should be disposed of to landfill or treated in energy recovery facilities, and wood can be processed as the local market demands. IVC can be used as a pre-treatment method in some MBT applications whereby the received material is dried to reduce volume prior to mechanical sorting.

## *5.4.7 Preparation for market*

**The compost can either be bulked for mass onward transit or bagged for collection by / sale to local small scale users** depending upon the desired end use. Other process outputs can be bulked for onward mass transport. It is sometimes required that compost needs further maturation in order to produce a good quality fully decomposed product suitable for use on land. Similarly, screening may be used to remove any oversize contaminants which still remain in the product before sale / final use.

In-vessel composting is not a technology that is commonly used in South Africa. The City of Cape Town recently de-commissioned their ageing Buhler in-vessel composting facility at Radnor due to high operating and production costs and the poor quality of compost that was being produced.

## *5.4.8 Concluding comments*

In-vessel composting is a technology that may be applied to specific waste streams, for example those containing food wastes, that require a greater degree of environmental control than garden waste only systems (for which open windrow composting is more appropriate). It is a net energy user and **requires active management to ensure a good mix of materials are processed**, in order to develop and maintain good quality compost outputs.

Where biodegradable wastes are treated there is often the **potential for odour issues** that may be mitigated through the use of environmental controls such as biofilters, good site management practices or housing units within buildings under negative pressure. A variety of occupational health and safety issues can arise at IVC plants and therefore good practice methods should always be employed, including consideration of workers exposure to Bioaerosols.

# 5.5 Mechanical biological treatment

**Mechanical biological treatment (MBT) combines both mechanical and biological treatment methods** previously discussed in Chapters 4.2 (open windrow composting), 4.3 & 4.4 (materials recycling facilities), 5.3 (anaerobic digestion) and 5.4 (in-vessel composting). These will be supported by a combination of pre-treatment and sorting techniques at the front-end of the process, and a selection of emissions control and quality control techniques at the back-end of the process.

*Table 11: Key characteristics of mechanical biological treatment*

| | |
|---|---|
| **Waste streams accepted** | MSW, wet type C&I |
| **Input capacity ranges** | 50k – 500k tonnes per annum |
| **Typical outputs** | Energy, recyclate, fines, stabilised material |
| **Purpose** | To stabilise non-hazardous waste, producing useable recyclable and organic products in the process. Potential to produce energy either through AD or production of RDF |
| **Indicative capital cost** | c. R 852.5m – R 1,162.5m for a 100ktpa facility |

The mechanical and biological processes can be arranged in either order, with mechanical treatment preceding biological treatment or vice versa. Typical mechanical treatments will include a range of sorting technologies; from simple sieve / trommel separation techniques through to more advanced positive selection techniques like near infrared segregation. Biological treatment will be in the form of either anaerobic digestion or aerobic composting (bio stabilisation or bio drying).

A process flow of typical MBT arrangements in Europe is illustrated in Figure 19.

## 5.5.1 Preliminary treatment / volume reduction stage

Waste is input into the process in an untreated form. A series of processes can be undertaken to either remove waste which cannot be treated (oversized items) or to prepare waste so that it can be accepted by the mechanical and biological processes at the next stage of the MBT process. Typically, a bag splitter will be used to split bagged waste and a simple form of treatment (hammer/ball mill, crushers and/or shredders) will be utilised in order to prepare the waste into a treatable form. These pieces of equipment are described in the Technical Glossary.

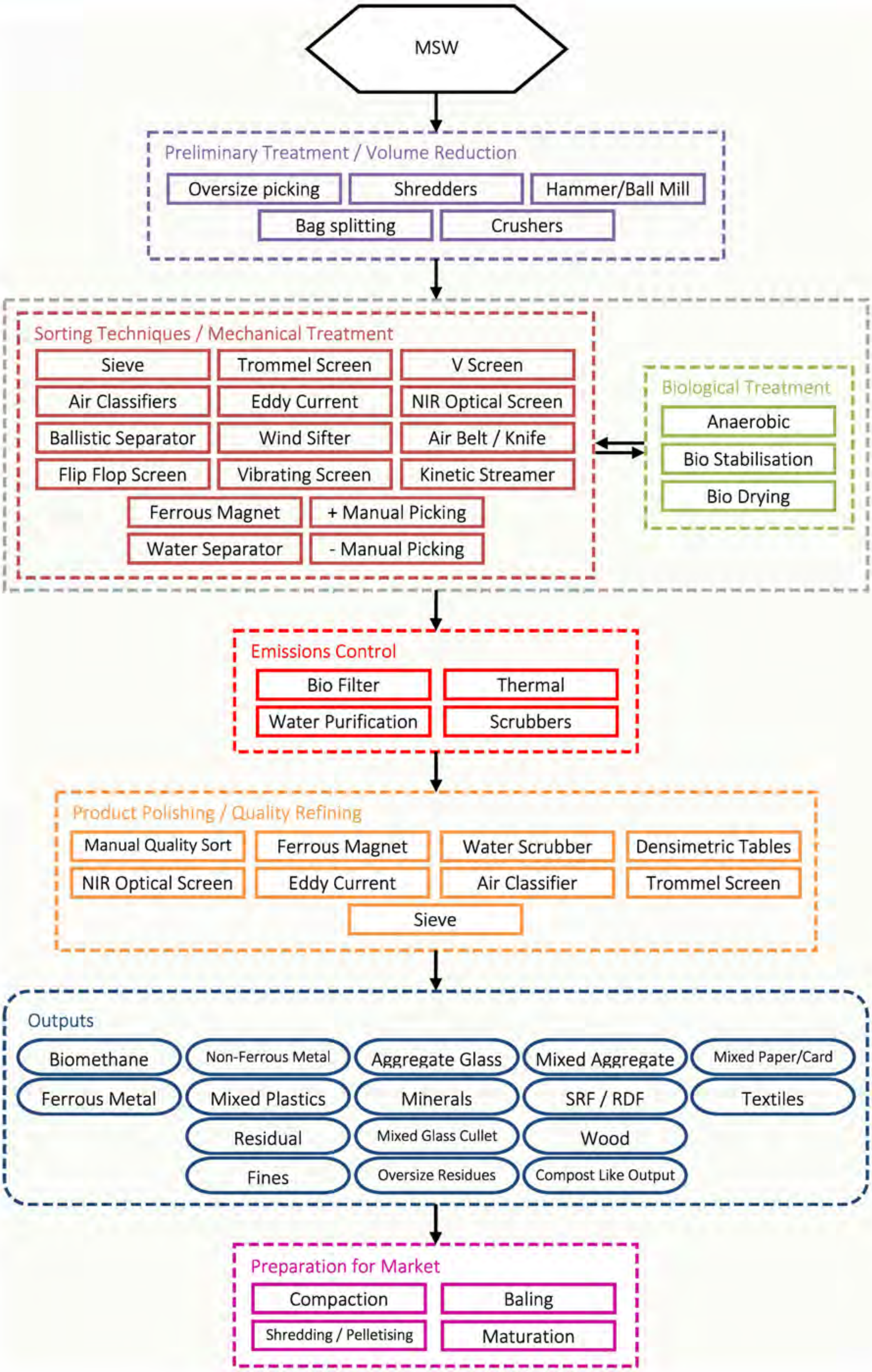


*Figure 19: Typical MBT process flow diagram*

# 5.5.2 Mechanical sorting treatment/ biological treatment stage

The second stage of an MBT process is either the mechanical treatment of waste feedstock, or the biological treatment of waste feedstock. **The order in which these treatments are undertaken will depend on the outputs intended and biological treatment chosen.** An anaerobic digestion biological treatment is likely to follow mechanical separation treatments (although an in-vessel composting option can also be used for the separated organic fraction), whereas a bio drying or bio stabilisation process may be undertaken before mechanical treatment in order to produce a more manageable feedstock for mechanical separation technologies.

### 5.5.2.1 Mechanical treatment

A variety of mechanical treatments exist suitable for an MBT process. These are designed to extract recyclable fractions from a mixed waste stream. **The qualities of materials recovered from MBT 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. However, these plants can help enhance overall recycling levels and enable recovery of certain constituent items that may not otherwise be collected in household systems (e.g. batteries, steel coat hangers, etc.). Other materials which may be extracted from MBT processes include glass, textiles, paper/card, and plastics. The most common of these is glass, which may be segregated with other inert materials such as stones and ceramics. These materials are typically segregated and arise as the 'dense' fraction from air classifiers or ballistic separation. This dense fraction could find application for use as a low grade aggregate; however this would be subject to achieving a suitable quality material. The least common / easy material to separate is paper/card. Typically, despite the use of advanced separation techniques including positive picking and near infra-red separation, **the quality of recyclate materials separated by MBT will be far lower than from segregated recyclable material waste streams.**

### 5.5.2.2 Biological treatment

Three typical biological treatments exist for the treatment of MSW in an MBT process. Anaerobic digestion will stabilise the organic fraction waste stream whilst producing biogas. The stabilised waste product (digestate) will be suitable for capping landfill and remediation works; however will not be suitable for horticultural and agricultural purposes due to the nature of the feedstocks used. If the digestate is further treated through a drying process then it will be suitable for energy recovery as an RDF. The biogas produced though the anaerobic digestion process can either be used in a CHP engine to produce electricity and/or heat, or it can be upgraded to biomethane and then either used as a vehicle fuel or distributed through a natural gas supply (as described previously). As an alternative to anaerobic digestion, for the separated organic fraction of waste feedstock, an in-vessel composting system can be used for bio stabilisation purposes.

**Bio stabilisation and bio drying are likely to precede mechanical treatment of the waste.** They are designed to stabilise the waste into a material suitable for mechanical separation technologies where nuisances and hazards are minimised. The biologically treated waste product will be passed through a series of simple or complex mechanical separation techniques and will leave a stable organic fraction which can be used as an RDF or for landfill capping and remediation works.

## 5.5.3 Emissions control stage

Following the waste treatment stage of an MBT process, with particular relevance to the biological separation element, there is a requirement of emissions control through the use of bio filters and other similar scrubbing technologies to reduce the health impacts, nuisance potential and environmental effects associated with the treatment of waste (for example from the creation of bio aerosols). MBT processes will often occur in enclosed buildings. **Applying negative air pressure to these buildings will reduce the prevalence of environmental effects on the facilities surroundings.**

*Figure 20: (clockwise from top left) Optical sorting (New Earth Solutions); bio stabilisation (New Earth Solutions); anaerobic digestion and gas storage (Viridor)*

## 5.5.4 Product refining / quality control stage

Material separated by either biological or mechanical treatment will require refining and quality assessment before it can be classed as an output. Often the separated waste streams at this stage will still be composed of several component materials, and therefore further separation will enable the production of marketable and higher value products. It is likely that the technologies used at this stage of the MBT process are more advanced capable of separating waste stream by specific polymers or precise properties. Technologies could include near infra-red and positive picking to separate paper or plastics by type (e.g. PET bottles), eddy currents to separate aluminium and magnets to separate steel.

## 5.5.5 Process outputs

**An MBT process will produce relatively low quality mixed or separated recyclable materials** (depending on the amount of separation activities undertaken to refine outputs). These materials are likely to be glass (as an aggregate), metals and plastics, however can include paper and other recyclate if extensive separation techniques are employed. Glass aggregate is more likely to find a market as a low grade aggregate, compared with glass cullet, and is unlikely to be a source of significant income and indeed the transport and delivery costs may outweigh its market value.

**Biological treatment will produce a compost like output (CLO) or digestate which can be used for landfill capping, energy recovery or remediation works.** Stabilised biowaste is generally a low value output from the treatment of mixed residual wastes that is likely to be unsuitable for uses other than as a soil improver or soil conditioner to improve the structure of the receiving soil. Typically such outputs have high levels of contamination from non-organic material, and are used for land reclamation, restoration or improvement of industrial land subject to the appropriate regulatory controls. Stabilised biowaste from the treatment of mixed residual waste is not suitable for use on agricultural land and may entail a cost rather than deliver a revenue stream for any outlets applied.

Mixed low grade papers, the 'light' fraction of the waste (e.g. plastic film) and mixed residue from the process may be segregated for use as an RDF fuel for energy recovery. If an anaerobic digestion process is used (see section 5.3) then a biogas fuel will be output which can either be used to generate energy or upgraded to biomethane.

## 5.5.6 Preparation for market

The final stage of an MBT process is preparation for market of the segregated materials. For recyclate this could involve baling and wrapping for onward transportation to reprocessor. Waste streams which are intended for RDF could be pelletised or compacted, baled, wrapped and bulked for transportation to an energy recovery facility. Organic materials, for example digestate and compost like outputs, will often require further maturation and stabilisation prior to application to land.

Mechanical biological treatment of general municipal waste has not been used in South Africa on a large-scale basis. Mechanical treatment has been used more in the area of waste recyclables recovery where the Kraaifontein Integrated Waste Management Facility (City of Cape Town) is an example of the use of bag-splitters, disc-screens, glass-breakers, flow-levellers, conveyors, bunkers, bottle-piercers, magnetic separators, compactors and balers. There are also examples of shredders, trommel-screens, hammer/ball mills, etc. being used at various waste management facilities. Similarly, there has been some limited use in South Africa of biological treatment, as described in previous chapters, but the combined use of both mechanical and biological treatment processes (MBT) has not yet been implemented by municipalities, despite strong interest being expressed in possible MBT technologies.

# 5.5.7 Concluding comments

Mechanical Biological Treatment represents **a family of technologies**, from mediocre technology to advanced technology, using anaerobic or aerobic biological treatment stages. The treatment may be used to derive recyclables or fuel (in a similar manner to Materials Recycling Facilities) but also to digest or compost the biodegradable elements for: refinement and application to certain land uses; as a pre-treatment to landfill, or; to dry the organics in order to include within the fuel fraction of the waste. Certain configurations of MBT facility also use Anaerobic Digestion technologies to derive a biogas from the organic element of the waste stream.

It is a treatment concept that is gaining in popularity as different countries grapple with the challenge of conserving resources and reducing climate change emissions. The **choice of technology employed should be influenced by the end markets available for fuel or residue from the process.** The relative pros and cons of each configuration will vary dependent on the waste stream and the technology employed within the plant however all MBT facilities are by their nature, a series of interconnected processes which can give rise to interface issues between pieces of equipment. T**he importance of seeking references and a working track record of MBT processes, on a similar waste stream to that proposed, is essential to inform decision making** in this area.

Wherever biodegradable wastes are treated there is often the **potential for odour issues** that may be mitigated through the use of environmental controls such as biofilters, good site management practices or housing units within buildings under negative pressure. A variety of occupational health and safety issues can arise at MBT plants and therefore good practice methods should always be employed, including consideration of workers exposure to bioaerosols.