

Chapter 3

ADVANCED WASTE TREATMENT TECHNOLOGY OPTIONS




3.1 Matching the technology to the waste stream

An initial action for any waste manager seeking to divert waste from landfill is to **consider the nature of the waste that is to be managed.** This will usually take the form of a variety of waste streams arising from the household or through construction activity or commerce. An initial characterisation of these wastes and estimates of tonnages, both annually and (where applicable) by seasonal variation is important because waste **treatment technology will usually be sensitive to both the nature and the amount of waste that requires treatment.**

Table 2 provides a summary of the key considerations of waste technology types, related to the waste stream that requires processing and also includes operational considerations and useful pointers to provide a reference source for waste managers.

Table 2: Overview of waste streams and suitable waste management treatment options

Waste Stream	Suitable Technologies	Description	Technology Restrictions	Signposts
Residual / Raw Waste	Dirty Materials Recycling Facility (dMRF)	A facility employing a number of separation techniques to recover recyclable materials from mixed waste, usually of a relatively low grade. The remaining residual will be processed into a fuel (refuse derived fuel, RDF) for use in energy recovery facilities.	Not suitable for hazardous materials. Will only recover a small amount (<25%) of relatively low grade recyclables.	Section 4.4 (See also 4.3.1)
	Mechanical Biological Treatment (MBT)	A facility combining mechanical separation techniques with biological treatment to either stabilise or dry the organic fraction of the waste. Mechanical separation is used to recoverrelatively low grade recyclable materials in much the same way as a dirty MRF. The organic fraction can be used as an RDF, a feedstock for anaerobic digestion (to recover biogas) or stabilised compost like output with reduced volume.	Not suitable for hazardous materials. Not suitable for bulky or large waste streams. Will only recover a small amount of relatively low grade recyclables.	Section 5.5 (See also 4.2.1, 4.3.1, 5.3.1, 5.4.1, 5.4.2)
	Mechanical Heat Treatment (MHT)	MHT facilities combine mechanical and thermal treatment techniques, often with the prime aim of extracting either relatively high quality recyclables and/or fuel fractions (refuse derived fuel) from the waste. In addition, and dependent on the technology employed, they may: reduce the volume of the waste; derive an organic fibre for use as a raw material / substitute fuel.	Not suitable for hazardous materials. Not suitable for bulky or large waste streams. Due to the nature of accepted waste, streams will only recover mid-grade and low quantities of recyclables.	Section 6.5 (See also 4.3.1)
	Incineration	The mass burning of waste to reduce volume. Modern facilities should be designed to recover energy from waste (often referred to as energy-from-waste (EfW) or waste-to-energy (WtE)) in the form of heat, electricity or heat and electricity. Metals can be extracted from the processed waste (bottom ash) ready for re-melting and preparation for new uses.	Not suitable for bulky or large items. Will destroy all non-metal recyclable materials. Energy recovery efficiencies are lower for electricity than heat. Energy recovery efficiencies are usually lower than conventional power plants and 'RDF only' thermal treatment facilities.	Section 5.2 (See also 6.5.2)

Wast Stream	Suitable Technologies	Description	Technology Restrictions	Signposts
	Landfill	The mass disposal of waste to land under controlled circumstances. Energy can be recovered from the waste through collection of gases resulting from natural decomposition of the waste.	Capture of gas from decomposition requires significant infrastructure to cover entire site. There will always be landfill gas that escapes to atmosphere and smaller quantities that are uneconomic to capture. Land intensive option with no material recovery.	Not Applicable
Commingled Dry Recycling	Clean Materials Recycling Facility (cMRF)	Mixed dry recycling is separated into fractions by a complex collection of mechanical and manual segregation techniques and conveyors. Fractions can be targeted dependent on value, with different levels of purity achievable if the end-market dictates.	Commingling of glass and paper will reduce the output quality of both materials. Mechanical technologies required for separation of materials by grade are capital intensive. Hand sorting can be used to varying degrees within the process.	Section 4.3
Segregated / Partially Segregated Recyclables	Clean MRF	Clean MRFs using advanced mechanical separation techniques can refine the quality in single waste fractions to meet specific end-user requirements and increase theeconomic value of the material. Partially segregated recycling can be separated in the same way as a commingled stream.	Mechanical technologies required for separation of materials by grade are capital intensive. Hand sorting can be used to varying degrees within the process.	Section 4.3
	Recycling reprocessor	Recycling that has been segregated by material type can be sent directly to the reprocessor if it meets their quality demands.	Requires diligent separation of materials at source and low contamination.	Not Applicable

Waste Stream	Suitable Technologies	Description	Technology Restrictions	Signposts
Refuse Derived Fuel (RDF) / Solid Recovered Fuel (SRF)	Incineration	When accepting a pre-treated residual waste (like RDF) incineration is used to burn the feedstock to reduce volume and to recover energy (electricity and/or heat) through generation of steam for use in a steam circuit. Metals can be extracted from the processed waste (bottom ash) ready for re-melting and preparation for new uses.	Incineration facilities with high energy recovery efficiencies are very capital intensive. Requires feedstock to be pre-treated (to an RDF) or a local producer of RDF. Will destroy all non-metal recyclable materials. Requires a specialist grate to handle higher temperatures generated by RDF.	Section 5.2 (See also 6.5.2)
	Co-combustion / industrial processes	RDF is used as an alternative feedstock for conventional power plants (when mixed with fossil fuels / conventional feedstocks) or as a substitute fuel for industrial facilities, e.g. cement kilns.	RDF needs processing to a high enough standard to suit the configurations of existing plant. Requires local or accessible facilities which are suitable for the waste derived fuel.	Not Applicable
	Gasification	Pre-treated waste feedstock (RDF) is treated in a reduced oxygen environment, therefore limiting the process to partial combustion and partial oxidation. The process produces a synthesis gas (syngas) which can be cleaned up as a replacement for natural gas, or combusted and used to feed a steam circuit producing electricity and/or heat. Metals can be extracted from the processed waste (ash / slag) ready for re-melting and preparation for new uses.	RDF is required to meet specifications determined by the technology chosen. Gasification systems can be capital intensive. Operational performance in Europe has been questioned (with regards to energy efficiency and emissions abatement). Will destroy all non-metal recyclable materials.	Section 6.2 (See also 6.5.2)

Waste Stream	Suitable Technologies	Description	Technology Restrictions	Signposts
	Plasma gasification	Plasma gasifiers combine the gasification technology described above with plasma torches generating very high temperatures (>1000oC). This in theory generates a cleaner syngas, enables use of gas in more efficient gas engines (after further clean up to remove sulphurs etc.), increasing the energy generation from the same quantity of feedstock.	As with gasification, however with extra expenditure required for the purchase and operation of plasma torches/arc. Plasma technology is energy intensive and will therefore drastically reduce the gross energy output of the facility; however more efficient theoretical energy recovery could improve net energy output.	Section 6.3 (See also 6.2.1, 6.2.2, 6.5.2)
	Pyrolysis	Refuse Derived Fuel (RDF) is thermally treated in an oxygen starved environment in order to facilitate the separation of waste into a char (non-combustibles, residues etc.) and syngas. Syngas from pyrolysis typically has a higher calorific value than syngas from gasification based processes, and will be fed through a steam circuit in the same way as an incineration or some gasification facilities.	Technology has a limited track record on mixed waste streams. Metals and inerts require separation before thermal treatment if they are intended for removal. Pyrolysis technology is capital intensive. Pyrolysis is energy intensive which reduces the gross energy output of plant significantly.	Section 6.4 (See also 6.2.1, 6.2.2, 6.5.2)
Mixed Organics	In-vessel composting (IVC)	Mixed organics contain food (and other potentially hazardous or nuisance materials) so require treating in-vessel. In-vessel composting decomposes the feedstock in an enclosed aerobic environment to produce compost suitable for application to agricultural or horticultural land.	Require several weeks to fully decompose and stabilise materials. Requires mechanical agitation techniques, some of which may have reliability issues.	Section 5.4 (See also 3.3.3)
	Dry anaerobic digestion	Mixed organics contain food (and other potentially hazardous or nuisance materials) so require treating in-vessel (IVC or AD). Anaerobic digestion utilises natural microbes to digestate and decompose materials in an anaerobic environment to produce biogas (suitable for use in CHP engines or clean-up for use as a replacement for natural gas) and nutrient rich digestate. The digestate can be spread to land either in its output state or after dewatering (more suitable if no immediate end user is available).	Requires low levels of contamination. Requires a high degree of monitoring and control over conditions to maintain digestion process. Can be sensitive to imbalances in feedstock (e.g. high quantities of food versus garden waste or vice versa)	Section 4.3 (See also 4.2.1)

Waste Stream	Suitable Technologies	Description	Technology Restrictions	Signposts
Garden Waste	Open composting	Garden waste generally has a lower moisture content and less potentially hazardous elements than mixed organic waste and is therefore best suited to aerobic composting processes, usually taking place in the open. Open composting follows the same biological processes as in-vessel composting; however , it is not practised in such controlled conditions and therefore requires a longer decomposition time.	Long process time (c.12 weeks) Requires low levels of contamination, or some mechanical treatment to remove contaminants. Compost turned by mechanical means. Should not be practised in close proximity to sensitive receptors (e.g. human populations) in case of odour / bioaerosol issues.	Section 4.2.1
Food Waste	Wet anaerobic digestion	Anaerobic digestion utilises natural microbes to digest and decompose food wastes (including animal products) in an anaerobic environment to produce biogas (suitable for use in CHP engines or clean-up for use as a replacement for natural gas) and nutrient rich digestate. The digestate can be spread to land either in its output state or after dewatering (more suitable if no immediate end user is available). Food waste has a higher moisture content than mixed organics and is therefore most suitable for 'wet' AD systems.	Requires low levels of contamination. Requires a high degree of monitoring and control over conditions to maintain digestion process.	Section 4.3 (See also 4.2.1)
	In-vessel composting	Food waste is suitable for in-vessel composting if either the moisture content of the food waste stream is suitable, or the food waste is blended with a co-substrate to ensure the natural digestion process occurs in optimal conditions. In-vessel composting decomposes the feedstock in an enclosed aerobic environment to produce compost suitable for application to agricultural or horticultural land.	Requires low levels of contamination, or some mechanical treatment to remove contaminants. Suitable providing moisture content is **controlled through blending of co-**substrates or use of dry feedstocks.	Section 5.4 (See also 3.3.3)

3.2 Classifying the technologies

This section covers the main advanced waste treatment options and presents them in terms of **those that are most appropriate for municipalities in South Africa.** The following groupings ( ) have been considered to provide some guidance as to which technologies are likely to be most viable in the short to long term.

Promising Technologies – short term	Technology options that are being practiced and / or under development in South Africa and those which have a strong potential for contributing to advanced integrated solid waste management in South Africa	Open Windrow Composting Clean Materials Recycling Facility Dirty Materials Recycling Facility
Potential Technologies – medium term	Technology options that have scope for successful applications in South Africa where appropriate conditions are in place. These conditions would require a technology well suited to the waste streams, one which is affordable, competitive, and represents a considered component of an advanced integrated solid waste management system.	Mechanical Biological Treatment Anaerobic Digestion Energy from Waste (Incineration) In-Vessel Composting
Potential Technologies – long term	Technologies that are unlikely to have applications in South Africa in the short to medium term, except under specific circumstances (e.g. for processing a 'difficult' waste stream) or where exceptional factors are in place (e.g. grant funding for a demonstration unit).	Gasification Pyrolysis Plasma Gasification Mechanical Heat Treatment

The consideration as to where technologies fall within this classification is based on experience, developments in South Africa, feasibility studies commissioned on specific technology types and the advice of the project steering group which includes specialist technology consultants, funding bodies and the Department of Environmental Affairs. It should be noted that this is a **generalised classification and that there will be specific circumstances that technologies described as medium term or long term become viable in the short term or are even already in evidence because of special conditions** (e.g. grant funding) or because the business case was shown as viable in a particular locality or on a particular waste stream.

The following three chapters apply this classification and give examples of the predominant configurations of advanced waste treatment. Within each option are a number of variables which can be configured to optimise treatment capacity, output type etc. depending on preferences. Some of the treatment configurations discussed are applicable to all waste streams, whereas others are more specifically inclined to a segregated waste stream, for example organics or dry recyclables, as demonstrated in the previous table.

As discussed in the previous chapter there are mechanical, thermal and biological elements to the different technologies. The configurations discussed in the following three chapters will often use an assortment of these, albeit one technology will be the predominant processing stage in a configuration.

Typically, mechanical separation methods are less time intensive and can apply relatively basic and robust techniques, and consequently are a common preliminary process stage prior to further more advanced processing. This principle, however, is not always the case, and indeed mechanical separation techniques may form the predominant technology type(s) in the configuration of some plant, for example in a clean materials recovery facility.

Each technology type is shown as a profile. These profiles will include an overview of the configuration purpose, accepted waste streams, typical capacities and a 'walkthrough' of the process stage by stage. The stages common to each configuration are colour coded as follows:

- Preliminary treatment and volume reduction stage
- Mechanical treatment / biological treatment / thermal treatment stage
- Emissions control stage
- Product polishing and quality refining stage
- Process outputs
- Preparation for market stage

Where cost and facility scale information is provided, this should be considered as an indication only of the typical scale of advanced waste treatment facilities and an indication of the range of capital costs involved. It should be noted that this information is only a guide: different technology providers will offer different solutions and the costs will depend on a variety of factors including site location, site specific issues, current market conditions and contractual arrangements. Furthermore, many of these facilities can be of a modular construction, such that there is no theoretical maximum throughput capacity. All costs are derived from examples in Europe, originally reported in either Pounds Sterling (£ GBP) or Euros (€). An exchange rate average based on 24 months (August 2012 – July 2014) has been used, leaving conversions of £1 to R 15.5 and €1 to R 12.6. These costs are indicative and should be used as a guide only.

It should also be noted that there may be an economy of scale with certain waste treatment processes. These arise from reduced capital requirements for site infrastructure, and other operational aspects such as equipment required or site specific costs such as an electricity grid connection.

On a site by site basis the capital costs will differ dependent upon a number of contributing factors. Capital costs will consist of different elements including civils costs, mechanical costs, and equipment / plant costs. Some sites will have low civils costs with high expenditure on machinery, whereas others will entail different breakdowns.