Selection of technologies and preliminary disaggregation

Contents

i. General Idea

The technological options one may choose among when he/she deals with municipal solid waste depend on whether wastes are source segregated or not.

For that reason, in order to identify the main technological options to be included in the model, the following options where identified regarding waste collection:

- Source separation of different fractions of dry recyclables (paper, glass, plastic, metals)
- Source separation of a comingled stream of dry recyclables (all the materials aforementioned in one bin)
- Source separation of food waste
- Mixed waste without source separation
- Residual waste ("rest" waste bin after source separation of dry recyclables and organics)
- Wet fraction bin ("rest" waste bin after source separation of dry recyclables but WITHOUT source separation of organics)

The concept of collecting wastes, on which the tool has been based for its development, is that the user will be able to choose among the following collection options:

1. <u>One – bin collection system</u>: a system without any source-separation of materials, where all mixed waste is collected in a single bin, called "mixed wastes bin"
2. <u>Two – bin collection system</u>: a system with source-separation of co-mingled dry recyclables (paper, plastic, metals, glass) in one bin ("rest recyclables" bin), and collection of the rest wastes in a second bin, called "wet fraction" bin"
3. <u>Three-bin collection system</u>: "rest recyclables" bin for source-separation of co-mingled dry recyclables (paper, plastic, metals, glass), "bin for organic" for source-separation of organic wastes and "Bin for Residuals" for the collection of rest wastes
4. <u>Multi-bin collection system</u>: combination of dedicated bins for source separation of paper, metal, glass and plastics and/or source separation of co-mingled dry recyclables ("rest recyclables" bin), with/without source separation of the organic fraction. Rest wastes are collected in the "Bin for Residuals" if source separation of organic wastes is selected by the user, otherwise the "wet fraction" bin is used

ii. Description of technological options

The above options, subsequently lead to technological options for the treatment of the collected streams that are described below:

Temporary Storage Facilities

Temporary Storage Facilities are used for the storage of recyclables prior to their sale to recyclers. Such facilities include minimal processing of the incoming material(s), since they receive recyclables coming from "multi-bin" collection systems (separately collected paper, plastic, glass, etc). In this sense, one can say that temporary storage facilities are MRFs (Material Recycling Facilities) of the simplest form.

The main technical components of such a facility include:

- Waste reception: usually a Reception Hall where trucks unload the materials on reinforced floor
- Waste Preparation: a front loader pushes the materials from the area where it has been unloaded into a chain conveyor. This conveyor leads materials to a hand-picking line which is a slowly moving conveyor in front of the hand-picking personnel. This hand-picking line includes a minimum number of people and is intended for the removal of unwanted material from the source separated recyclate
- Temporary Storage: At the end of the line (conveyor) the "clean" material is fed into either a storage container or into a baler press (in case pressing into bales is required, which is usual for paper and plastics). With the aid of a forklift bales are stored to the storage area
- Temporary Storage of residues prior to landfilling

Material Recovery Facilities (MRFs)

The MRF comprises a large shed or several industrial buildings in a complex, where several types of recyclable wastes ('co-mingled' - as sorted by the householder) is sorted further, bulked up into load sizes suitable for transport, made ready for collection and transportation, sold, stored, and shipped to the buyers including some of the original manufacturers. The Material Recovery Facility is made up of a series of conveyor belts and a mix of manual and automatic procedures to separate the materials and remove the items that are not needed.

According to the collection system applied, a number of recyclate fractions are comingled inside a bin. The design of the MRF aims to separate the recyclable waste in a number of fractions (in order to increase after sales price): printed paper, cardboard, mixed paper, PET, PVC, PE, PS/PP, PE film, ferrous metals, aluminium and mixed glass.

The main technical components of such a facility include:

- Waste Reception: usually a Reception Hall where trucks unload the materials on reinforced floor
- Waste Preparation: usually a bag opener
- Sorting: Combination of mechanical separation equipment (i.e. magnets, eddy current separators, trammels) and hand picking
- Temporary Storage of products prior to their sale to recyclers
- Temporary Storage of residues prior to landfilling

Composting Facilities

Composting facilities receive either source segregated organics or the organic fraction of residual waste.

Source Segregated Organics

In case a composting facility aims to treat source segregated organics, its main technical components include:

- Waste Reception: it can be a Reception Hall where trucks unload the organic material on reinforced floor, a silo, or a trench
- Waste Preparation: usually includes a bag opener and/or a shredder

- Sorting: Combination of mechanical separation equipment (i.e. magnets, eddy current separators, trammels) to remove "impurities"
- Composting Facility: Composting is the aerobic, or oxygen requiring, decomposition of organic materials by micro-organisms under controlled conditions. During composting the microorganisms consume oxygen while feeding on organic matter. This generates heat, carbon dioxide and water vapour, which are released into the atmosphere. Composting reduces both the volume and mass of the raw materials while transforming them into a composted organic material. Composting technologies come in a range of designs, categorised mainly into two categories: open systems and contained systems. All systems are designed and engineered to control and optimise the biological stabilisation, sanitisation, and/or, in some cases, drying of biodegradable materials. These processes can last anywhere from a few days to 8 or more weeks depending on the degree to which the material is to be stabilised.
- Refinement of compost to remove non-composted material and small particles (stones, glass, etc)
- Temporary Storage of compost and other products (i.e. metals) prior to their sale
- Temporary Storage of residues prior to landfilling

Organic Fraction of Mixed Waste (wastes selected in the "wet fraction" bin, or the "Bin for residuals" or the "Mixed Wastes Bin")

In case a composting facility aims to treat the organic fraction of residual or mixed waste it is combined with an extensive mechanical separation step. Such facilities are more known as Mechanical Biological Treatment facilities and are included in the model as a separate technological option (description follows later on)

Anaerobic Digestion (AD) Facilities

AD facilities receive either source segregated organics or the organic fraction of residual waste.

Source Segregated Organics

In case an AD facility aims to treat source segregated organics, its main technical components include:

- Waste Reception: it can be a Reception Hall where trucks unload the organic material on reinforced floor, a silo, or a trench
- Waste Preparation: usually includes a bag opener and/or a shredder
- Sorting: Combination of mechanical separation equipment (i.e. magnets, eddy current separators, trammels) to remove "impurities"
- Anaerobic Digestion Facility: The process of Anaerobic Digestion (AD) employs specialised bacteria to break down organic waste, converting it into biogas, a mixture of carbon dioxide and methane, and a partially stabilised wet organic mixture (digestate) in the absence of oxygen. Anaerobic digestion (AD), also known as biogas technologies, are designed and engineered to control and optimise the biological digestion of biodegradable materials to produce methane gas for energy production.

The technologies are, by their nature, enclosed, using specifically designed vertical and/or horizontal vessels, interconnecting pipe-work, mixers, macerators and pumps. AD processes last around two to three weeks depending on the ease and degree to which materials are converted into biogas and the technology used. For example, for waste containing a larger amount of woody (high lignin content) material, longer residence times will be required to achieve the desired biogas production. The material remaining consists of a wet solid or liquid suspension of non-biodegradable materials; recalcitrant organics; microbes (biomass) and microbial remains; and decomposition by-products. This partially stabilised wet mixture is known as 'digestate'. This wet mixture can be dewatered into its solid and liquid fractions. Sometimes these 2 fractions may both be referred to as 'digestate', but for clarity they will be referred to as digestate and liquor further on.

- Post Treatment of Digestate: Digestate is dewatered (usually in a screw press) and undergoes a further stabilisation step (composting).
- Refinement of compost to remove non-composted material and small particles (stones, glass, etc)
- Temporary Storage of compost and other products (i.e. metals) prior to their sale
- Temporary Storage of Biogas and Biogas Engines to produce electricity and/or heat
- Temporary Storage of residues prior to landfilling

Organic Fraction of Mixed Waste (wastes selected in the "wet fraction" bin, or the "Bin for residuals" or the "Mixed Wastes Bin")

In case an Anaerobic Digestion facility aims to treat the organic fraction of residual or mixed waste it is combined with an extensive mechanical separation step. Such facilities are more known as Mechanical Biological Treatment facilities and are included in the model as a separate technological option (description follows)

Mechanical Biological Treatment (MBT) Facilities

MBT is a generic term for an integration of several processes commonly found in other waste management technologies such as Materials Recovery Facilities (MRFs), sorting and composting or anaerobic digestion plant.

MBT plant can incorporate a number of different processes in a variety of combinations. Additionally, an MBT plant can be built for a range of purposes.

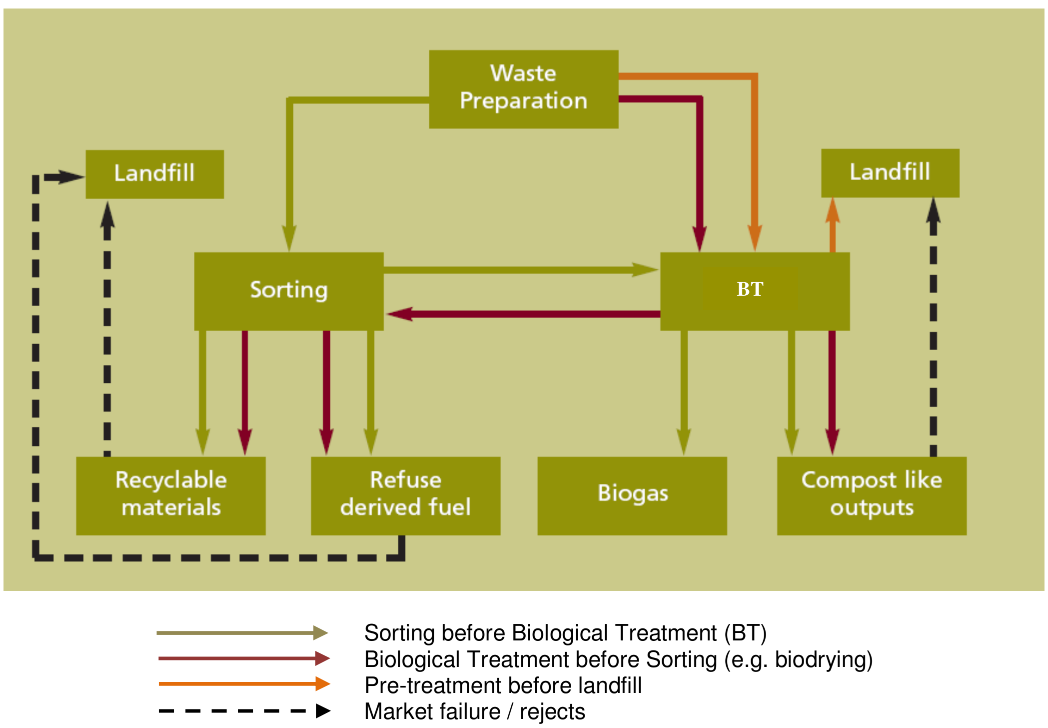
MBT is a residual waste treatment process that involves both mechanical and biological treatment processes. The first MBT plants were developed with the aim of reducing the environmental impact of landfilling residual waste. MBT therefore compliments, but does not replace, other waste management technologies such as recycling and composting as part of an integrated waste management system.

A key advantage of MBT is that it can be configured to achieve several different aims. In line with the EU Landfill Directive and recycling targets, some typical aims of MBT plants include the:

- Pre-treatment of waste going to landfill;

- Diversion of non-biodegradable and biodegradable MSW going to landfill through the mechanical sorting of MSW into materials for recycling and/or energy recovery as refuse derived fuel (RDF);
- Diversion of biodegradable MSW (BMSW) going to landfill by:
  - Reducing the dry mass of BMW prior to landfill;
  - Reducing the biodegradability of BMW prior to landfill;
- Stabilisation of the organic fraction of MSW into a compost-like output (CLO) for use on land (*Compost-like Output (CLO) is also sometimes referred to as 'stabilised biowaste' or a soil conditioner; it is not the same as a source segregated waste derived 'compost' or 'soil improver' that will contain much less contamination and has a wider range of end uses*);
- Conversion of the organic fraction of MSW into a combustible biogas for energy recovery; and/or
- Drying materials to produce a high calorific organic rich fraction for use as SRF.

The Figure below illustrates configurations for MBT and highlights the components within each.



The main technical components of an MBT Facility include:

- Waste Reception: it can be a Reception Hall where trucks unload the organic material on reinforced floor, a silo, or a trench
- Waste Preparation: Residual waste requires preparation before biological treatment or sorting of materials can be achieved. Initial waste preparation may take the form of simple removal of contrary objects, such as mattresses, carpets or other bulky wastes, which could cause problems with processing equipment downstream. Further

mechanical waste preparation techniques may be used which aim to prepare the materials for subsequent separation stages. The objective of these techniques may be to split open refuse bags, thereby liberating the materials inside; or to shred and homogenise the waste into smaller particle sizes suitable for a variety of separation processes, or subsequent biological treatment depending on the MBT process employed.

- Sorting: A common aspect of many MBT plants used for MSW management is the sorting of mixed waste into different fractions using mechanical means. As shown in the Figure above, the sorting of material may be achieved before or after biological treatment (BT). No sorting is required if the objective of the MBT process is to pre-treat all the residual MSW to produce a stabilised output for disposal to landfill. A variety of different techniques can be employed, and most MBT facilities use a series of several different techniques in combination to achieve specific end use requirements for different materials. Separation technologies exploit varying properties of the different materials in the waste. These properties include the size and shape of different objects, their density, weight, magnetism, and electrical conductivity.
- Biological Treatment (BT): The biological element of an MBT process can take place prior to or after mechanical sorting of the waste, as illustrated in the previous Figure. The biological processes used are either:
    - Aerobic Bio-drying (it is included as separate option in the model)
    - Aerobic in-vessel composting (including the elements of composting, and refinement of compost as described before)
    - Anaerobic digestion (including the elements of anaerobic digestion, energy production from biogas and post treatment of digestate as described before)
- Temporary Storage of compost and other products (i.e. metals) prior to their sale
- Temporary Storage of residues prior to landfilling

Biodrying (biological drying)

Biodrying is an option for the bioconversion reactor in mechanical–biological treatment (MBT) plants, an alternative for treating residual municipal solid waste (MSW).

As already mentioned, waste treatment plants defined as MBT integrate mechanical processing, such as size reduction and air classification, with bioconversion reactors, such as composting or anaerobic digestion.

In MSW management, the term ‘‘biodrying” denotes: (1) the bioconversion reactor within which waste is processed; (2) the physiobiochemical process, which takes place within the reactor; and (3) the MBT plants that include a biodrying reactor: ‘‘biodrying MBT”.

Typically, the biodrying reactor within MBT plants receives shredded unsorted residual MSW and produces a biodried output which undergoes extensive mechanical post-treatment. Within the biodrying bioreactor the thermal energy released during aerobic decomposition of readily degradable organic matter is combined with excess aeration to dry the waste.

This is attractive for MBT plants established to produce solid recovered fuel (SRF) as their main output, because removing the excessive moisture of the input waste facilitates mechanical processing and improves its potential for thermal recovery. A major benefit of SRF production in MBT with biodrying is the opportunity to incorporate the biogenic content of the input waste, a carbon dioxide (CO_2)-neutral, alternative energy source, into a fuel product. This produces an SRF low in CO_2 specific emission loading, mitigating the waste management contribution to climate change.

The residence time within the reactor, affects the degree of completion of biochemical and physical processes. Typical residence times are in the range of 7-15 days.

An MBT plant incorporating a biodrying reactor, is similar to the MBT facilities describe before, with a difference in the order the various process steps are implemented:

- Waste Reception (as previously described)
- Waste Preparation (as previously described)
- Biodrying
- Sorting of dried waste (as previously described)
- Temporary Storage of SRF and other products (i.e. metals) prior to their sale
- Temporary Storage of residues prior to landfilling

The fact that biodrying is applied prior to sorting, has resulted in a term often found in literature the: "BMT - Biological Mechanical Treatment facility".

In the model, the user under the term "biodrying" actually selects an MBT plant incorporating a biodrying reactor. It has been separated from the generic "MBT" term because it is a relatively new technology compared to the more "conventional" MBTs incorporating composting or anaerobic digestion.

Thermal treatment technologies

Thermal treatment technologies of mixed/residual waste and of RDF/SRF (Refuse-Derived Fuel/Solid Recovered Fuel) come in a range of designs. All systems are designed and engineered to control and optimise the incineration process and maximize the recovery of energy and heat.

The main types of incineration plants, that have been developed, are two:

- ✓ Plants that require little pretreatment of the waste (mass-fired),
- ✓ Plants operating with treated waste (SRF/RDF) as fuel.

The most known advanced thermal treatment (ATT) technologies of MSW and RDF/SRF are the followings:

- ❑ Incineration (combustion)
- ❑ Pyrolisis
- ❑ Gasification
- ❑ Plasma technologies

However the most mature and well developed waste thermal technology is incineration. According to an extensive literature review it has been evident that so far applications on waste are limited and only some factions may be used in advanced thermal treatment technologies like biomass (straw, wood chips) and RDF.

In Europe, currently some gasification plants operate on RDF/SRF but are limited in number while pyrolysis is mainly used in Japan. The application of pyrolysis for the treatment of MSW is limited in geographical scope and has not yet been fully commercially proven in Europe, but has been used at several operational plants in Japan. There currently appears to be a reticence amongst Japanese companies to transfer these technologies to the European Market.

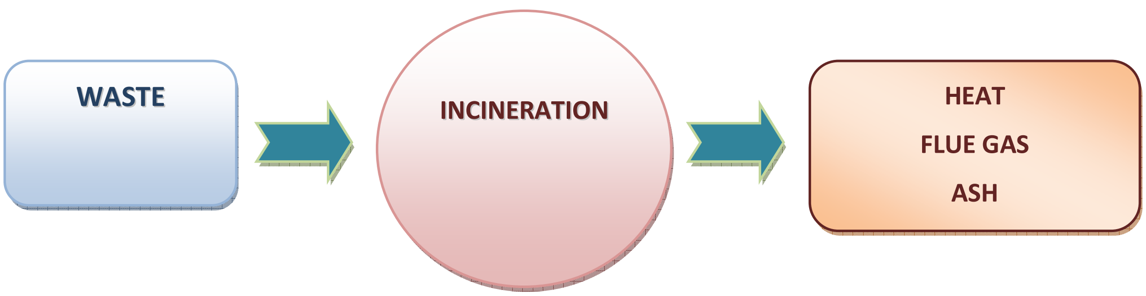
ATT is ideally suited to smaller scale applications and to the treatment of wastes which have undergone pre-treatment via MBT offering a potential alternative to incineration.

Plasma technologies have not demonstrated yet a track record in municipal waste processing.

The limited number of applications leads to scarce data regarding emissions and costs and for that reason the above-mentioned options are not included in the model.

Waste Incineration Process

Incineration of waste is essentially a rapid oxidation process of the combustible materials of the waste that generates heat and converts the waste to the gaseous products of combustion (flue gases), namely carbon dioxide and water vapour, which are released to the atmosphere. At the end of the burning process, there may be residual materials and ash that cannot burn.



The main stages of incineration process are:

1. **drying and degassing** – here, volatile content is evolved (e.g. hydrocarbons and water) at temperatures generally between 100 and 300 °C. The drying and degassing process do not require any oxidising agent and are only dependent on the supplied heat
2. **pyrolysis and gasification** - pyrolysis is the further decomposition of organic substances in the absence of an oxidising agent at approx. 250 – 700 °C. Gasification of the carbonaceous residues is the reaction of the residues with water vapour and CO_2 at temperatures, typically between 500 and 1000 °C, but can occur at temperatures up to 1600 °C. Thus, solid organic matter is transferred to the gaseous phase. In addition to the temperature, water, steam and oxygen support this reaction
3. **oxidation** - the combustible gases created in the previous stages are oxidised, depending on the selected incineration method, at flue-gas temperatures generally between 800 and 1450 °C.

There are two major incineration technologies that can be employed to burn MSW or RDF/SRF:

- ***Grate technologies***
  - ✓ Moving grate
  - ✓ Fixed grate

- ***Fluidized bed technologies***
  - ✓ Bubbling FB
  - ✓ Circulating FB

In general a Waste to Energy Incineration plant may include the following operations:

- ✓ incoming waste reception
- ✓ storage of waste and raw materials
- ✓ pretreatment of waste (where required, on-site or off-site)
- ✓ loading of waste into the process
- ✓ thermal treatment of the waste (furnace)
- ✓ energy recovery (e.g. boiler) and conversion
- ✓ flue-gas cleaning
- ✓ flue-gas cleaning residue management (from flue-gas treatment)
- ✓ flue-gas discharge
- ✓ emissions monitoring and control
- ✓ waste water control and treatment (e.g. from site drainage, flue-gas treatment, storage)
- ✓ ash/bottom ash management and treatment (arising from the combustion stage)
- ✓ solid residue discharge/disposal

Each of these stages is generally adapted in terms of design, for the type(s) of waste that are treated at the installation.