Development of a sustainable Waste Management Concept for Khanty-Mansiysk, Russia

Annex II

- Description of Waste Management Technologies -

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1 Introduction

Basically, waste management can be categorised into three process phases

(1) waste collection & transport,

(2) waste treatment and

(3) recovery & disposal.

(1) Waste collection can be implemented by a pick-up system, which means, that the waste is collected at each estate, or by a drop-off system, which means, that the citizens will bring the waste to a certain place (e.g. bring banks or recycling centres).

(2) Waste treatment means, that the waste is processed mechanically, biologically or thermal before the residues are brought to recycling facilities or to a landfill site. Waste treatment serves several purposes: reduction of landfill volume, reduction of carbon emission, reduction of human pathogens, production of recyclables and production of energy.

(3) At the third stage the waste will be recovered (recycled or converted into energy) or disposed. For recycling of materials such as metals, glass, paper, plastics etc. a functioning recycling industry has to be established.

2 Waste Collection and Transport

There are different options for the pickup of waste and respective collection arrangements. Generally, two arrangements can be distinguished,

- the pick-up arrangement/system and
- the drop-off arrangement/system.

2.1 Pick-up system / arrangement

By using the pick- up arrangement/system, residual waste from households and commercial sources (e.g. bulky waste, C&D waste) are collected in the pick-up system. In this system, receptacles or containers used for collection are placed from their storage site to the kerbside either by the waste generator or by the collection crew. The system is hence also referred to as kerbside collection. The collection vehicle then passes by each container and picks up/empties its content at the kerbside. The use of specially assigned containers simplifies the work. However, an appropriate space must be made available at each collection point. This often poses a problem in the densely built-up city area, whereas pick-up arrangements in remote places can be rather costly due to the long distances between the individual collection points.

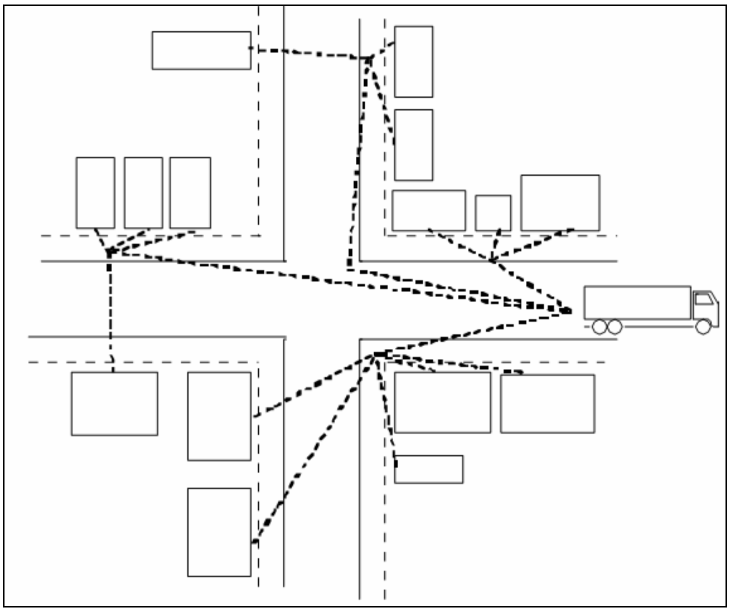

figure 1: Pick-up system / arrangement (Bilitewski 2000)

2.2 Drop-off system / arrangement

In the drop-off system, accumulated waste amounts are taken by the waste generator to a central location and are being dropped there into specially set up containers. For the most part, drop-off stations or bring bank type of waste containers are used. Collection vehicles need to go to these central sites only to pick up the waste. The containers should be emptied regularly or as needed. Collecting waste in this way is most economical in areas with a high population and particularly suitable for source separated recyclables. In order to maximise public acceptance and participation, the drop-off containers and the collection schedule must consider certain local and organisational demands, for example give respect to times of quietude, be adapted to the local environment and reach area wide coverage. Successful locations are sites with a high visibility and a high frequency of customer traffic such as near shopping centres or parking areas. Special care must be given to the regular cleansing of these sites.

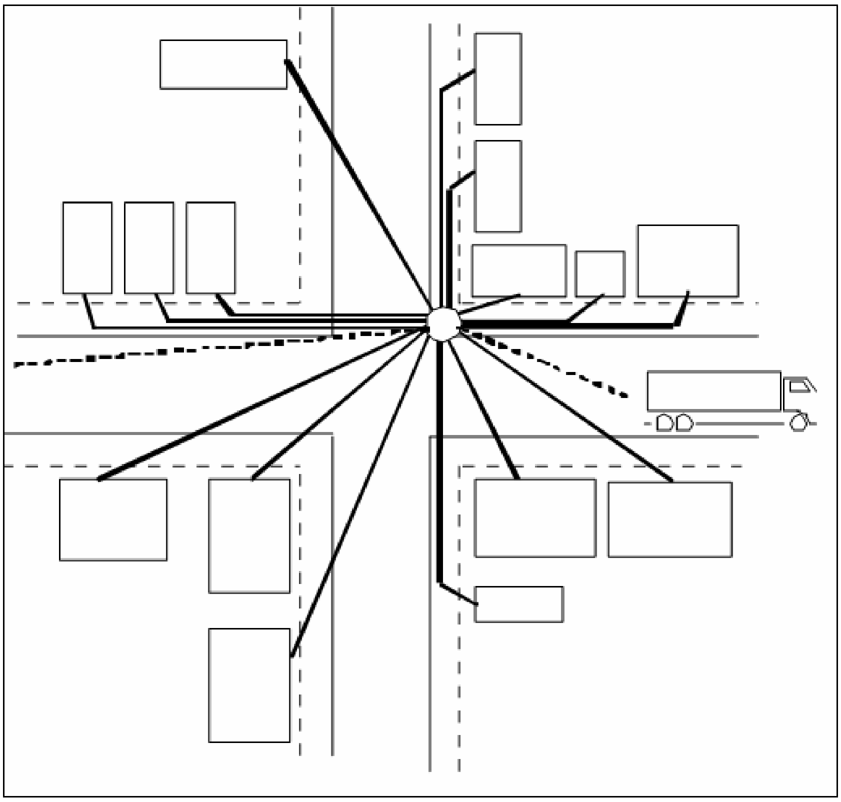

figure 2: Drop-off system / arrangement (Bilitewski 2000)

2.3 Waste transfer station

Waste transfer stations are technical facilities used for accumulating and reloading the waste from collection trucks onto larger container and long-distance transport vehicles for shipment (by road, railroad or ship transportation) to landfills or other treatment plants. By adding the loads of several individual waste collection trucks into a single shipment, municipalities can save money on the labour and operating costs of transporting the waste to a distant disposal site. The waste transfer is especially sensible, if the place of treatment, the disposal site or recycling facilities is in such distance to the collection area that the costs of waste transportation with the collection vehicles exceed those for reloading and transportation with long distance vehicles (Intecus 2004)

2.4 Collection Containers and Vehicles

For an efficient execution and management of waste collection and transport, following characteristics have to be regarded:

- size of the collection area,
- economic structure
- lifestyle,
- urbanistic conditions,
- demands of users/citizens,
- choice of a suitable collection arrangement

(Bilitewski 2000).

There are two basic kinds of container systems, without regard to the container size. The container size and material depends mainly on the waste amount, waste composition and the frequency of collection. Moreover, the type of container is dependant on the collection vehicle and the collection method.

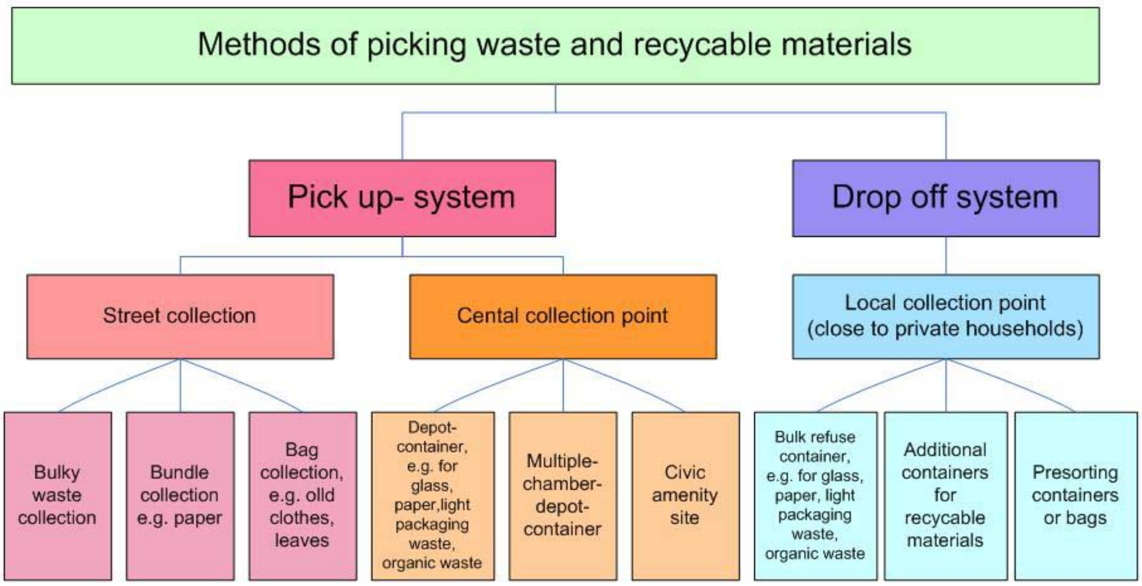

figure 3: Variation of methods of seperate waste collection (TU Berlin 2009)

2.4.1 Swap body transportation

Firstly there is the swap body transportation, where full container bodies are exchanged against empty ones. The swap is suitable for wastes with a high density, e.g. construction waste or slurry. For waste types with a low density like MSW and CSW (commercial solid waste) the swap system is only applicable at huge waste accumulation points, e.g. industrial plants, large hotels, institutions, etc. An advantage of that system is the prevention of reloading- and transportation-based emissions. Another benefit is the cost efficiency, because nowadays there is no necessity for extra reloading equipment. The Vehicles for swap collection are of quite simple construction. Because of economic reasons usually containers as of 4 m^3 are used (Bilitewski 2000).

For the swap body transportation system two types of containers are mainly relevant:

- The roll-of container (also with compressing station) and
- The skip container

figure 4: roll- off container attached to stationairy compressing station

figure 5: basic version of an roll- off container with truck

figure 6: Basic version of skip container and superstructure at the truck in tipping

figure 7:skip container with cover

2.4.2 Fixed body transportation

The second system is the fixed body transportation, whereat the full containers are discharged into the collection vehicle. This method is very common for the collection of MSW and the separate collection of recyclable materials, e.g. paper, glass, light packages and organic waste. Depending on amount of waste and the characteristics of the location, different types and sizes of containers are employed. For this kind of transport there are three main different types of fixed body vehicles, which are rear-end loaders (most common), side-loaders and front-loaders. In many of these vehicles, a waste compressor is integrated. The fixed body transportation is rather applicable in pick up systems (Intecus 2004).

figure 8: mobile garbage bins

figure 9: rear end loader

figure 10: side loader

figure 11: front loader

2.4.3 Established producers:

➢ Waste transfer station

Waste transfer stations of different arrangement and technical design are set up worldwide. They can be set up from ordinary construction firms and with equipment provided by a large spectrum of producer firms for transhipment technologies.

Germany:

Waste transfer stations exist in Germany in almost each large city or waste management association of a district, for example Bielefeld, Berlin, etc.

Austria: Salzburg

The UK: Edinburgh, Birmingham (approx. 120,000 t/a)

➢ Roll off container systems:

For the truck superstructure:

Germany:

- F.X. Meiller Fahrzeug- und Maschinenfabrik GmbH & Co KG, Untermenzinger Str. 1 D-80997 München
- Hüffermann Nutzfahrzeuge GmbH, Ahlhorner Str.89, D-27793 Wildeshausen
- PALFINGER GmbH, Feldkirchener Feld 1, D-83404 Ainring

For the container:

- Avermann Maschinenfabrik Gmbh, Lengericher Landstr.35, D-49078 Osnabrück
- F. Mannschott GmbH, Tank- u. Apparatebau, Neue Industriestr,. 8, D-74934 Reichartshausen
- Husmann Umwelttechnik GmbH, Am Bahnhof, D-26892 Dörpen
- Austria:
- Pöttinger Entsorgungstechnik GmbH & Co KG, Industriegestr. 30, A-4710 Grieskirchen
- Werner &Weber Warenhandelsgesellschaft m. b. h., A-1050 Wien, Margaretengürtel18/2

➢ Skip container systems:

For the truck superstructure:

Germany:

- F.X. Meiller Fahrzeug- und Maschinenfabrik GmbH & Co KG,
- Untermenzinger Straße 1 D-80997 München
- PALFINGER GmbH, Feldkirchener Feld 1, D-83404 Ainring

For the container:

Germany:

- Werner & Weber Deutschland GmbH, Langemarkstrasse 20, D-46045 Oberhausen
- Husmann Umwelttechnik GmbH, Am Bahnhof, D-26892 Dörpen

➢ <u>For transport systems with swap body technology:</u>

Germany

- Max Aicher GmbH & Co., Teisenbergstraße 7, D-83395 Freilassing
- AWILOG-Transport GmbH, Eichendorffstraße 1, 71739 Oberriexingen
- Palfinger Bermüller GmbH, Georg-Wimmer-Ring 25, D-85604 Zorneding – Pöring
- Cleanaway Delmenhorst GmbH & Co., Steller Str. D-36, 27755 Delmenhorst The Netherlands
- Translift Nederland B.V., Staalwijk 7 – 11, 8251 JP Dronten Switzerland
- Tuchschmid AG, Kehlhofstrasse 54, CH-8501 Frauenfeld

Producers of collection vehicles and container systems often also offer swap body systems and the corresponding vehicles.

➢ <u>Fixed body transportation systems:</u>

For the chassis:

- DaimlerChrysler AG, Epplestr. 225, D-70567 Stuttgart
- MAN Nutzfahrzeuge AG, Dachauerstr. 667, D-80995 München

For the body and lifting device:

- Haller Umweltsysteme GmbH und Co., Rigistraße 1-3, D-12277 Berlin
- Schmidt Kommunalfahrzeuge GmbH, Ortsstraße 49, D-07554 Brahmenau
- RIES Entsorgungsanlagen GmbH, Industriestraße 1, D-76297 Stutensee- Spöck
- OTTO Liftsysteme GmbH, Alter Postweg 94, D-86159 Augsburg

- Dünschede Fahrzeugbau GmbH & Co. KG, Gewerbegebiet Enste Im Schlahbruch 4, D-59872 Meschede

(Intecus 2004)

2.4.4 Cost dimension

➢ Waste transfer stations

Investment and operating costs:

The cost examples are given on the basis of the depreciation rate for investment and running costs (depreciation period of 20-25 years):

1) up to 10,000 Euro/a

2) 250,000 – 350,000 Euro/a plus the personnel costs (2 persons)

3) 300,000 – 450,000 Euro/a plus the personnel costs (4 persons)

Mass specific overall costs:

Under standard arrangements up to 15 Euro per ton (including the possibility of costs below 0.5 Euro/ton)

(Intecus 2004)

➢ Roll off container systems

Investment costs:

- 1 truck (3 axes, 20 Mg carrying capacity): 65,000- 80,000 €
- Superstructure: basic version approx. 25,000 €
- Basic version with a crane (e.g. to empty a roll- off container used as a bring back): 45,000- 48,000 €
- Container- basic version approx. 1,600- 3,500 €
- Roll- off container for collection trucks: 3,200- 5,300 €
- Price for additional items: Coverage (with a tarpaulin): 1,000 €
- Roll- off container with slots and cover: 3,500- 4,800 €

Operating costs:

- Repair and maintenance: per annum 11% of the initial investment
- Personnel: 1 person per truck (2 in maximum, depending on the operation mode, e.g. shift working)

➢ <u>Skip container system</u>

Investment costs:

- 1 truck (3 axes, 13 Mg carrying capacity): 45,000-55,000 €
- Superstructure: basic version approx. 27.000 €
- Container: basic version approx. 1,500-3,000 €

Operating costs:

- Repair and maintenance: per annum 11 % of the initial investment
- Personnel: 1 person (2 in maximum, depending on the operation mode)

➢ <u>Swap body technology:</u>

Investment:

- Swap body container: ~ 10,000 Euro
- Truck trailer combination for long-distance transportation carrying 2-3 swap bodies: ~140,000 €

Mass specific overall costs:

- depending on the employed transportation system (truck, railway, ship)

(Intecus 2004)

➢ Container System

table 1: container for waste collection from Bauer, costs and size

Bauer GmbH Eichendorffstraße 62 46354 Südlohn Germany (+49 (0) 2862 709 - 07 +49 (0) 2862 709 - 156 info@bauer-suedlohn.de (request per E-Mail am 31.01.2012; answer on 31.01.2012)	note: Bauer has business partners in St. Petersburg. The price per container is higher, but transporting is cheaper. Construction can be done on-site, instead of Germany, customs duty is also cheaper for „spare parts" than for „container"

Picture	**brief description**	**size in m^3**	**spatial needs**	**net single price ex works [€]**
	C 301 **Recycling container for recovered glass** (single chamber)	2.5	***1.7m²*** 1400 x 1180 mm	730
	C 304 **Recycling container for recovered paper**	3.0	***2m²*** 1700 x 1180 mm	730

table 2: container for waste collection from IVB Umwelttechnik, costs and size

IVB Umwelttechnik GmbH (Mrs. Wagner, Tel. und E-Mail: +49 (0) 3733 5599 – 138, pw@IVB-Umwelttechnik.eu; on 31.01.2012)
Bleiche 4; D-09456 Annaberg-Buchholz
Tel.: +49 (0) 3733 5599 -0 • Fax: -111; E-Mail: info@IVB-Umwelttechnik.com; Internet: www.IVB-Umwelttechnik.com

Picture	**brief description**	**size in m^3**	**spatial needs**	**net single price ex works [€]**
	**Recycling container for recovered paper** from zinc coated steel sheet with deposit slot	2.0	***2m^2*** 1255 x 1215 mm	480.00
		2.7	***2.1m^2*** 1690 x 1215 mm	580.00
		3.0	***2.3m^2*** 1870 x 1215 mm	690.00
	**Recycling container for recovered glass** from zinc coated steel sheet with noise control- classification 1 (Blauer Engel) Coloured slots for identification of the glass colour ***-two- chamber- system-***	2.0	***2m^2*** 1255 x 1215 mm	630.00
		2.7	***2.1m^2*** 1690 x 1215 mm	780
		3.0	***2.3m^2*** 1870 x 1215 mm	820/ 920 (two-chambers)

	**Refuse container** **MGB 1100 l** Made from steel with sliding lit and undercarriage (according to EN 840-3 und EN 840-6)	1.1	***1.5m²*** 1360 x 1055mm	273

table 3: container for waste collection from Schäfer, cost and size

Fritz Schäfer GmbH

SSI SCHÄFER
Fritz-Schäfer-Strasse 20
D-57290 Neunkirchen / Siegerland
Tel.:02735/70-1
Fax:02735/70-396
eMail:info@ssi-schaefer.de

Picture	brief description	size in m^3	spatial needs	net single price ex works [€]
	**Recycling container for recovered glass**	3.2	***1.8m²*** 1500 x 1200 mm	1.180
	**Recycling container for recovered glass**	3.2	***1.8m²*** 1500 x 1200 mm	1.460
	**Refuse container** **MGB 1100 l**	1.1	***1.1m²*** 1370 x 820 mm	485

➢ <u>Fixed body transportation systems:</u>

Rear end loader:

Investment costs:

- 1 truck (3 axles, 20 Mg carrying capacity): 60,000-80,000 €
- Body: 30,000-40,000 €
- Lifting device: 10,000-20,000 €
- Price for additional items: Low entry cabin: 10,000 €
- Vehicle superstructure for exchangeable body: 20,000 €
- Swap body: 3,000-5,000 €

Operating costs:

- Repair and maintenance: ~11 % of the initial investment per annum
- Personnel: 2-6 persons (most common is a crew of 2-3 staff depending on the mode of operation)

Front loader:

Investment:

- 1 truck (3 axles, 20 Mg carrying capacity): 60,000-80,000 €
- fixed body, hopper and lifter device: 60,000-80,000 €
- exchangeable body, hopper and lifter device: 70.000-90.000 €

Operating costs:

- Repair and maintenance: ~11 % of the initial investment per annum
- Personnel: 1-(2) persons (most common is a crew of one person depending on the mode of operation)

Side loader:

Investment costs:

- 1 truck (3 axles, 20 Mg carrying capacity): 60,000-80,000 €
- body, hopper and lifter; manually operated: 30,000-60,000 €
    - exchangeable body, hopper and automated lifter: 50.000-100.000 €
    - Price for additional items:
    - Low entry cabin: 10,000 €

- Vehicle superstructure for exchangeable body: 20,000 €
- Swap body: 3,000-5,000 €

Operating costs:

- Repair and maintenance: ~11 % of the initial investment per annum
- Personnel: 1-2 persons (most common is a crew of one person depending on the mode of operation)

(Intecus 2004)

3 Treatment/disposal methods

3.1 Landfilling

Landfilling is the most established and prevalent method of waste disposal. However it is continually being replaced by more sophisticated and efficient treatment processes.

The requirements of the location of a landfill depend on the type of waste that is to be landfilled. A suitable site with certain geological and hydrological conditions has to be chosen:

- an underground that should have a maximum permeability of 10^{-6} cm/s in an undisturbed state (underground protection),
- adequate distance to the groundwater table and
- a basis with a sealing and drainage layer reliant on type of waste.

Aftercare measures need to be undertaken as long as a potential endangerment still exists. It includes first of all securing the area, regular inspections (in annual and six months-intervals) and monitoring of the wells and other control systems. Emissions from a landfill are mainly leachate and landfill gas.

For the deposition of municipal solid waste a sanitary landfill is needed and should undergo pre-treatment, in order to minimize emissions (Intecus 2004).

3.1.1 Inert landfill-site

An inert landfill can be applied for quiet homogenous material which pose no potential danger for the environment, such as mineral matter or inert materials. Inert waste is e.g. construction waste excluding hazardous wastes, plastic materials or glass. Inert landfills are less demanding with regard to their location, the need for aftercare and costs. For these types of landfills a basis with a mineral sealing and a drainage layer are sufficient (Intecus 2004).

Aftercare demands for an inert landfill are:

- The landfill area should be enclosed by a fence,
- regular inspections and monitoring shall be undertaken.

The spatial needs depend from the planned capacity of the facility and the profile of the deposit area. Generally, higher space consumption must be assumed for depositing the same amount of waste in a flat area than using an excavated site, valley or abandoned quarry for landfilling. Depending on the overall size and the daily input, the actually operated deposit area should not exceed 2,000 m² for a small to medium sized landfill and 8,000 m² for large landfills. As an exemplary figure a deposit area of 42,000 m² and a total operation area of 55,000 m² is given for a landfill with a capacity of 340,000 m³ and about 30,000 t annual receipt deposited 15 m in height. For the total landfill capacity of 2 million m³, a space consumption of 240,000 m² is estimated. To operate a landfill site, space required for supply networks (fresh water, electric power), road connections, railroad or waterways and for leachate catchment, groundwater control and green belts must also be considered. Non-actively operated parts/completed cells must be properly covered.

3.1.2 Sanitary landfill-site

A sanitary landfill is an engineered area for a final, but environmentally friendly disposal of non-hazardous solid waste. The optimal size of the area and facilities depends on waste amount disposed on of the landfill and local circumstances.

For avoiding risks of public health, waste disposal safety and ecological problems such as contamination of surface or groundwater resources or uncontrolled emissions of gases, the landfill is to be equipped with a full leachate collection and treatment, landfill gas collection and utilisation as well as appropriate landfill surface and base sealing system. Furthermore, the waste is to be spread in layers and covered with inert material at the end of each operating day.

An operation of a sanitary landfill has an economic advantage in comparison to more expensive treatment options. For amortization of the investment for the construction and closure of the landfill, an operation time between 15-20 years is imperative.

The unpredictable behaviour of the deposit requires a long permanent control at least 20-30 years after closure of the landfill and aftercare about 80-100 years after closure of the landfill.

The spatial needs depend from the planned capacity of the facility. For a deposit area with 110,000 m³ annual receipt of waste and 20 years time of operations a space of approximately 200,000 m² is needed Further space is required for:

- installations for fresh water and power supply
- road connection, optional also to access railroad or navigable waterways.

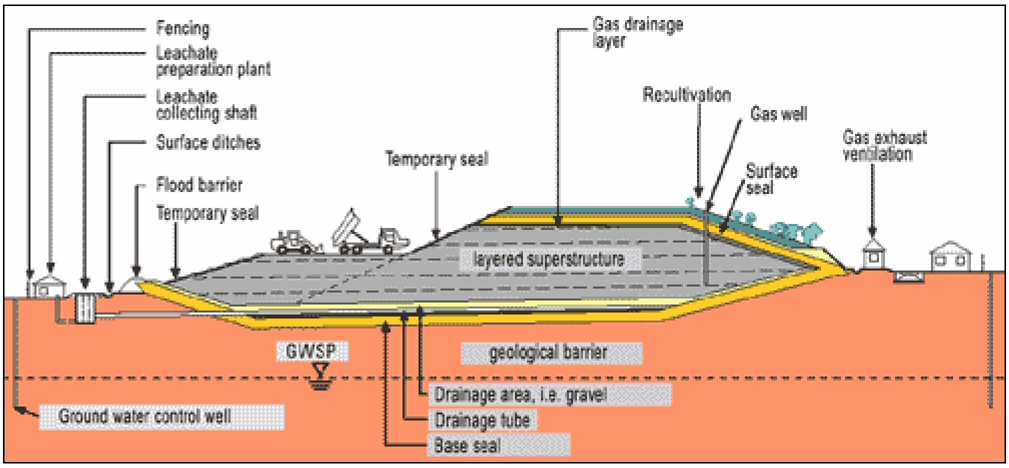

figure 12: typical sanitary landfill (http://www.eko-urba.com)

3.1.3 Hazardous waste landfill-site

A hazardous waste landfill needs to be executed for waste types of potential environmental risk that cannot be treated. Such wastes are e.g. contaminated industrial materials (ashes, sludge, etc.), waste oil, old paint and lacquer or organic waste. They can be constructed as temporary dumps or long-lasting storage places. The construction of a hazardous landfill is more complex in order to protect the adjacent environment from harmful emissions.

Aftercare measures must principally be undertaken as long as a potential danger still exists. Aftercare comprises first of all safeguarding of the area, regular inspections and monitoring of the wells and other control facilities. Under normal circumstances the expenses for aftercare should reach a steady state at relatively low level after about 80-100 years after closure, depending on the deposited material. (Intecus 2004).

The requirements on the barrier system for hazardous landfills are:

- a geological barrier of min. 5 m with a permeability of 10^{-9} m/s or lower
- a base liner system, including a double sealing and a ground drainage
- a surface sealing system with a gas collection system, a double sealing, a seal control system, a drainage and a reclamation layer

(Deponieverordnung 2009)

The spatial needs depend from the planned capacity of the facility.

Also needed are:

- Fresh water supply
- Power supply
- Connection to road, optional also railroad or waterway network

(Intecus 2004)

3.1.4 Cost dimensions and market information

- Inert Landfill

Investment:

- acquisition and preparation of the area,
- construction: The construction costs should be well below that of a sanitary landfill for mixed waste
- equipment: usually wheel loader(s) and weighing at the entrance gate

Operating costs (equipment used):

♦ Running, maintenance and personnel costs are supposed to be well below that of a sanitary landfill for mixed waste, especially due to the very limited aftercare demands.

Possible proceeds:

♦ From tipping fees and possible landfill taxes

Market information

Reference facilities:

Important note: the list of firms does not constitute a complete compilation of companies active in the specified fields. Most countries in Europe do run facilities for the storage and deposition of inert waste. Also Germany has a number of these facilities, examples are:

- Norddeutsche Gesellschaft zur Ablagerung von Mineralstoffen www.norgam.de
- Schlackedeponie Offenbach der Rhein-Main Deponie GmbH
- www.rhein-main-deponie.de/offenbach.html
- Deponie Horm der Dürener Deponiegesellschaft mbH www.ddg-mbh.de

Recognized producer and provider firms:

Numerous firms in Germany do produce and/or offer specialized technical components, construction and other services for the erection of facilities for the storage and safe deposition of inert wastes. Some examples are:

Setting of mineral sealing:

- TD Umwelttechnik GmbH & Co. KG www.trisoplast.de
- Bickhardt bau AG www.bickhardt-bau.de
- Kügler & Belouschek www.kuegler-textoris.de
- Remarks and reference documents

A list of companies dealing with the construction of deposit sites and landfill areas and further information on the subject can be obtained from:

- AK GWS Arbeitskreis Grundwasserschutz e.V. www.akgws.de
- Überwachungsgemeinschaft Bauen für den Umweltschutz BU www.ueberwachungsgemeinschaft-bu.de

(Intecus 2004)

➢ Sanitary landfill

Investment costs:

(the following figures are corresponding to a facility with an annual receipt of 110,000 m³ waste material and an operating time of 20 years. The assumed price level is the one of Germany in the 90-ies.) 110,000 m³ annual receipts are estimated at:

- ♦ Construction and equipment costs incl. financing: approx. 12 mill. €
- ♦ Additional costs incur from the erection of the different sealing systems which can cost between 40-60 Euros/m².

Operating costs

- ♦ (the total annual operating costs for the given example are estimated at):
- ♦ Running costs: approx. 360,000 €
- ♦ Repair and maintenance: approx. 1.1 mill. €
- ♦ Personnel + administration: approx. 215,000 €

Possible proceeds:

- ♦ From tipping fees and possible landfill taxes

Mass specific overall costs:

The following overall estimates can be used as indicative figures of total costs

table 4: Mass specific overall costs for sanitary landfills

Annual receipt of material for deposition [m³/a]	50,000	250,000
Estimated investment [mill. Euro] for:		
Landfill allocation survey, underground expertise, permitting	2.6	8.0
Construction planning, supervision and quality assurance	77.0	133.0
Operating equipment, closure and recultivation	61.0	110.0
Monitoring equipment, leachate/gas collection and treatment	74.0	123.0

Market information:

<u>Reference facilities:</u>

Important note: the list of firms does not constitute a complete compilation of companies active in the specified fields. During the recent years a vast number of German landfills were closed because of the legal termination of the landfilling of untreated waste. Following hereafter some examples of landfills are listed which are still in operation to deposit the pre-treated waste:

- RAVON: www.ravon.de

- Abfallwirtschaftsgesellschaft des Kreises Warendorf mbH (Zentraldeponie
- Ennigerloh) www.awg-kreis-waf.de
- Deponie Pohlsche Heide: www.pohlsche-heide.de
- Zentraldeponie Cröbern Zweckverband Abfallwirtschaft Westsachsen) www.zaw-wachau.de

<u>Recognized producer and provider firms:</u>

Numerous firms in Germany do produce and/or offer specialized technical components, construction and other services for the erection and safe operation of sanitary landfill facilities. Some of them are:

Producers of plastic sealing:

- GSE Lining Technology GmbH www.gseworld.com
- Naue Fasertechnik GmbH & Co. KG www.naue.com

Setting of plastic sealing:

- G² G-quadrat Geokunststoffgesellschaft GmbH www.gquadrat.de
- NAUE Sealing GmbH & Co. KG www.nauesealing.com
- von Witzke GmbH & Co www.vonwitzke.de
- SIEBERT + KNIPSCHILD GmbH www.ibsiebert.de
- Hafemeister GeoPolymere GmbH www.hafemeister.de

Setting of mineral sealing:

- TD Umwelttechnik GmbH & Co. KG www.trisoplast.de
- Bickhardt bau AG www.bickhardt-bau.de
- Kügler & Belouschek www.kuegler-textoris.de

Collection and utilization of landfill gas:

- Haase Energietechnik AG www.haase-energietechnik.de
- LAMBDA Gesellschaft für Gastechnik mbH www.lambda.de
- Green Gas Germany GmbH www.g-a-s-energy.de

(Intecus 2004)

➢ <u>Hazardous landfill</u>

Investment costs:

(The following figures are corresponding to a facility with an annual receipt of 110,000 m³ waste material and an operating time of 20 years. The assumed price level is the one of Germany in the 90-ies.)

- Construction and equipment costs incl. financing: approx. 12mill. € (Additional costs incur from the erection of the different sealing systems which can cost between 40-60 €/m².)

Operating costs

(The total annual operating costs for the given example are estimated at):

- Running costs: approx. 360,000 €
- Repair and maintenance: approx. 1.1 mill. €
- Personnel + administration: approx. 215,000 €
- Possible proceeds From tipping fees and possible landfill taxes

Mass specific overall costs (The following overall estimates can be used as indicative figures of the total costs):

table 5: Mass specific overall costs for hazardous landfills

Annual receipt of material for deposition [m³/a]	50,000	250,000
Estimated investment [mill. Euro] for:		
Landfill allocation survey, underground expertise, permitting	2.6	8.0
Construction planning, supervision and quality assurance	77.0	133.0
Operating equipment, closure and recultivation	61.0	110.0
Monitoring equipment, leachate/gas collection and treatment	74.0	123.0

Market information

<u>Reference facilities:</u>

Important note: the list of firms does not constitute a complete compilation of companies active in the specified fields. Most countries in Europe do run facilities for the storage and safe deposition of hazardous waste. Also Germany has a number of these facilities with some examples being:

Overground deposits:

- HIM GmbH www.him.de
- GSB - Sonderabfall-Entsorgung Bayern GmbH www.gsb-mbh.de

- GBS Gesellschaft zur Beseitigung von Sonderabfällen mbH www.sad-rondeshagen.de

Subterrestrial facilities:

- K+S Entsorgung GmbH www.ks-entsorgung.com
- HABES GmbH www.gses.de/ra_habes.htm
- Grube Teutschenthal Sicherungs GmbH & Co. KG www.grube-teutschenthal.de

Recognized producer and provider firms:

Numerous firms in Germany do produce and/or offer specialized technical components, construction and other services for the erection and safe operation of facilities for the storage and safe deposition of hazardous waste. Some examples are:

Producers of plastic sealing:

- GSE Lining Technology GmbH www.gseworld.com
- Naue Fasertechnik GmbH & Co. KG www.naue.com

Setting of plastic sealing:

- G² G-quadrat Geokunststoffgesellschaft GmbH www.gquadrat.de
- NAUE Sealing GmbH & Co. KG www.nauesealing.com
- von Witzke GmbH & Co www.vonwitzke.de
- SIEBERT + KNIPSCHILD GmbH www.ibsiebert.de
- Hafemeister GeoPolymere GmbH www.hafemeister.de

Setting of mineral sealing:

- TD Umwelttechnik GmbH & Co. KG www.trisoplast.de
- Bickhardt bau AG www.bickhardt-bau.de
- Kügler & Belouschek www.kuegler-textoris.de

Collection and utilization of landfill gas:

- Haase Energietechnik AG www.haase-energietechnik.de
- LAMBDA Gesellschaft für Gastechnik mbH www.lambda.de
- Green Gas Germany GmbH www.g-a-s-energy.de

(Intecus 2004)

3.2 Thermal treatment processes

Thermal treatment processes for MSW are

- Incineration/ Co-incineration,
- Pyrolysis and
- Stabilisation by drying processes.

Usually MSW is treated thermal plants. Inert, non-combustible Materials (e.g. glass, stones, metals, etc.) are not suitable for thermal treatment methods.

There are some environmental disadvantages of thermal processes that are discussed:

- Emission of toxic pollutants into the air,
- Toxic residues for disposal in landfills and
- Waste of raw materials and hindrance of material recovery and recycling.

(Cord- Landwehr 2002)

3.2.1 Incineration and Co-incineration

Incineration is the most important thermal method of waste management by far. The main reasons for incinerating of solid waste are firstly inertisation and the degradation of organic pollutants. Inorganic pollutants, which are diffusely distributed in the MSW, are concentrated. Hence, the furnace residues act as a pollutant sink (Cord- Landwehr 2002). Moreover a reduction of waste volume and weight is reduced and the residues can be utilised as secondary products, e.g. gypsum, hydrochloric acid or road construction material. Last but not least modern incineration plants use the calorific values of the waste, which can be used for electricity generation and district heating (Bilitewski et al. 2000).

The typical units of an incineration plant are:

- Waste Bunker: stores the waste and is the part where the plant operator can pick up, sort the waste and feed the incinerator.
- Feeding Unit: pre-dries the waste and feeds the incinerator.
- Furnace with firing grate: incinerates the waste and destroys the organic component at temperatures above 800 °C; ash and metals are recovered.
- Boiler: utilizes the heat from the burning waste to superheat the water pipes.
- Energy Generation: the superheated steam is piped to a turbine generator to generate electricity.
- Flue Gas Cleaning: remove solid and gaseous pollutants from the gas before releasing through the stack

(WtERT 2010)

The spatial demands of a grate combustion plant (including flue gas cleaning) is approx. 10,000 m² for a throughput rate of 50,000 t/a and approx. 30,000 m² for a throughput rate of 200,000 t/a.

The groundwater levels should not be too high because of the depth of the bunker (Intecus 2004).

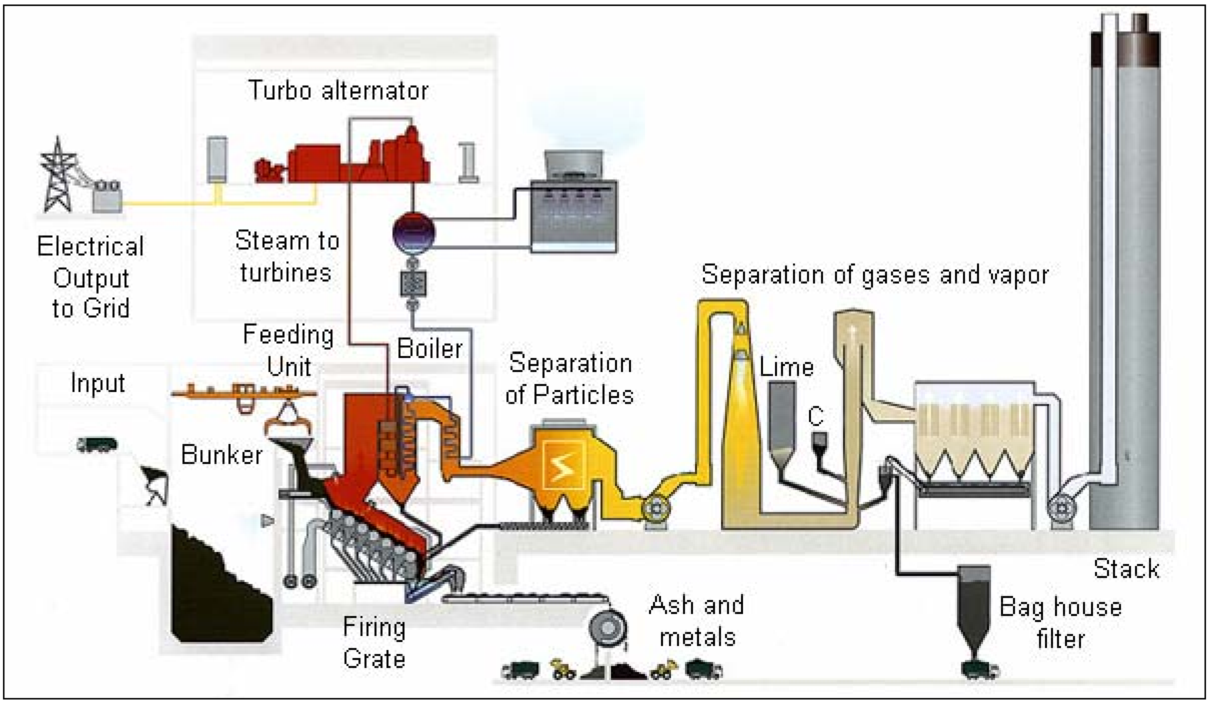

figure 13: Waste incineration plant schematic (Image: London Waste at: WtERT 2010)

In Germany there are about 70 incineration plants for MSW with a firing grate and an overall capacity of 18.829.000 Mg/a (UBA 2011). In Europe there are approximately 440 Waste to Energy plants (CEWEP 2007).

Apart from dedicated waste incinerators, where onlly waste is burn, the energetic content of MSW can also be recovered in industrial facilities, where waste acts as a substitute fuel, or in some cases as raw material, and is not the only feedstock present in the furnace. The main limitations of co-incineration result from the fact that "not every waste is appropriate for co-incineration" (IFEU 2009) and to the "possible contamination with elements that can impact the quality of the industrial products" (Bontoux, 1999).

Examples of practical co-incineration facilities include power and steam plants, cement and lime kilns, as well as steel works. In order to be able to co-incinerate waste in these industrial facilities it is necessary to detect which waste streams are able to adapt to the existing process. The potential fuel substitution capacity of waste in power plants is approximately five percent in hard coal plants and 10 percent in brown coal plants, while in cement and lime works the potential rises up to 50 percent. Particularly cement producers not only utilize waste as a substitute fuel but also as a raw material as the mineral fraction of the waste is utilized for the clinker (WtERT 2010).

3.2.2 Pyrolysis

Pyrolysis is known from process engineering. It is the thermal degradation of organic material, without an extra source of fumigation gas, e.g. oxygen, air, damp, etc. At a temperature from 150 to 900°C, volatile substances are expelled and higher hydrocarbons are decomposed. The products resulting from pyrolysis, which can be energetically used are pyrolysis coke, syngas and tar. The development of the pyrolysis process in order to be applicable for waste was undertaken to reduce the disadvantages of waste incineration. The main goals of pyrolysis are equivalent to those of incineration. The waste should be reduced significantly in weight and volume and should be dissipated in a type of material that can be landfilled without disturbing the environment considerably.

The additional advantages that were expected pyrolysis are:

- energy- and raw material generation;
- storage stability of the products;
- versatility at different waste compositions.

Because of varied problems and a low availability compared to incineration, pyrolysis as a waste treatment process could not win recognition (Bilitewski et al. 2000).

If the reuse and recycling rates of paper, plastics and biowaste streams are increased, WtE plants base on pyrolysis technologies may not be able to operate profitably (FOE 2009), as their feedstock is rich on these types of waste (dge 2009).

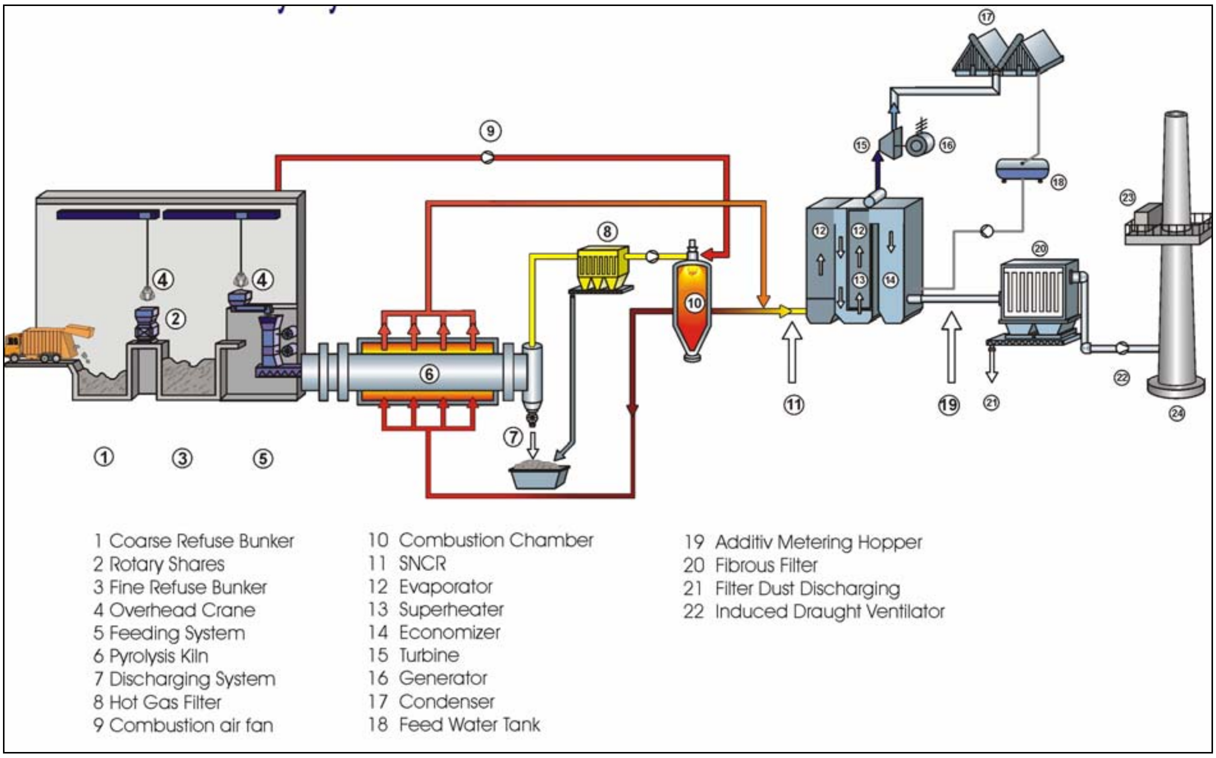

figure 14: pyrolysis plant with flue gas treatment (dge 2009)

The emissions of incineration and pyrolysis are highly polluted with inorganic contaminatnts like heavy metals. Because of that the flue gas cleaning has to be executed. The residues of the exhaust gas cleaning are significantly contaminated dusts, which have to be preferably stored in salt cavities.

3.2.3 Thermal stabilisation

Thermal stabilisation is usually used to dry sludges for later incineration. In order to produce substitute fuel for co-incineration MSW can be dried in a drying drum. The gas for drying is the exhaust of natural gas incineration. The difficulty is to avoid any potential fire outbreaks. This method is not very common, due to the fact that it is a quite complex and expensive process. In Germany, only two waste treatment plants use this technology.

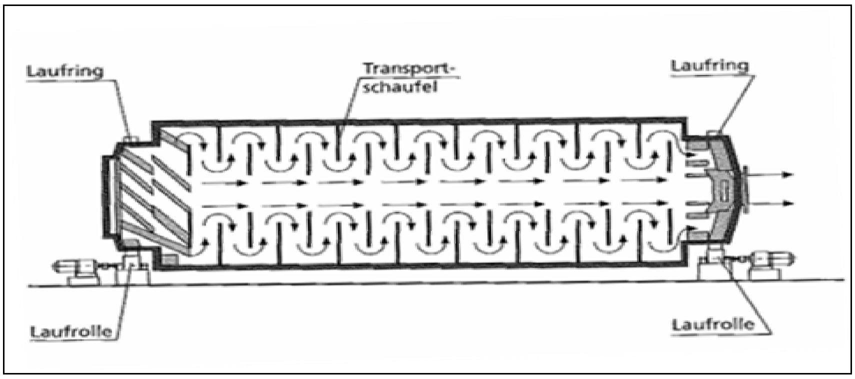

figure 15: drying drum from Vandenbroek (Kragting & Hoffmann 2002)

The drying gas is intensively mixed with the wet waste. Under a high turbulence, the volatile surface moist is evaporated fulgurous by the very hot carrier gas (Kragting & Hoffmann 2002).

figure 16: drying drum for MSW, Berlin

3.2.4 Cost dimension and market information

- <u>Grate combustion without flue gas cleaning</u>

Investment costs

Capital investment by unit to be set up (average price range): Assumption: throughput rate at 200,000 t/a; without flue gas treatment

- Site development >1,000,000 €
- Deep bunker: 4,000,000 €
- Any further structural element: 6,500,000 €
- Caldron and steam generator: 32,000,000 €
- Electric generator: 4,000,000 €
- Other constructional and capital costs: 7,000,000 €

Operating costs:

- Running costs: depending on market price for operating materials (fuel oil)
- Repair and maintenance:
  - for each structural element approx. 1% of the initial investment
  - machinery and electronic: 3 - 4% of the initial investment
- Personnel, depending on the price on the local labour market

Mass specific overall costs

- 80 to 250 €/t (incl. flue gas cleaning)

Larger plant designs, a simple flue gas treatment and better proceeds for the heat/electric energy sold may improve the cost situation, however.

Market information:

<u>Reference facilities:</u>

Important note: the enumeration of firms does not constitute a complete compilation of companies active in the specified fields. The incineration of solid waste with grate combustion techniques has a worldwide dispersion. Germany alone has more than 50 plants of that kind.

Examples:

- Magdeburg Rothensee (630,000 t/a, 4 lines) http://www.mhkw-rothensee.de
- Hamburg Borsigstraße (320,000 t/a; 2 lines) www.mvr-hh.de
- Breisgau (150,000 t/a, 1 line) www.sotec.de

Other countries, where incinerators with this type of process are operated on a large scale are: France, Switzerland, Netherlands, Austria, USA, Japan and others.

Recognized producer and provider firms:

Important note: the enumeration of firms does not constitute a complete compilation of companies active in the specified fields. Recognized producer/provider firms for grate incineration technology are for example:

- MARTIN GmbH für Umwelt- und Energietechnik, München http://www.martingmbh.de
- Fisia Babcock Environment GmbH, Gummersbach www.fisia-babcock.com
- Oschatz GmbH www.oschatz.com

Remarks and reference documents:

Further informationen and links to relevant facilities and firms can be obtained through:

- ITAD - Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland e.V. www.itad.de
- a member of the CEWEP - Confederation of European Waste-to-Energy Plants http://www.cewep.com

(Intecus 2004)

- flue gas treatment

Investment costs:

Dry and quasi-dry flue gas cleaning processes are marked by the lowest capital requirements in comparison to other options. Wet sorption processes show a larger range in their necessary investment costs. However, the investment needs for a simple wet sorption system may only slightly rise above that for a quasi-dry flue gas cleaning system.Capital investment per unit to be set up (average price range):

Example: Incineration throughput at 200,000 t/a; simple flue gas cleaning (dry)

- Construction costs: 4,500,000 €
- Equipment: 13,000,000 €
- Additional expenses, financing: 5,500,000 €

Example: Incineration throughput at 200,000 t/a; more complex flue gas cleaning (wet)

- Construction costs: 7,500,000 €
- Equipment: 20,000,000 €

- Additional expenses, financing: 5,500,000 €

Operating costs

- ♦ Running costs: depending on market price for operating materials.
- ♦ Repair and maintenance:

- for each structural element approx. 1% of the initial investment
- machinery and electronic: approx. 3 – 4% of the initial investment

Possible proceeds:

- ♦ from the sale of the flue gas gypsum (REA-gypsum)

- Pyrolysis

Investment costs:

- ♦ Investment costs (€/t input): Within the range of about 100 - 200 €/t, depending on local conditions.

Operating costs:

- ♦ Ranging of about 50 - 80 €/t, depending on local conditions and especially the cost for the disposal of the generated coke/char product.

Possible proceeds:

- ♦ Proceeds for the generated syngas (in dependence from the substituted conventional fuel)

Mass specific overall costs:

Under consideration of the proceeds made for the generated syngas within the range of about 25 - 50 €/t, depending on local conditions and costs for the disposal of the generated coke/char product

Established producers

There are more than 150 companies around the world that are marketing systems based on pyrolysis and gasification concepts for waste treatment (Source: Jupiter Inc., UK). Many of these are optimised for specific wastes or particular scales of operation and vary widely in the extent to which they are proven in operation (Intecus 2004).

3.3 Biological treatment processes

Biological methods are based upon the degradation of organic material by different microorganisms. Composting takes place with aeration, while fermentation processes are carried out under anaerobic conditions.

The aim of biological degradation of waste is either the material utilisation or the disposal of waste. The process has to be adjusted, depending on which aim the focus is. For example, if an ameliorant is requested, the composting or fermentation has to be executed with separately collected organic waste. In case of disposal, biological methods can be also used in combination with mechanical processes (cf. 3.5) (Bilitewski 2000).

3.3.1 Composting

Wastes which should be composted have to be predominantly consisting of organic material. Moreover, the composted material doesn't have to be only little contaminated. The most important waste types used for composting are:

- Organic waste from separate collection,
- Green wastes from parks and gardens,
- MSW-like commercial wastes, kitchen wastes,
- Organic residues from food product industries and
- Sewage sludge.

figure 17: green waste (UBA 2009)

figure 18: organic waste from separate collection

Because the degradation of the organic material is done by microorganisms, a balanced nutritional proportion (especially C/N-ratio) has to be available. The ph value of the material should be between 7 and 9.

Process parameters:

- Water content: 55%
- C/N ratio from 25/1 to 30/1 (Intecus 2004)
- Air- filled porosity: 25-35%
- Oxygen demand: 2 g O2/g ODM
- Aeration:

- o In closed rotting cells and aerated windrows, aeration is done by pressure and drawing systems.
- o In unaerated systems oxygen supply is achieved by diffusion, thermal, respectively by turning the windrow
- o .An under- supply of oxygen can lead to fermentation and anaerobic digestion, hence putrid smell can appear.

- ➢ Active surface: for an successful rotting a large as possible surface of the feedstock is necessary, this demands crushing before composting.

(Bilitewski 2000)

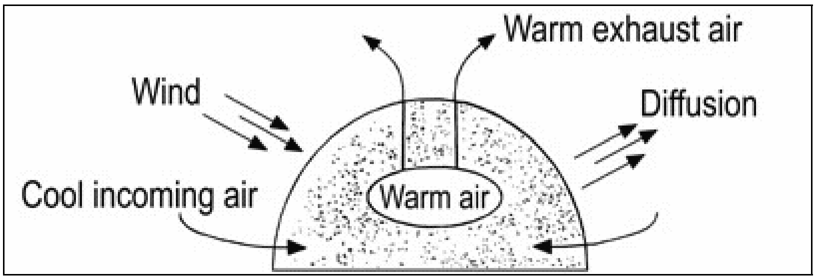

figure 19: air exchange with windrow composting (intecus 2004)

Windrow Composting needs a minimum space dependant from the planned capacity whereas the largest space demand arises from piling up the windrows. The space demand for each section can be calculated in the following manner.

- ➢ 5% receipt area
- ➢ 10 % storage area for compost
- ➢ 10 % temporary storage area
- ➢ 75 % rotting area (of which 40% are reserved for movements of equipment)

The space covered by the windrow(s) results from the windrow type, the concrete dimension (length, width, height) and the applied turning method. A triangular shaped windrow with a basis width of 3 m requires 1.40 m^2/m^3. A windrow of trapezoid shape with a basis width of 10 m and a height of 3 m requires 0.45 m^2/m^3. If the process does not require space for the movements of mobile equipment (due to the use of an self-propelled turning machine) the space requirements for triangular shaped windrows goes down to 1 m^2/m^3. Which method/windrow type will be applied is often determined in dependence of the available space (Intecus 2004).

The space needed for enclosed composting depends on the planned capacity, but is generally lower than the space needed for windrow composting.

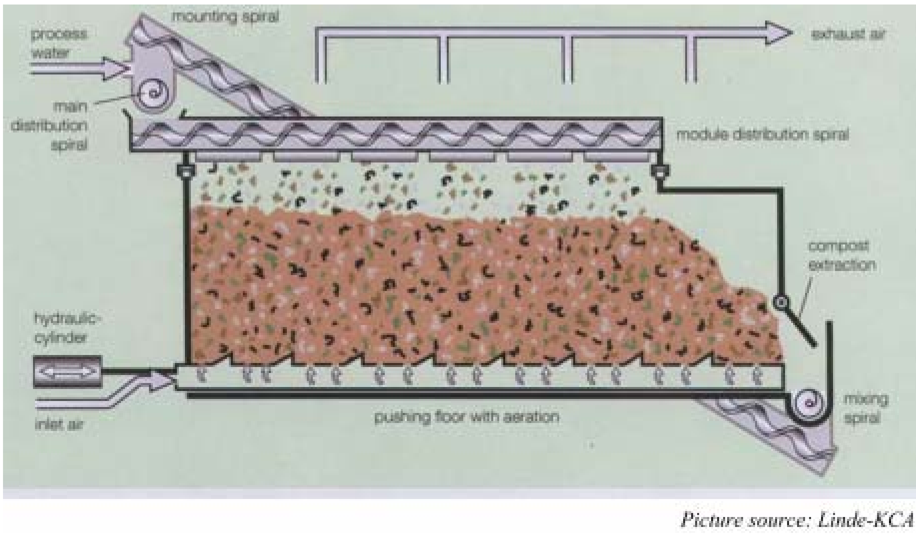

figure 20: Technical process scheme for composting in a rotting box (Intecus 2004)

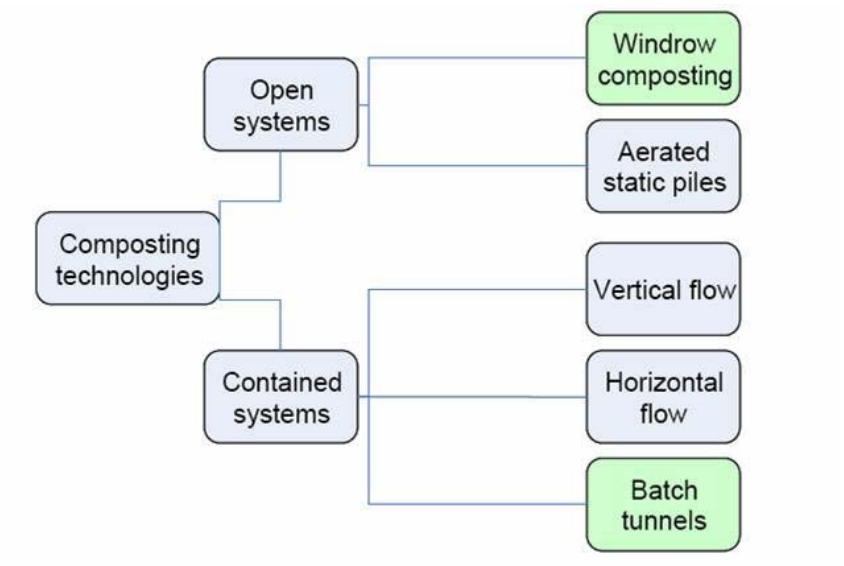

figure 21: Categorisation of composting systems (http://www.epem.gr)

figure 22: view into rotting box

figure 23: rotting hall

figure 24: turning of an open windrow

- Emissions:

The adverse effects on the environment by composting are marginal compared with other waste treatment methods. Liquid residues are leachate and highly polluted rainwater. However, the amount of liquid residues is less than the amount of an compacted landfill. Other occurring emissions are dust and odour.

3.3.2 Fermentation

Another method of biological waste treatment is fermentation. It is a treatment process for wastes with a high organic fraction. Green wastes with high lignin content are rather unsuitable. Separately collected organic waste and food leftovers are suited for fermentation. Before starting fermentation, impurities (e.g. metal, glass, stones, etc.) have to be sorted out. Afterwards the waste is usually milled or with wet fermentation a suspension is produced (Cord-Landwehr 2002)

It is basically distinguished between continuous and discontinuous fermentation processes. In the continuous operation mode, the organic waste is automatically apportioned into the digester, which supports an even biogas-production with constant quality. In the discontinuous mode, the digester is filled with a wheeled loader, emptied after some weeks and filled again. This doesn’t allow continuous biogas production, which can be compensated by parallel arrangement of time shifted-working digesters.

Discontinuous methods are utile, because of their simpler reactor system. On the other hand, continuous processes need less reactor volume and they are normally easier automatable (UBA 2009).

Fermentation takes place under anaerobic conditions. The bio-chemical process is described in figure 25 below. The hydrolysis and acidogenesis can be separated from the following strongly associated acetogenesis and methanogenesis. This allows a two-staged process.

Advantages of the fermentation are described as:

- treatment of wastes without structure and high water content,

- rapid degradation of organic wastes,
- collectability of odour emissions,
- energetic value of biogas,
- valuable residues (compost),
- energy surplus and
- simple precipitation of impurities.

(Cord-Landwehr 2002)

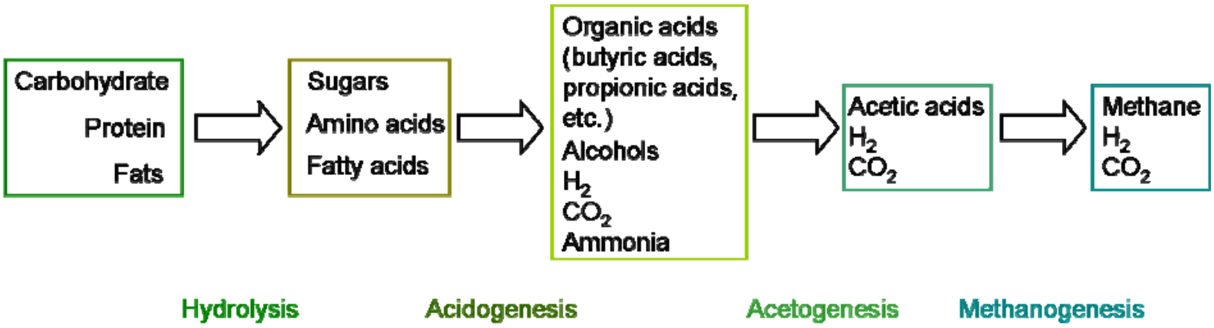

figure 25: biogas- fermentation process (http://willyyanto.wordpress.com)

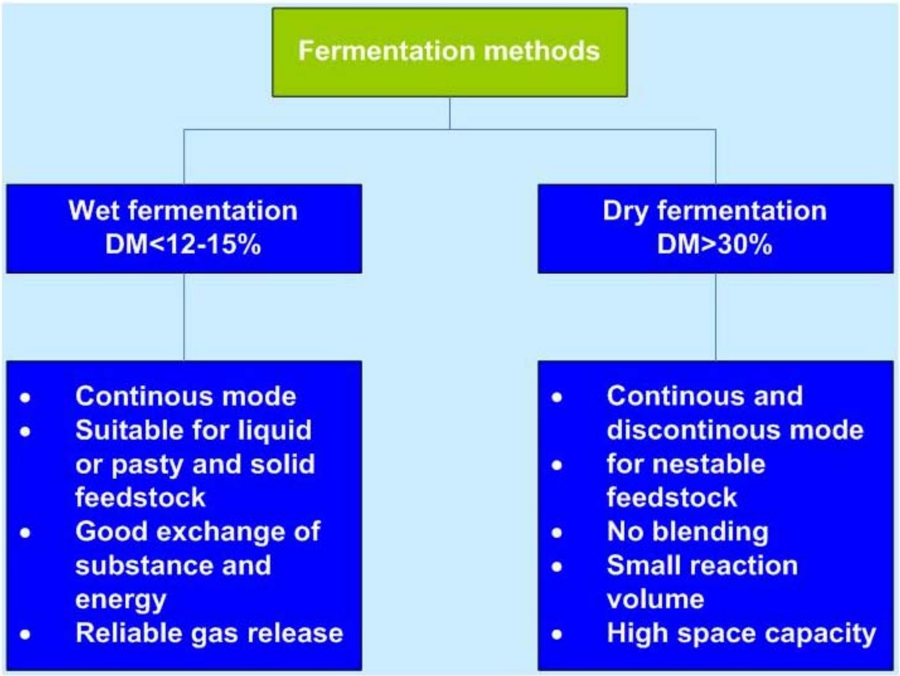

figure 26: fermentation methods

table 6: Spatial needs (m²/t input)(Intecus 2004)

Plant size	5,000 t/a	10,000 t/a	>20,000 t/a
Anaerobic digestion	0,15-0,70	0,10-0,40	0,05-0,35
Anaerobic digestion with downstream composting of residues	0,30-1,00	0,25-0,70	0,10-0,70

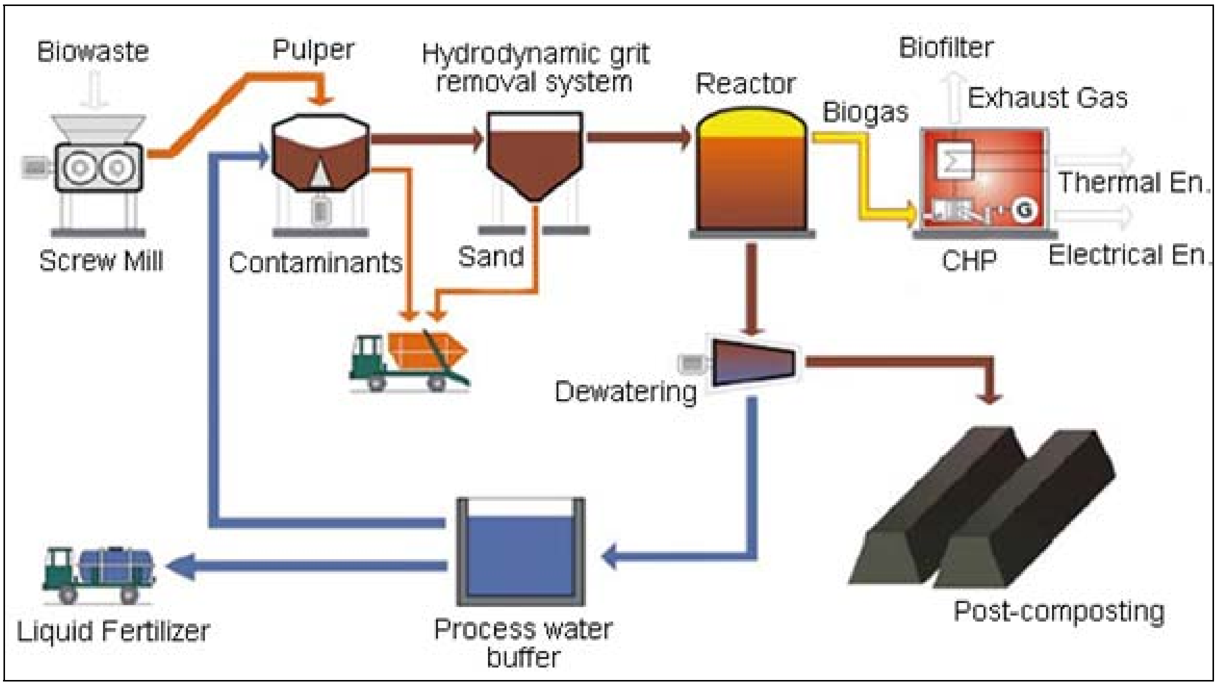

figure 27: scheme of-fermentation (WtERT 2009)

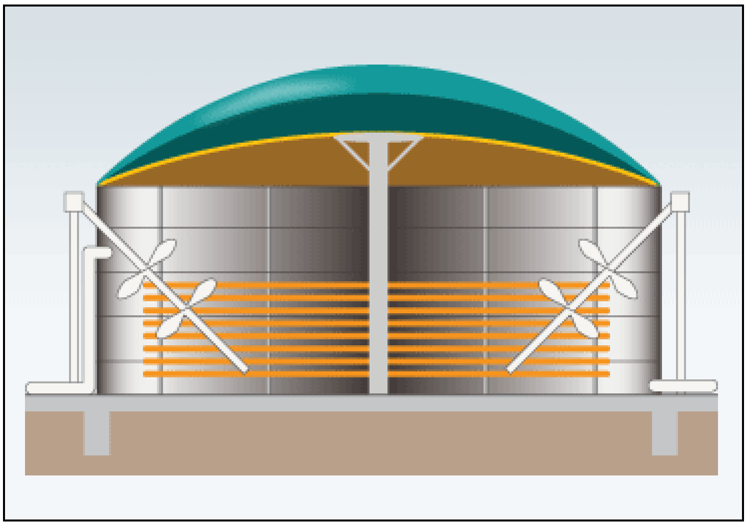

figure 28: wet digester

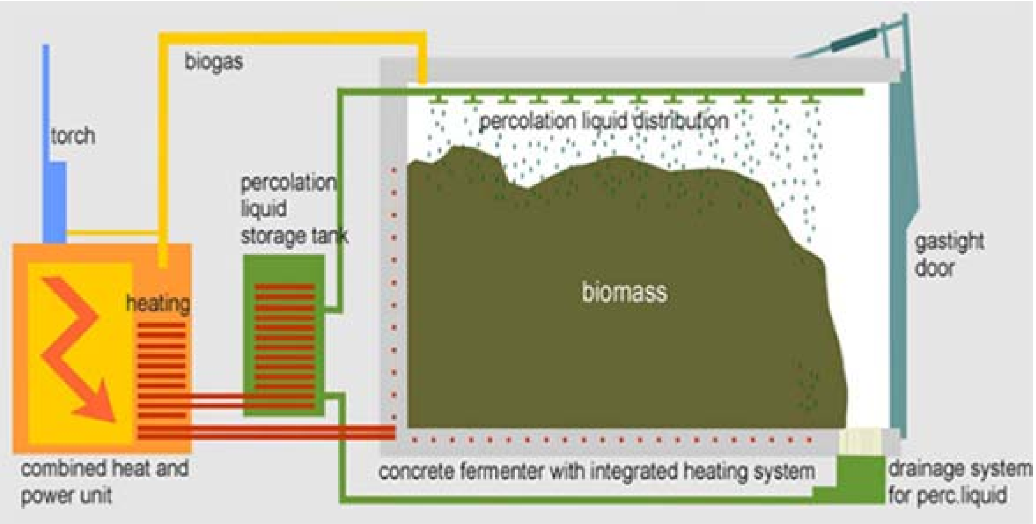

figure 29: process of dry fermentation (germanbiogas.com)

In Germany, there are several thousand fermentation plants, whereat most of them are designed as agricultural fermentation plants of manure and energy-plants.

3.3.3 Biological stabilisation

The advantage of biological drying processes compared wit thermal drying, is that there is no demand of an extra energy supply from fossil combustible material. Biological stabilisation doesn't differ basically from composting, however it rather used for MSW. The benefits of biological stabilisation are:

- Reduction of volume and weight,
- Reduction of the water content,
- Decomposition of organic material and
- Increasing the calorific value of the waste for incineration.

3.3.4 Cost dimension

- Open windrow composting

Investment costs:

The investment comprise in the main of the following positions:

- Costs for area development: depend from the local conditions and planned capacity, above all the costs for the acquisition and preparation of the area. Lower space demands reduce these costs considerably.
- Constructional elements: 70 to 90 €/t*a
    - costs to pave the surface of the rotting area may range from 20-45 €/m²;

  - costs for a simple roof atop the rotting area may range from 70-90 €/m²

- Equipment: machinery: 110 - 140 €/ t*a (with purchase price of a turning aggregate from 2,000 € up)

Operating costs:

- Daily operations (consumption of fuel/electricity, insurances etc.)
  - The minimum costs for the turning operations are 0.25 €/m³ if done with a turning aggregate hauled by a tractor; 0.40 €/m³ if done by a wheel loader
- Repair and maintenance
- for each structural element approx. 1% of the initial investment
- machinery and electronic: 3 - 4% of the initial investment
- mobile equipment (e.g. wheel loader): 8 – 15% of the initial investment
- Personnel (depending on the local labour market)

Possible proceeds:

- From the sale of the compost product

Mass specific overall costs

- In the range from 40-110 €/ t
  - Composting of biowaste from households generally results in higher costs (50-110 €/t) as compared to green waste (30-50 €/t).

Unlike in order waste treatment plants no degression in the mass specific costs can be observed with an increasing plant size. This is because expenses for constructional elements grow almost proportional with the throughput capacity in such simple installations.

Market information

<u>Reference facilities:</u>

existing everywhere in Europe and the world. In Germany more than 70% of the nearly 600 composting plants with a capacity bigger than 1,000 tons per year make use of windrow composting.

<u>Established producers:</u>

Appropriate equipment is available from various providers. Provider firms specialised in complete configurations of windrow composting technology are for example

Germany:

- BACKHUS Kompost-Technologie, Wischenstr. 26, D-26188 Edewecht
- Weser Engineering GmbH, Königstrasse 45, D-32547 Bad Oeynhausen
- B&L, Kleineschonbuschallee 69 , D-63741 Aschaffenburg

Denmark:

- Tim Environment Products A/S, Fabriksvej 13, DK-6980 Tim

Switzerland:

- Bühler AG, Industriestrasse, CH-9240 Uzwil

(Intecus 2004)

- <u>Compostingin encapsulated systems</u>

Investment costs:

Costs for area development: depend on the local conditions and planned capacity, above all the costs for the acquisition and preparation of the area. Lower space demands reduce these costs considerably.

- Constructional elements: 80 to 100 €/t*a
- Equipment: machinery: 110 - 140 €/ t*a

Operating costs:

- Daily operations (consumption of fuel/electricity, insurances etc.)
    - Repair and maintenance
- for each structural element approx. 1% of the initial investment
- machinery and electronic: 3 - 4% of the initial investment
- mobile equipment: 8 – 15% of the initial investment
    - Personnel (depending on the local labour market)

Possible proceeds:

- From the sale of the compost product

Mass specific overall costs:

- In the range from 40-110 € per ton

Market information

<u>Reference facilities:</u>

existing everywhere in Europe and the world. Of the nearly 600 composting plants in Germany with a capacity bigger than 1,000 t/a about 11% make use of box or container composting, about 5 % do tunnel and 3% drum composting.

Established producers:

Appropriate equipment is available from various providers. Provider firms specialised in complete configurations of encapsulated composting technology are for example:

Germany:

- Herhof-Umwelttechnik GmbH, Riemannstraße 1, D-35606 Solms-Niederbiel
- Linde-KCA GmbH, P.O.Box 21 03 53, D-01265 Dresden
- BACKHUS Kompost-Technologie, Wischenstr. 26, D-26188 Edewecht
- Bernh. Bruns GmbH, Industriestraße 26, D-49744 Geeste-Dalum

Austria:

- Thöni Industriebetriebe GesmbH, Obermarktstraße 48, A-6410 Telfs,

The Netherlands:

- Panbo systems bv, Schuurkenspad 7, NL-5986 PD Beringe

(Intecus 2004)

- Fermentation

Investment costs

table 7: Investment costs (EUR/t input)

Plant size	5,000 t/a	10,000 t/a	20,000 t/a	>50,000 t/a
Anaerobic digestion with downstream composting of residues (without mechanical pre-treatment)	450-950	350-650	250-550	180-250

Operating costs:

table 8: Running costs (EUR/t)

Plant rating	10,000 t/a	20,000 t/a	30,000 t/a	50,000 t/a
Anaerobic digestion with downstream composting of residues (without mechanical pre-treatment)	100-190	80-130	70-110	55-90

Possible proceeds

The overall operating costs of such plants can be covered, at least in part, by revenues from the sale of generated energy, digested sludge and/or compost. A favourable price situation can even yield a profit (Intecus 2004).

Mass specific overall costs

table 9: Mass specific overall costs including proceeds from energy production (EUR/t)

Plant size	5,000 t/a	10,000 t/a	20,000 t/a	50,000 t/a
Anaerobic digestion with downstream composting of residues and sale of energy (without mechanical pre-treatment)	90-140	75-130	50-100	45-70

Market information

Reference facilities:

Applied throughout the entire EU, biggest facilities in Germany, Spain, Austria, Belgium, Italy, France, Denmark, Netherlands (Groningen) but also used in Portugal, Sweden and the UK

Established producers

Germany:

- Linde KCA GmbH Dresden,
- Haase Energietechnik AG Neumünster,
- VALORGA Process Worblingen,
- Noell Abfall- und Energietechnik GmbH Goslar,
- Schwarting-Uhde Flensburg,
- DSD Gas- und Tankanlagenbau Berlin,

The Netherlands:

- Grontmij Water & Waste Management De Bilt

Israel:

- Arrow Ecology ltd., P.O.Box 25175, Haifa 31250

(Intecus 2004)

3.4 Mechanical treatment processes

Treating MSW mechanically is usually used for recycling processes, respectively for upgrading the waste material for further treatments.

3.4.1 Crushing

Crushing is used to produce a smaller grain size, hence a surface enlargement. The kind of crushing machine used, is dependant on:

- physical properties of the feedstock (e.g. hardness, brittleness or cleavage property),
- the intended purpose, e.g. further treatment or chemical reaction
- the requested quality of the finished material (e.g. grain size distribution)

(Bilitewski 2000).

Crushing can be done with slow- or fast- running mills. Fast- running mills are e.g. hammer mills and impact crushers. A typical slow- running mill is the edge mill, which is often used to grind MSW or separately collected organic waste (Cord-Landwehr 2002).

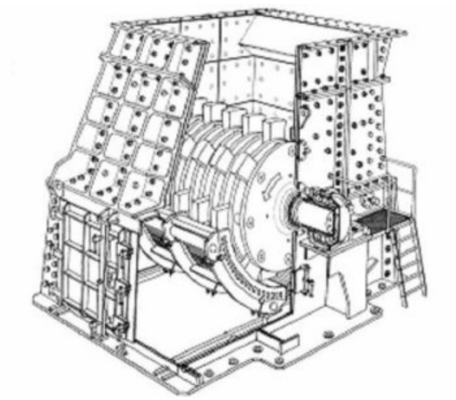

figure 30: hammermill (http://www.skf.com)

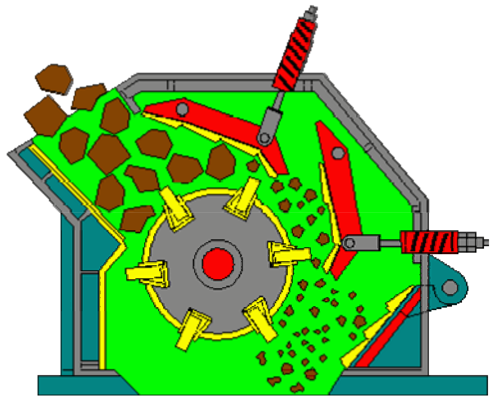

figure 31: impact crusher (www.hensen-lataster.nl)

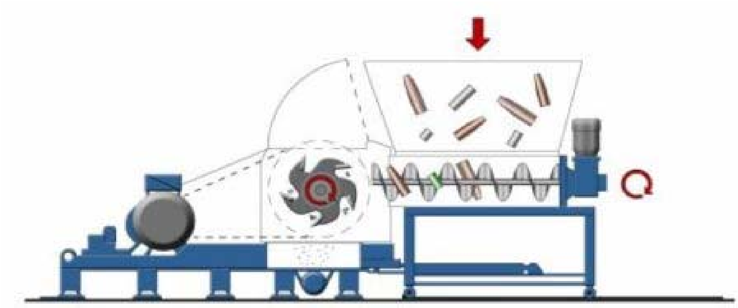

figure 32: edge mill (www.herbold.de)

3.4.2 Sorting and Screening

The most effective way of sorting in order to achieve clean and separate materials, can be done trough separate collection. In this case, the consumer already pre-sorts the waste. The following categories are common in Germany:

- Paper,
- Glass (also colour-sorted),
- Light packages (including metal and plastics),
- Organic waste
- Residual waste

MSW can be sorted in sorting plants; at times a certain sorting is necessary for further treatment (e.g. metal separation).

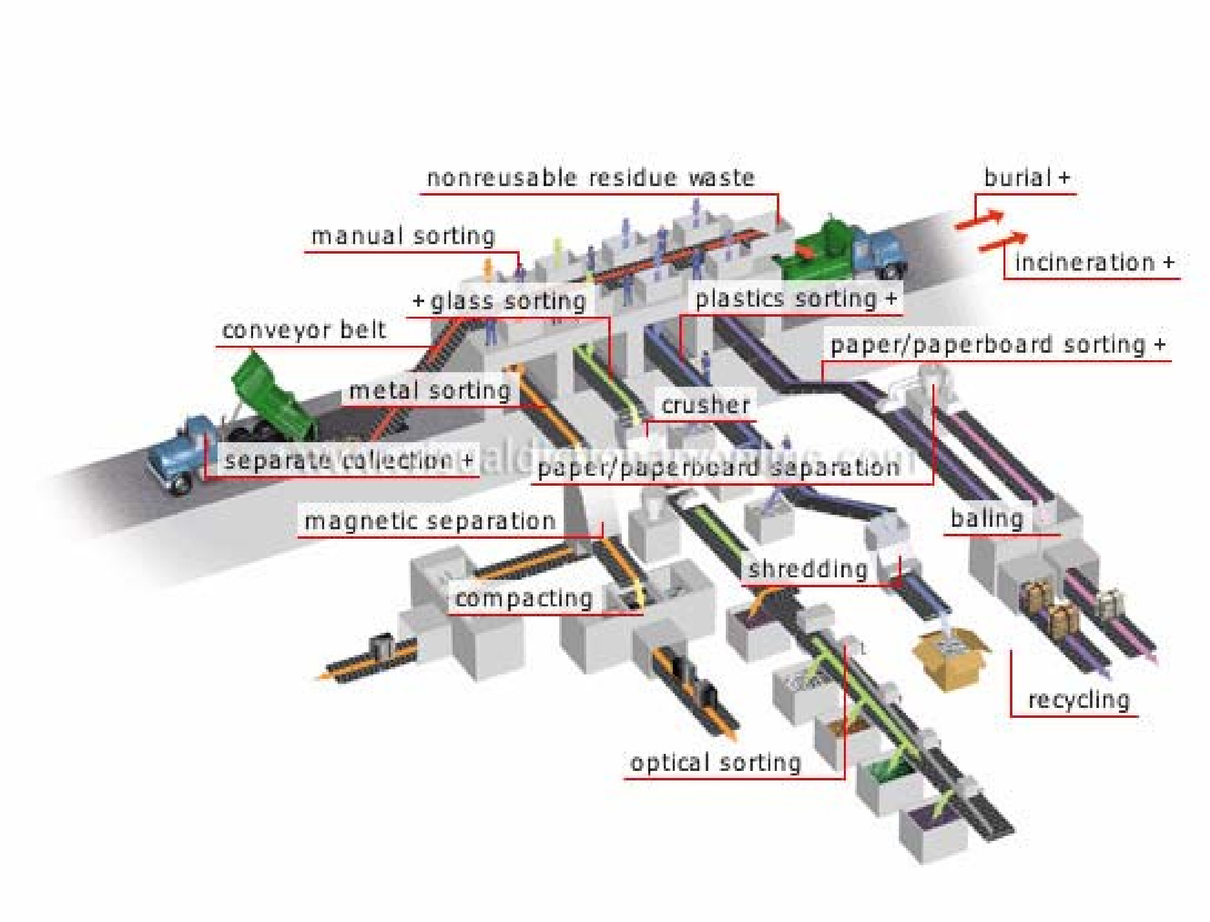

figure 33: **sorting plant (http://visual.merriam-webster.com)**

By Classification material is sorted according to their grain size. Classification can be done by:

- Sieving (separating according to the mesh size),

- air separation (separates light material, e.g. plastic sheets),
- floatation (separation in a fluid, according to density)

(Cord-Landwehr 2002)

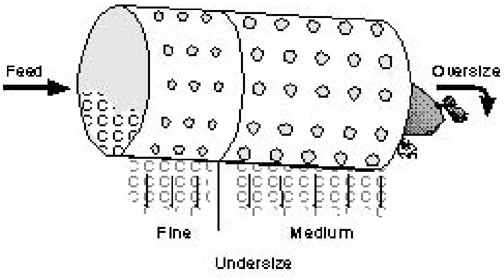

figure 34: sieve drum (compost.css.edu)

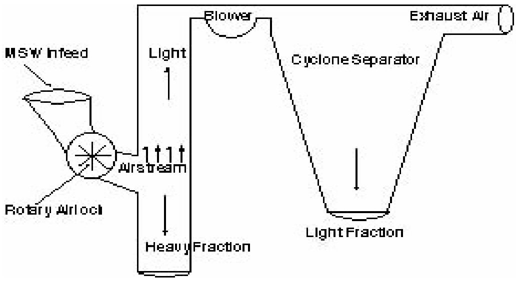

figure 35: air classification(compost.css.edu)

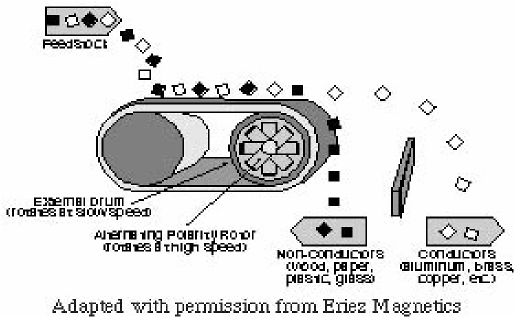

figure 36: eddy-current separator (compost.css.edu)

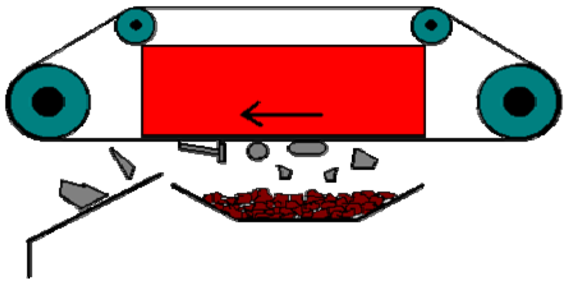

figure 37: electric overbelt magnet (www. hensen-lataster.nl)

There are basically two types of sorting: negative and positive sorting. With negative sorting, the unwanted materials are sorted out. This takes place for example by taking metals out of organic waste for composting. With positive selection the "product" is systematically picked out (Cord-Landwehr 2002).

Sorting can be done by:

- hand sorting,
- a magnet separator (separates ferrous metals),
- a eddy current separator (separates non-ferrous metals) or
- optical sorting (e.g. separates different glass-colours or different types of plastics).
- <u>Conditioning for recycling of certain materials</u>

Following conditioning methods still have to be used for the separately collected materials. The process generally contains a mechanical processing for the removal of fine matter and disturbing materials (e.g. mineral substances, small metal parts) and sorting operations. The goal of sorting material like paper, glass or plastics, is to achieve a recyclable material of a defined quality (Intecus 2004).

waste paper sorting

The basic configuration of waste paper sorting and processing is relatively simple, little capital intensive, highly flexible, quite reliable (i.e. little failure prone) and has a low energy demand. However, it is highly labour intensive and has a relatively low throughput (approx. 5 Mg/h). For an average plant, approximately 5,000 m² are needed (Intecus 2004).

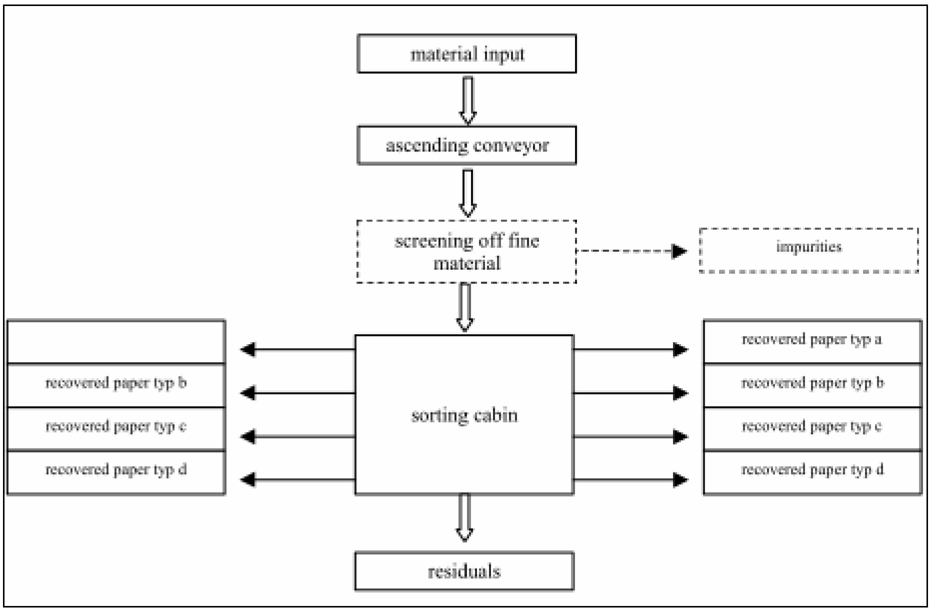

figure 38: basic configuration of waste paper processing (Intecus 2004)

waste glass sorting

The sorting of recovery glass is a largely automated process with a high throughput and an out put with a stable quality. Though, processing of waste glass is rather expensive and a large supply area is needed. The basic configuration including storing facilities demands up to 8,000 m². The throughput in a one-line arrangement about 20 Mg/h supposed to be practicable (Intecus 2004).

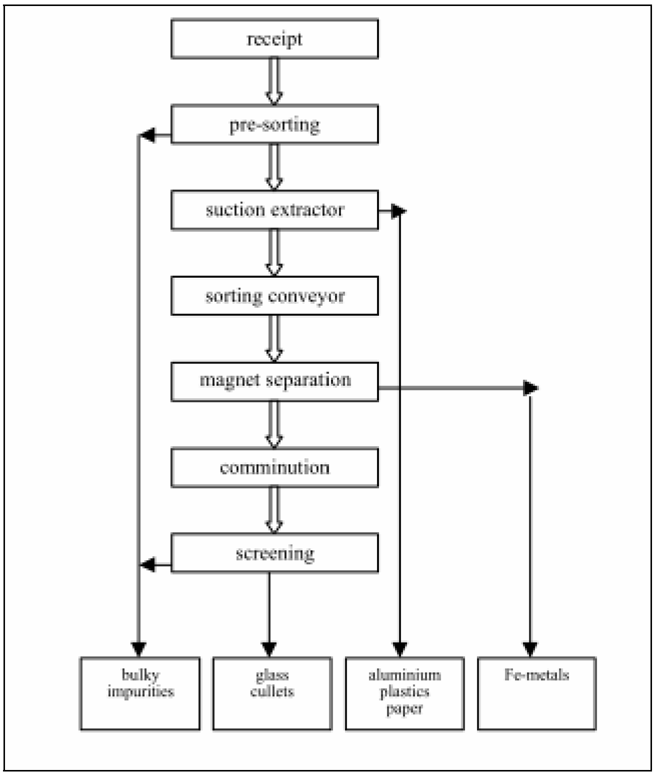

figure 39: basic configuration of waste glass processing (Intecus 2004)

sorting of packaging (plastics and metals)

A basic configuration of sorting recyclable plastics is quite cheap, flexible and reliable. However, there is a high labour demand and a relatively low capacity approx. 1Mg/h. For an sorting plant with basic configuration, about 5,000 m² are necessary (Intecus 2004).

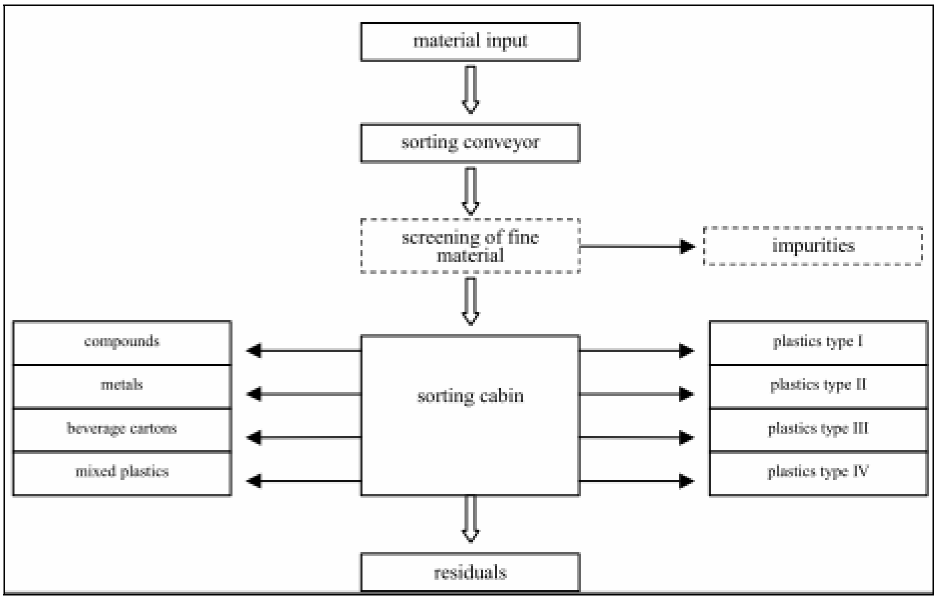

figure 40: basic configuration of waste glass processing (Intecus 2004)

3.4.3 Costs and market situation

➢ Paper recovery (Basic configuration)

Investment costs:

♦ In the range of 30,000–80,000 € for an average processing line

Operating costs

♦ The average running costs are 15-20 €/Mg, of which repair and maintenance costs amount to about 2,000 – 5,000 €/a (6 % of the initial investment)

Possible proceeds:

The following are the average obtainable market prices on the European markets during the last decade

♦ Mixed paper (1.02): 32.8 €/Mg

♦ Supermarket paper and board (1.04): 50.3 €/Mg

♦ Grades for de-inking (1.11): 71.3 €/Mg

♦ Newsprint (2.01): 85.5 €/Mg

Mass specific overall costs:

♦ The mass specific overall costs are at 15-20 €/Mg

Market Information

Established producers

Almost all large waste management providers undertake waste paper processing with the basic and/or medium scale configuration, for example:

- RWE,
- Cleanaway,
- SITA,
- Rethmann,
- Becker

(Intecus 2004)

➢ Glass recovery

Investment costs:

- Total capital needs: approx. up to 12,000,000 Euro

Operating costs:

- Repair and maintenance: about 5 % of initial investment p.a.
- personnel

Possible proceeds:

The obtainable market price for sorted glass has been in the following range during the recent years

- transparent glass: 20-35 €/Mg
- green glass: 0- 5 €/Mg
- brown glass: 20-35 €/Mg

Market information

References:

Large scale applications of these processes can be found everywhere in Europe and the world. In Germany large facilities exist for example in Velten and Groß Särchen

Established producers:

Many of the large and medium waste management providers undertake the processing of the collected waste glass in this manner. In Germany it is for example ALBA and Rhenus (Intecus 2004).

➢ Plastics and metal recovery

Investment costs:

- In the range of 50,000–150,000 € for an average processing line

Operating costs:

- The average running costs are from 150 to 300 €/Mg, including the costs for the disposal of the process residuals (German pricing level).

Possible proceeds:

The fractions obtained from the processing and sorting are marketable materials that have different prices depending on the actual market situation and quality achieved. Price examples for two fractions shall be given here:

- Fe-metals: approx. 145 €/Mg
- hollow wall HDPE products: 20-100 €/Mg

Packaging processing is often compensated by special financial schemes (such as the licensing scheme of the Green-dot) (Intecus 2004).

3.4.4 Physical-chemical treatment processes

The ambition of physical-chemical-treatment is basically the pre-treatment of hazardous waste and the environmental friendly disposal (destruction) of the therein contained pollutants.

3.4.5 Neutralisation

Neutralisation is mainly used for liquid hazardous waste, such as acid or bases. However it is also applicable on residues of MSW incineration.

3.4.6 Solidification

Residues from incineration, such as air pollution control residues can be managed through chemical solidification. This fine particulate material is mainly composed of minerals such as SiO_2, $CaCO_3$, $CaSO_4$, $Ca(OH)_2$,Fe_2O_3,Al_2O_3, CaO, HCl, NaCl, KCl, and several heavy metals such as Pb, Cd, Zn, Cu, Cr, Ni, Hg. chemical stabilization of the residues may be an interesting alternative, having as main goal to convert pollutants into less soluble or less toxic forms. This can be achieved by using specific chemicals such as hydroxides, sulphides, silicates, carbonates, phosphates and chelating agents. In the end, the stabilized pollutants stay bounded within the solid matrix as part of its structure (Quina et al. 2010).

3.5 Combined methods for MSW treatment

3.5.1 MBT

Mechanical biological treatment comprises a combination of mechanical and biological processes that further treat mixed residual waste before disposal. The aim of this process combination is to minimise the environmental impacts of end disposal and to gain some further value from the waste through the recovery of recyclables and, in some cases, energy. The possible process configurations are numerous although consisting always of mechanical processes (cf. 3.4) and a core biological treatment (cf. 3.3.1). With rising environmental standards and higher recycling requirements, integrated systems have been developed to combine the two technology stages as an integrated entity and include emissions and odour control facets within a closed cycle. They can offer a reasonably flexible approach to the management of different waste materials, due to their high tolerance of variation in waste composition. They can even function without any additional collection infrastructure, means they are also suited to the unseparated household waste stream.

Mechanical biological waste treatment shall achieve:

- a stabilisation and reduction of the risk potential together with a significant weight and volume loss through biological decomposition, which could count towards the diversion of biodegradable waste from landfill and in conjunction therewith

- the processing of the waste in order to generate separate material streams and improve suitability for subsequent treatment processes and
- the recovery of recyclable materials (e.g. metals).

The minimum space demand depend from the planned capacity but the additional space needed could be very low, if the treatment is part of the landfill operations where it must not exceed that for the windrows or rotting bays. Practically the figures provided for composting and anaerobic digestion could be used (Intecus 2004).

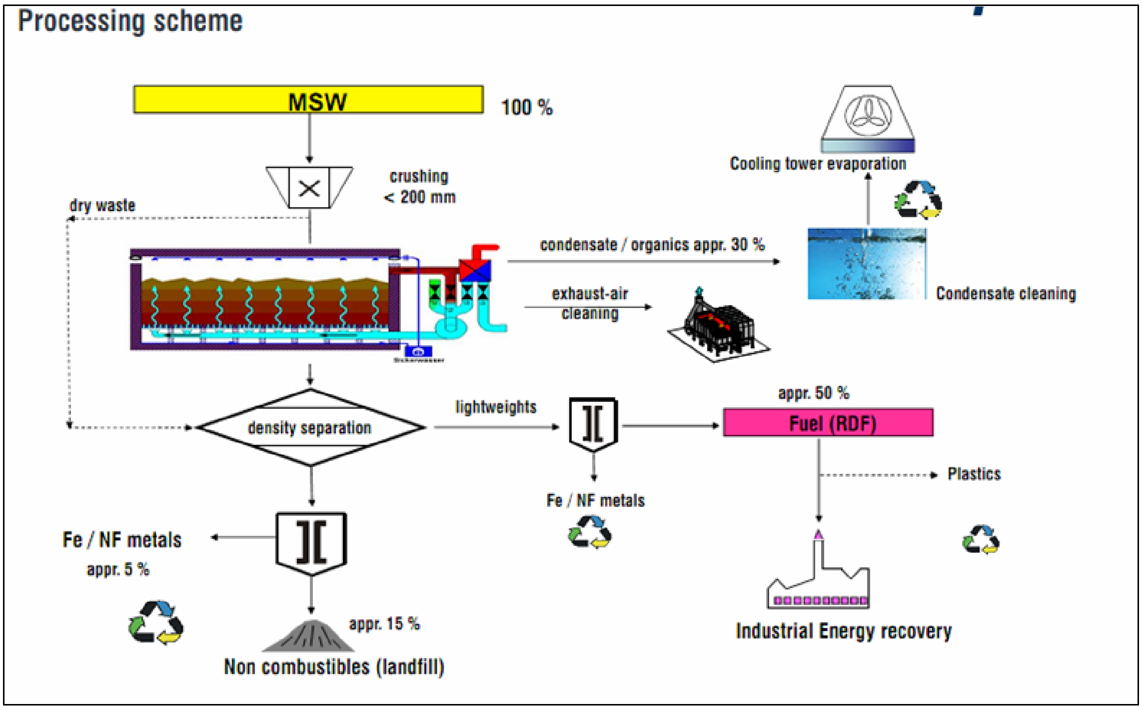

figure 41: MBT – scheme

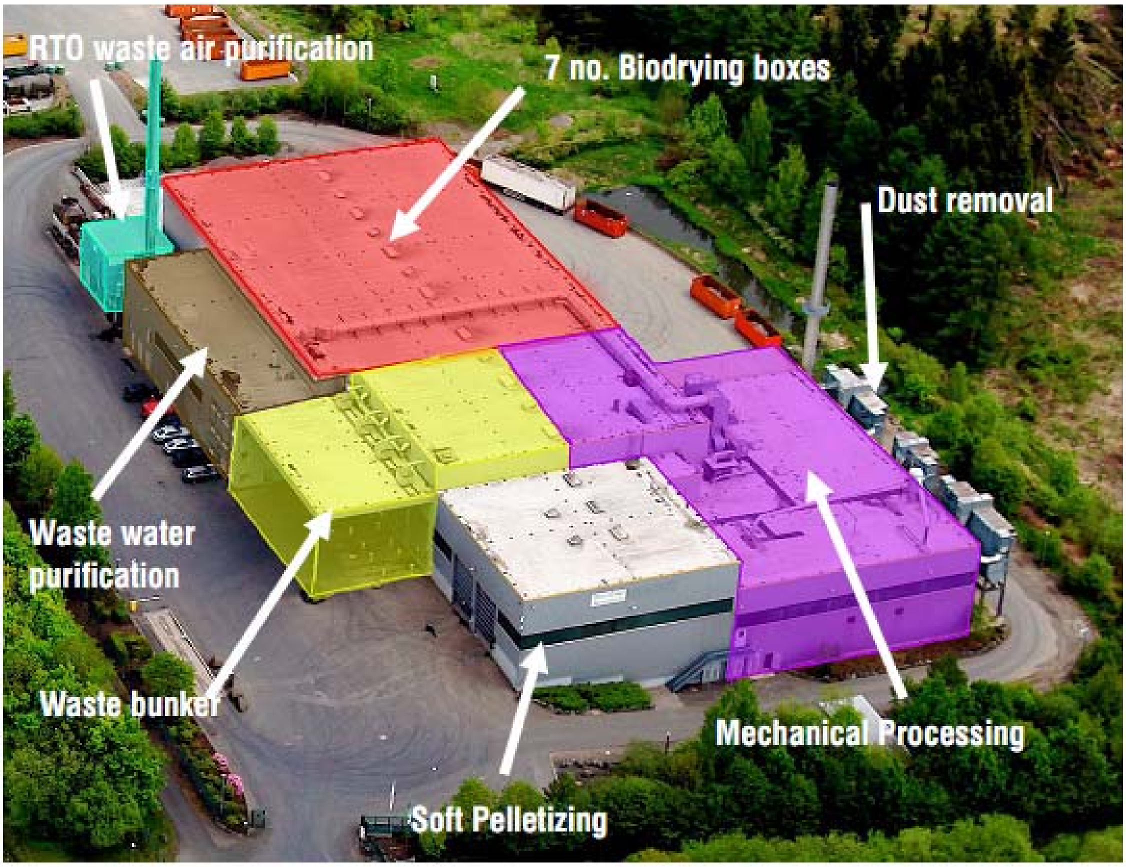

figure 42: MBT – facility

figure 43: RDF

figure 44: Fe-metals

figure 45: NF-metals

figure 46: Non-combustibles

3.5.2 Costs and Market information of MBT

Investment costs:

The investment comprise in the main of the following positions:

Costs for area development: depend from the local conditions and planned capacity, above all the costs for the acquisition and preparation of the area (costs may be rather low if the treatment is part of the operations on a landfill)

Equipment:

Mechanical stage:

- constructional elements incl. storage bunker:40 €/t*a
- stationary machinery: 20 - 80 €/ t*a
- mobile equipment (vehicles): 5 - 10 €/ t*a

Biological stage:

♦ Rotting method:	constructional elements:	70 to 90 €/t*a
	stationary machinery:	110 to 140 €/ t*a
♦ Anaerobic digestion:	constructional elements:	50 to 60 €/t*a
	stationary machinery:	130 - 180 €/ t*a

Overall estimates for the capital needs of complete MBT installations are ranging from 12 mill. Euro for a 50,000 tonnes per annum facility to 40 mill. € for 220,000 tonnes.

Operating costs:

- Daily operations (consumption of fuel/electricity, insurances etc.)
- Repair and maintenance:
  - for each structural element approx. 1% of the initial investment
  - machinery and electronic: 3 - 4% of the initial investment
  - mobile equipment (e.g. wheelloader): 8 – 15% of the initial investment
- Personnel (depending on the local labour market)

The higher wear out in digesting residual waste results in higher costs for repair and maintenance of MBT installations with an anaerobic digestion, as compared to pure biowaste digestion systems (see table 10).

table 10: running and maintenance costs

R&M costs in the first five years (in percent of investment)	Machinery and electric installations	Constructions
anaerobic digestion of biowaste	2-3	1

Possible proceeds:

Possible from the sale of recovered material, particularly metals. The supply of RDF up to this moment does in general not provide for revenues.

Mass specific overall costs:

In the range of 40-100 Euros/ton only for the treatment operations (possible proceeds and/or costs for the dispsoal of residues and supply of RDF to the incinerating industries not included)

3.5.3 MPT-Mechanical-physical treatment

Mechanical- physical treatment combines a mechanical treatment (crushing, screening and metal-separation) with a physical stabilisation (cf. 3.2.3 and 3.4). The aim of this method is to produce RDF (Refuse Derived Fuel) with a stable quality for co-incineration processes.

This treatment is relatively new and not very common. The question of supply and demand of the substitute fuel is still uncertain. Hence the technology and information about it are not easily available.

figure 47: process of MBT (Alba 2004)

figure 48: substitute fuel from mpt (http://www.alba.info)

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