TEXTE
40/2018

Best Practice Municipal Waste Management

Information pool on approaches towards a sustainable design of municipal waste management and supporting technologies and equipment

For our Environment

Umwelt Bundesamt

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Information pool on approaches towards a sustainable design of municipal waste management and supporting technologies and equipment

by

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Introduction

The need to curb natural resources depletion and climate change and secure a healthy living space for an ever growing human society has become a global challenge which increases the demand to minimise waste generation and manage arising wastes effectively and sustainably on a worldwide scale. This task applies to all countries independently from their status of development. Many countries are therefore faced with the necessity to initiate a process of transformation from the conventional scheme of waste disposal through simple dumping or landfilling towards the gradual implementation of a closed loop management of their wastes.

Germany went through this process during the last decades and has got a very high recognition for its achievements in adopting innovative solutions and implementing a modern, future-oriented waste management. There have rarely any technical, organisational or legal changes been made in the waste management of the country which didn't at the same time prompt and accelerate the development of novel waste management solutions and technologies. Through this, all actors and stakeholders involved in the management of wastes have got an increasing expertise and been able to develop the necessary capabilities in order to stand the rising challenges and requirements which they were exposed to with the new policy and the legal provisions that were adopted at the level of the European Union later on. A large spectrum of suitable measures and different type technical solutions for different types of problems and wastes could be developed and realised by them as a result.

German technology and equipment providers have become frontrunners in this way, a position that up to date not only relies on the very high degree of innovation, reliability and effectiveness their products incorporate but also draws from the vast experiences they made during their application over many years now. Providers and users of the different solutions meanwhile know perfectly the requirements and conditions in order to have a certain measure or technology efficiently adopted, the limitations that apply and how all this must be considered in order to establish an effective and well functioning waste management system.

Having recognised the serious challenges ahead and the need for better environmental protection in many countries all over the world, Germany has the commitment to support the transfer of suitable environmental protection technology and know how and promote the export of proven technologies in general and that of techniques and equipment to manage waste materials properly in particular. An essential part of this effort is to provide potential adopters state-of-the-art information about sustainable management practices, achievements as well as products and services that German companies are able to offer in this respect, may it be for waste collection, transportation, material processing or entire plant installations. This information pool offers a comprehensive nonetheless systematic overview on the approaches and techniques Germany successfully applied for waste management. It provides insights as to the possibilities of their application at home and abroad and facilitates convenient access to technical details, key figures and German technical providers and reference facilities.

Guiding principles for a sustainable resource and waste management and ways towards their implementation

Introduction

Wastes including such that are toxic and hazardous in nature are an inevitable consequence of today's life styles and economic activities. In order to secure the ecological balance and an adequate living quality for our human society also in the future it is more than ever before necessary to manage these wastes, utilize them to the extent possible to save primary resources and where this is not feasible, to ensure a safe disposal. Simultaneously our efforts must also be directed on preventing new waste emergence and thus reducing the needs for having waste treated. It is hence a great challenge for human society to combine the protection of the environment with the preservation of economic power and to guarantee a sustainable development in this way.

The European Community plays an essential role in the efforts for environmental protection and creation of a sustainable development, and is trying to take the position of a front runner in many areas and to set a good example for other regions in the world. The approach she has adopted for this is not essentially based on the prohibition of certain, environmental-damaging practices but reflects a policy that stems from the idea that strict environmental standards and norms would stimulate innovation and create new business opportunities in addition to pollution prevention and that it will be necessary to link all spheres of policy, i.e. economy, trade, social life and environmental protection in order to facilitate this to happen.

The development of guiding principles and their application in all political and practical activities is an important process and delivers the basis for the formulation of an appropriate legislation. With regard to resources and waste management this process has got a vivid reflection in Environmental Action Plans and a number of coherent initiatives and strategies covering different sectors and issues of concern. Within these documents the precautionary principle[1] and the polluter pays principle[2] are taking firm positions as basic orientations for environmental policy.

The application of these guiding principles for environmental policy shall make sure that the consumption of renewable and non-renewable resources does not go beyond the regeneration capacity of nature and our planet's ability to accommodate future generations. Decoupling economic growth and resource consumption, using available resources more efficiently and reducing the wastage of materials are the most prominent steps that shall be achieved. A European target with regard to waste is for example set with a reduction of the waste requiring final disposal by at least 50 % until the year 2050 from the level at the end of the last century.

The strategy that has explicitly been developed to support this goal aims further at a reduction of the environmental impacts of products over their entire life cycle, beginning from the extraction of the raw materials up to the moment where the generated product becomes a waste including its recycling. In that way waste is not any longer seen as a cause of environmental pollution only but also regarded a potential source for the raw materials needed. With this the management of waste takes the perspective of a substances flow and closed loop management with the main aims being the protection of resources and sustainable living patterns.

It is quite clear therefore that landfilling is not any longer a viable solution and simply burning the waste is unsatisfactory due to the resulting emissions and highly concentrated, polluting residues. The far better solution is to prevent the generation of waste first of all, and next to this preparing the reuse of goods. Whenever these options do not exist the waste shall be reintroduced into the product cycle by a recycling of its components. The source separation of certain waste materials or a subsequent segregation of materials for recycling or further

[1] The precautionary principle may be invoked where urgent measures are needed in the face of a possible danger to human, animal or plant health, or to protect the environment where scientific data do not permit a complete evaluation of the risk. It may not be used as a pretext for protectionist measures

[2] The Polluter Pays Principle implies that those who cause environmental damage should bear the costs of avoiding it or compensating for it. Therefore public financing of environmental policy is in most cases to be avoided, as it should be financed by the polluters themselves as far as they can be identified. In some cases the polluter may also be obliged to undertake investments to comply with the higher norms set. Producers may also be obliged to take back their products after use and take care for their recycling or safe disposal. Further possibilities are to tax practices which contribute to higher resources consumption or environmentally damaging products through special schemes. Producer and product responsibility are part of the polluter pays principle.

utilization purposes have great meaning here.

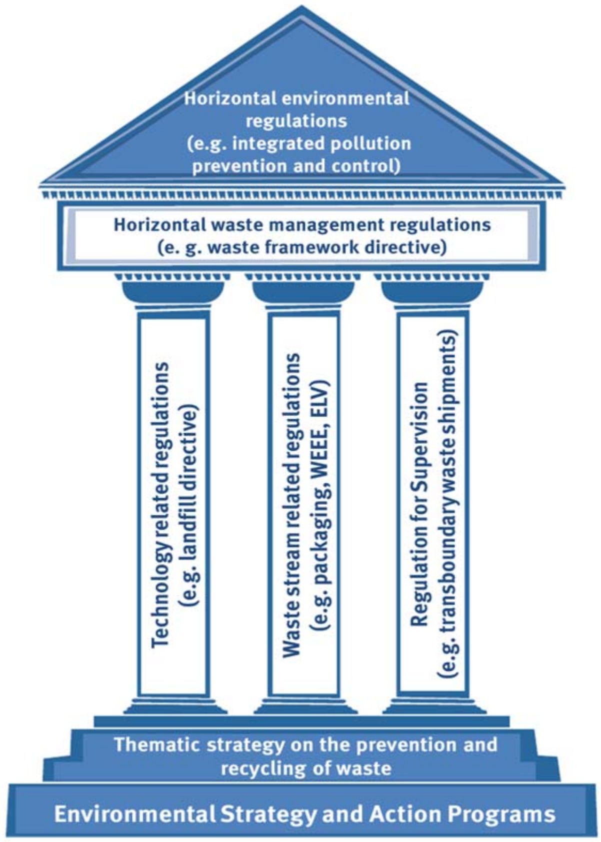
The described ranking of priorities is based on the concept known as the waste hierarchy. European member states have agreed on this concept and adopted it as the basis for all legislative measures in the waste sector in addition to the other guiding principles mentioned earlier. The five step hierarchical perspective in EU waste management legislation demands any activity to be strictly oriented on that:

- hazardous content in and the generation of waste out of products are prevented first of all,
- products are given a second life before they become waste,
- those amounts which do not suit for reuse are recycled, and
- where this isn't feasible treated to recover the energy they contain.
- Only what remains after all above possibilities have been exhausted shall be safely disposed of on landfills.
- A common orientation that consequently can be found in the environmental policy of EU countries is:
- to limit waste amounts and intensity;
- to decouple waste generation from economic growth;
- to promote the reuse, recycling and other forms of product utilization.

Under this premise, the waste hierarchy is not the hard-and-fast rule as it might seem, particularly since different waste treatment methods can have different impacts. However, the aim of moving towards a circular economy means moving up the hierarchy, away from landfills to more and more recycling. To give consideration on both, environmental impacts and the life-cycle of resources is at the core of an advanced waste management concept.

The solid building formed by European waste policy and legislative framework to enable the realization of such concept can be illustrated as in Figure 1. The overarching framework is made up from regulations for an integrated environmental policy which influences and takes into consideration all spheres of human activities and well-being, and a coordinated framework law aimed at limiting the generation and hazardousness of waste and to ensure a safe, well controlled and organized handling of waste in general (overall or horizontal waste management framework). A coordinated set of more detailed directives concerning waste treatment and disposal operations and to regulate the management of specific waste streams is complementing this building.

Figure 1: Basic structure of the EU's legislative building for the management of waste



Within this set of directives, one can distinguish:

- Directives which concern certain techniques and installations used for waste management (technology-oriented directives),
- Directives which concern certain priority waste streams and waste materials (waste stream-related directives) and
- Directives pertaining to the supervision and monitoring of waste management.

(More details and links can be found in Table 1)

These directives provide the EU member states, including Germany, a legislative framework which must be filled from them individually with a corresponding set of national laws and measures. Giving respect to the specific conditions and goals of their country, local legislative bodies and authorities may formulate their own regulations in a way that local needs are being addressed without that European targets are compromised. The principles adopted and practiced by the European member states for waste management have therefore a general meaning and can serve at any place of the world as an orientation to achieve a sustainable development and realize a waste management that corresponds to the best practices exercised elsewhere.

Supporting documents for the practical implementation and to understand better the norms and practices referred to in the European legislation have been provided with the **B**est available techniques **REF**erence documents (BREFs). BREFs should serve as a driver towards improved environmental performance across the European Union.

BREFs do not prescribe techniques or emission limit values but contain a number of elements leading up to the conclusions of what are considered to be "best available techniques" (BAT) in a general sense for the sector concerned. The definition of BAT requires that the technique is developed on a scale that allows implementation in the sector. The evidence to support a technique as BAT can come from one or more plants applying the technique somewhere in the world.

- BREF – Waste Treatments Industries (de / en)
- BREF – Waste Incineration (de / en)
- BREF – Management of Tailings and Waste-Rock in Mining Activities (de / en)
- BREF – Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (en)
- BREF – Slaughterhouses and Animal By-products Industries (de / en)

Table 1: Detailed overview on European framework documents and legislative acts for waste management

<table>
<tr><th colspan="3">Horizontal waste framework of the EU</th></tr>
<tr><td colspan="3">EU Waste Framework Directive (Directive 2008/98/EG on waste)
Closing the loop – An EU action plan for the Circular Economy COM(2015) 614 final
A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy COM (2011)0021 final
General Union Environment Action Program to 2020 1386/2013/EU</td></tr>
<tr><th>Specific waste streams</th><th>Supervision and monitoring</th><th>Treatment and disposal installations</th></tr>
<tr><td>· Packaging and packaging waste (94/62/EC)
· End-of life vehicles (2000/53/EC)
· Waste electrical and electronic equipment (2012/19/EU)
· Batteries and accumulators and waste batteries and accumulators (2006/66/EC)
· Disposal of polychlorinated biphenyls and polychlorinated terphenyls (96/59/EC)
· Protection of the environment when sewage sludge is used in agriculture (86/278/EEC)
Management of waste from extractive industries (2006/21/EC)</td><td>▸ Supervision and control of shipments of waste within, into and out of the European Community (EC) Nr. 1013/2006
▸ Supervision and control of shipments of radioactive waste and spent fuel (2006/117/Euratom)</td><td>▸ Landfill of waste (99/31/EC)
▸ Port reception facilities for ship-generated waste and cargo residue (2000/59/EC)
▸ Industrial emissions (integrated pollution prevention and control) (2010/75/EU)</td></tr>
</table>

Horizontal framework of EU waste legislation

- Waste Framework Directive
- Waste Shipment Regulation
- EU-Flagship Initiative for a resource-efficient Europe
- Environmental Action Program

Waste Framework Directive

Directive 2008/98/EC of 19 November 2008 on waste	
References	OJ L 312/3, 22.11.2008 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF
Main content / objective	Provides a framework for coordinating waste management in the Member States in order to limit the generation of waste and to optimize the organization of waste treatment and disposal.
Principal definitions	‘Waste‘ pursuant to Article 3 of the Waste Framework Directive is “any substance or object which the holder discards or intends or is required to discard”. A ‘waste holder’ in this sense is „the waste producer or the natural or legal person who is in possession of the waste“. The Waste Framework Directive is further providing definitions for a multitude of subjects related to the various aspects of waste management and for creating consensus in view of the EU-wide communication on waste and a circular economy. These are for example definitions on what ‘collection‘, ‘separate collection ‘, ‘treatment‘, and ‘recovery‘ mean. Article 2 also excludes certain substances, such as gaseous effluents or radioactive waste from the scope of the Directive, basically those are wastes regulated by separate Directives.
Key provisions	▸ obliges all holders of waste to deal with and dispose them in compliance with the stipulated framework and measures ▸ lays down a priority order of what constitutes the best overall environmental option in waste legislation and policy by way of a five-stage hierarchy, with the ranking of options as follows: 1) prevention; 2) preparing for re-use; 3) recycling; 4) other recovery, e.g. energy recovery; and 5) disposal ▸ demands the establishment of an adequate network of waste management installations in order to prevent illegal disposal practices and give waste holders the possibility to act in a compliant manner with above hierarchy and get the waste handled in accordance with the principles of proximity and self-sufficiency. ▸ the efficient use of resources is to be promoted in that products shall be reused and waste materials provide the feedstock for production processes ▸ Member States have to regularly elaborate waste management plans and develop waste prevention programmes ▸ control over the undertakings that dispose of and utilise waste shall be exercised ▸ the costs of disposing of waste must be borne by the holder of waste (application of the polluter pays principle).

Waste Shipment Regulation

Regulation (EC) No 1013/2006 of 14 June 2006 on shipments of waste	
References	OJ L 190/1, 12.7.2006 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006R1013&from=EN
Main content / objective	Predominant objective and component of this Regulation is the protection of the environment for which a system of supervision and control of all movements of waste within, into and out of the European Community has to be established and exercised.
Key provisions	▸ shipments of hazardous waste are to be reduced to a minimum, consistent with environmentally sound and efficient management of such waste ▸ in the case of shipments of waste for disposal, the principles of proximity, priority for recovery and self-sufficiency at Community and national levels should be taken into account ▸ an integrated and adequate network of waste disposal installations shall be established ▸ in case of shipments of waste destined for recovery it shall be ensured that the waste management facilities receiving this waste apply best available techniques ▸ waste from shipments which have been illegal or could not be completed as intended is to be taken back to the country of dispatch and disposed of in an alternative way ▸ stipulates the possibilities for the shipment of waste as well as the conditions under which the import/export of certain wastes in countries outside the EU are limited or forbidden ▸ sets up different categories of wastes and groups them in lists (green, yellow, red) which serve as the basis to determine shipment possibilities, limitations and the procedures applying ▸ stipulates a common, compulsory notification system and standard consignment note for waste shipments ▸ organizes supervision and control of shipments of waste in a way which takes account of the need to protect the environment and human health and promotes a uniform application of the regulation

EU-Flagship Initiative for a resource-efficient Europe

A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy COM (2011) 0021 final	
References	COM (2011) 0021 final http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0021&from=EN
Main content / objective	This flagship initiative provides a long-term framework for actions in many policy areas, supporting policy agendas for climate change, energy, transport, industry, raw materials, agriculture, fisheries, biodiversity and regional development. This is to increase certainty for investment and innovation and to ensure that all relevant policies factor in resource efficiency in a balanced manner. Member states are advised under this initiative to make a shift towards a resource efficient, low carbon economy and take appropriate measures that: ▸ boost economic performance while reducing resource use (decoupling goal); ▸ create new opportunities for economic growth and greater innovation and boost the EU's competitiveness; ▸ ensure security of supply of essential resources; ▸ fight climate change and limit the environmental impacts of resource use.

A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy COM (2011) 0021 final	
Key provisions	An important goal of the initiative is the long-term inclusion of resource efficiency in well-balanced way in all economic activities. As an essential component to achieve a long-term resource protection coordinated roadmaps for certain activities are being proposed to: ▸ outline what the EU needs to do to create a low-carbon economy in 2050, cutting greenhouse gas emissions by 80-95%, as part of global efforts to fight climate change, while improving energy security and promoting sustainable growth and jobs; ▸ analyse how the EU can create an energy system by 2050 which is low-carbon, resource-efficient, secure and competitive. This should provide the necessary certainty for investors, researchers, policy makers and regulators; ▸ present a vision for a low-carbon, resource-efficient, secure and competitive transport system by 2050 that removes all obstacles to the internal market for transport, promotes clean technologies and modernises transport networks; ▸ define medium and long-term objectives and means for achieving them with the main aim to decouple economic growth from resource use and its environmental impact. The appendix of the Communication paper for this initiative lists the different roadmaps which shall serve the realization of the said activities. Some with a closer relation to waste management are mentioned hereafter: ▸ European Energy Efficiency Plan 2020 ▸ Tackling the challenges in commodity markets and on raw materials ▸ Low-carbon economy 2050 roadmap ▸ Roadmap for a resource-efficient Europe

Environmental Action Program

7th Environment Action Programme (EAP) of the EU: Decision No 1386/2013/EU of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet	
References	L 354/171 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D1386&from=EN
Main content / objective	Successive Environment Action Programmes (EAPs) have provided the framework for EU action in the field of the environment since 1973. The current program is the seventh of its kind and covers the period up to 2020. Through this environment action program, the EU has agreed to step up its efforts to protect our natural capital, stimulate resource-efficient, low-carbon growth and innovation, and safeguard people's health and wellbeing – while respecting the Earth's natural limits.
Key provisions	The program lists nine priority objectives and what the EU needs to do to achieve them by 2020. They are: ▸ to protect, conserve and enhance the Union's natural capital ▸ to turn the Union into a resource-efficient, green, and competitive low-carbon economy ▸ to safeguard the Union's citizens from environment-related pressures and risks to health and well-being ▸ to maximise the benefits of the Union's environment legislation by improving implementation ▸ to increase knowledge about the environment and widen the evidence base for policy ▸ to secure investment for environment and climate policy and account for the environmental costs of any societal activities

7th Environment Action Programme (EAP) of the EU: Decision No 1386/2013/EU of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet	
	▸ to better integrate environmental concerns into other policy areas and ensure coherence when creating new policy ▸ to make the Union's cities more sustainable ▸ to help the Union address international environmental and climate challenges more effectively

Waste stream specific EU regulations

- Directive on packaging and packaging waste
- Directive on waste electrical and electronic equipment (WEEE)
- Directive on end-of-life vehicles
- Directives on batteries and accumulators and waste batteries and accumulators
- Other directives, incl. Directive on the protection of the environment when sewage sludge is used in agriculture Directive 2006/21/EG on the management of waste from extractive industries

Directive on packaging and packaging waste

Directive 94/62/EC of 20 December 1994 on packaging and packaging waste amended by Directive 2004/12/EC of 11 February 2004, and Directive 2013/2/EU of 7 February 2013	
References	OJ L 365, 31.12.1994; OJ L 284, 31.10.2003; OJ L 47, 18.2.2004; OJ L 70, 16.3.2005; OJ L 87, 31.3.2009; OJ L 37/10, 08.02.2013; OJ L 115, 6.5.2015 http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31994L0062
Main content / objective	The main objectives are to harmonize the differing national measures concerning the management of packaging and packaging in order, on the one hand, to prevent and reduce the impacts thereof on the environment and, on the other hand, to ensure the functioning of the internal market and to avoid obstacles to trade and distortion and restriction of competition.
Principal definitions	The Directive covers all packaging placed on the market in the Community and all packaging waste, whether it is used or released at industrial, commercial, office, shop, service, household or any other level, regardless of the material used. Directive 2004/12/EC (amending Directive 94/62/EC) establishes criteria clarifying the definition of the term "packaging" whilst Directive 2013/2/EU extends this by a list of illustrative examples to clarify additional cases where the borderline between what is packaging and what is not, was unclear.
Key provisions	▸ the management of packaging and packaging waste should include as a first priority the prevention of packaging waste ▸ recovery and recycling of packaging wastes must be ensured for which Member States have to introduce systems for the return and/or collection of used packaging to attain specific targets for the recovery and recycling of packaging materials. Accordingly the following minimum recycling targets must be met since 31 December 2008: *- 60 % by weight for glass,* *- 60 % by weight for paper and cardboard,* *- 50 % by weight for metals,* *- 22.5 % by weight for plastics, whereby only those amounts will be considered which are fully recyclable into plastics again,* *- 15 % by weight for wood.* ▸ the use of plastic bags in Member States must be progressively reduced, with an initial threshold of 90 bags per person per year by 2019, followed by 40 bags in 2025. From 2019 vendors will no longer be allowed to give away customers plastic bags for free unless other measures ensure compliance with the reduction goals ▸ harmonised databases for monitoring the implementation of the directive objectives must be developed ▸ lays down essential requirements as to the composition and the reusable and recoverable (including recyclable) nature of packaging, whereas especially the presence of noxious metals and other substances with significant environmental impact in packaging should be limited.

Directive on waste electrical and electronic equipment (WEEE)

Directive 2012/19/EU of 4 July 2012 on waste electrical and electronic equipment (WEEE)	
References	OJ L 197, 24.07.2012 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012L0019&qid=1438929351669
Main content / objective	Principal target of the Directive is the prevention of waste electrical and electronic equipment (WEEE) together with a promotion of the reuse, recycling and other forms of recovery of such wastes so as to reduce their disposal. In this context it also aims at improving the environmental performance of all operators involved in the life cycle of electrical and electronic equipment.
Principal definitions	Electrical and electronic equipment and the waste of it (WEEE) refers to items from households and the commercial sector which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields. Excluded from the scope of this directive is electrical and electronic equipment which served special military purposes, exceeds certain voltage and filament bulbs
Key provisions	‣ the design and production of electrical and electronic equipment which take into account and facilitate dismantling and recovery, in particular the reuse and recycling of WEEE, their components and materials is to be encouraged ‣ appropriate measures in order to minimize the disposal of WEEE as unsorted municipal waste and separate collection of WEEE from households shall be adopted ‣ the possibility for end-users to return small WEEE free of charge and with no obligation to buy EEE of an equivalent type must be created by retail shops above a certain size ‣ stipulates producer responsibility obligations in that producers shall provide at least for the financing of the collection, treatment, recovery and environmentally sound disposal of WEEE from private households deposited at collection facilities ‣ mandatory collection rates to help the installation of effective collection systems (till 2019 minimum collection of 45 % of the average weight of EEE placed on the market, from 2019, 65 % or alternatively 85 % of WEEE generated) ‣ recovery and recycling rates depending on product categories with a minimum of 75%/85% of recovery and 55–80% of recycling from 2016 ‣ demands specific treatment for WEEE using best available treatment, recovery and recycling techniques and a minimum takeout of certain substances during the treatment ‣ establishes minimum criteria to distinguish between reusable appliances and WEEE when being shipped ‣ obliges producers to provide information on reuse and treatment options for each type of new electronic equipment put on the market ‣ stipulates an inspection and monitoring infrastructure through which the proper implementation of the directive can be verified ‣ demands to draw up registers on producers and collect information, including substantiated estimates, on an annual basis on the quantities and categories of electrical and electronic equipment put on their market, collected through all routes, reused, recycled and recovered within the Member States, and on collected waste exported, by weight or, if this is not possible, by numbers.

Directive on end-of-life vehicles

Directive 2000/53/EC of 18 September 2000 on end-of-life vehicles as amended by Directive (EU) 2016/774 of 18 May 2016	
References	OJ L 269, 21.10.2000; last changed by OJ L 128, 19.05.2016 in line with Commission Directive (EU) 2016/774 of 18 May 2016 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2016_128_R_0002
Main content / objective	Core objective is to minimise the impact of waste from used vehicles on the environment, to ensure the better reuse of the materials used in vehicles and to improve energy conservation. It therefore stipulates in particular the establishment of appropriate collection schemes and measures for the recycling of used cars and the parts used therein.
Principal definitions	Vehicles designated as category M1 or N1 defined in Annex IIA to Directive 70/156/EEC, and three wheel motor vehicles as defined in Directive 92/61/EEC that become a waste within the meaning of Directive 2008/98/EG are considered end-of life vehicles (ELV)
Key provisions	▸ demands the establishment of conditions leading to recycling-friendly vehicle design and construction, the creation of a collection and recycling network for end-of-life vehicles and used parts, and eventually to compliance with target rates prescribed for the reuse, recycling and recovery of ELV components ▸ Implementation of the separate collection of used parts and hazardous components and of measures leading to the take back of ELV by the relevant actors from the car industry and trade at no additional costs for the final car holder ▸ obligation for take back and treatment facilities to undergo approval and registration ▸ records and a proof on the disposal and recycling of ELV must be produced ▸ Obligation to remove and separate certain components and hazardous substances during the processing of ELV ▸ Certain quota for re-use and recycling of vehicle components (85 % since 2015) and total utilization (95% since 2015) ▸ Exclusion resp. limitation of certain heavy metals such as mercury, hexavalent chromium, cadmium or lead in car components ▸ Use of the standard material coding in view of an easier identification during the dismantling process. ▸ Car producers pursuant to Directive 2005/64/EG must comply with minimum requirements in view of the reusability and recyclability of car components used in production

Directive on batteries and accumulators and waste batteries and accumulators

Directive 2006/66/EC of 6 September 2006 on batteries and accumulators and waste batteries and accumulators	
References	OJ L 266, 26.9.2006; OJ L 76, 11.03.2008; OJ L 327, 5.12.2008; OJ L 329, 10.12.2013 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006L0066:EN:NOT
Main content / objective	The primary objective is to minimize the negative impact of batteries and accumulators and waste batteries and accumulators on the environment. Further hereto requirements concerning the heavy metal content and labeling of batteries and accumulators shall be harmonized so to ensure the smooth functioning of the internal market and avoid distortion of competition within the Community.

Directive 2006/66/EC of 6 September 2006 on batteries and accumulators and waste batteries and accumulators	
Principal definitions	▸ are provided for different types of batteries placed on the market ▸ in the scope of the Directive are all batteries and accumulators placed on the market within the Community with some exemptions which include equipment designed to serve military purposes and used in space missions
Key provisions	▸ prohibits placing on the market batteries or accumulators, whether or not incorporated into appliances, that contain more than 0,0005 % of mercury by weight; and portable batteries or accumulators, including those incorporated into appliances, that contain more than 0,002 % of cadmium by weight ▸ prohibits disposal of industrial and automotive batteries and accumulators in landfill sites or incinerators ▸ demands all operators involved in the life cycle of batteries and accumulators, e.g. producers, distributors and end-users and, in particular, those operators directly involved in the treatment and recycling of waste batteries and accumulators to improve environmental performance ▸ specifies rules for the collection, treatment, recycling and disposal of waste batteries and accumulators and sets minimum collection and recycling targets ▸ collection schemes ensuring a high collection rate should be established (minimum collection rate of 45 % to be achieved by 26 September 2016). Collection schemes so that end-users can discard all waste portable batteries and accumulators free of charge must be established ▸ minimum recycling efficiencies of the following kind: *-recycling of 65 % by average weight of lead-acid batteries and accumulators* *-recycling of 75 % by average weight of nickel-cadmium batteries and accumulators* *-recycling of 50 % by average weight of other waste batteries and accumulators.* ▸ Treatment and recycling schemes should use best available techniques, whereas the definition of recycling should exclude energy recovery ▸ arrangements for a labeling system should be made ▸ demands realization of producer responsibility, for this all producers should be registered. Producers should finance the costs of collecting, treating and recycling all collected batteries and accumulators

Other directives

Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture	
References	OJ L 181, 04.07.1986 http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31986L0278
Main content / objective	The European Union regulates use of sewage sludge in agriculture to prevent harmful effects on soil, vegetation, animals and humans. In particular it sets limits on the concentrations of certain substances in these sludge, bans the use of these sludge in certain cases and regulates the treatment of sludge. *Important remark:* New knowledge and technological progress have emerged since the Directive came into force and aren't therefore properly reflected in the provisions this legal act contains. This led to numerous initiatives to change the policy soon, or to let the entire subject go up in other, more advanced regulations. At national level, among others also in Germany,

	the commitments and objectives of sewage sludge use have already partly been expanded or changed and a long-term reduction of sewage sludge utilization in agriculture been initiated and/or the restrictions for such use significantly been increased vis á vis the kind of stipulations in the Directive .
Principal definitions	Sludge as defined and covered by the Directive is any residual sludge from: ▸ sewage plants treating domestic or urban waste waters and from other sewage plants treating waste waters of a composition similar to domestic and urban waste waters; ▸ septic tanks and other similar installations for the treatment of sewage; or ▸ sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use
Key provisions	▸ prohibits the use of untreated sludge on agricultural land unless certain practices of integrating it to the soil and limit values for concentrations of harmful content are kept ▸ restricts the sludge use to certain types of land, crops and time slots and requires that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired. ▸ specifies rules for the sampling and analysis of sludge and soils and sets out requirements for the keeping of detailed records

Directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT)	
References	OJ L 243, 24.09.1996 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0059:EN:NOT
Main content / objective	This directive lays down rules to approximate the laws of the Member States on the controlled disposal of PCBs, the decontamination or disposal of equipment containing PCBs and/or the disposal of used PCBs in order to eliminate them completely.

Directive 2006/21/EG on the management of waste from extractive industries and amending Directive 2004/35/EC	
References	L 102/15, 15.03.2006 http://eur-lex.europa.eu/legal-content/DE/TXT/?uri=CELEX:32006L0021
Main content / objective	Provides for measures, procedures and guidance to prevent or reduce as far as possible any adverse effects on the environment, in particular water, air, soil, fauna and flora and landscape, and any resultant risks to human health, brought about as a result of the management of waste from the extractive industries
Principal definitions	Covers the management of waste resulting from the prospecting, extraction, treatment and storage of mineral resources and the working of quarries, referred to as ‘extractive waste’

Technology-related EU regulations (Waste treatment and disposal installations)

- Directive on industrial emissions
- Directive on the landfill of waste

Directive on industrial emissions (integrated pollution prevention and control)

Directive 2010/75/EU of 24 November 2010 on industrial emissions (integrated pollution prevention and control)	
References	OJ L 334/17, 17.12.2010 http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010L0075
Main content / objective	This Directive lays down rules on integrated prevention and control of pollution arising from industrial activities. It also contains rules designed to prevent or, where that is not practicable, to reduce emissions into air, water and land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole
Principal definitions	► are provided for a multitude of issues related to emissions (e.g. ‘substances’, ‘pollution’), industrial installations (e.g. ‘combustion plant’, ‘multi-fuel firing combustion plant’) and their operating and approval practice (e.g. ‘emission limit value’) ► Certain installations, namely those operated for research activities, development activities or the testing of new products and processes are excluded from the scope of the directive
Key provisions	► a framework of stringent operating conditions, technical requirements and emission limit values for plants treating, incinerating or co-incinerating waste within the EU (other industries covered are the energy sector and metal working industry) is set ► each installation should operate only if it holds a permit, in addition it is necessary that any planned change which might affect the environment is reported to the competent authority, and in case that such changes to an installation is substantial it should not be made without a permit ► installations must be designed and operated in a way that all appropriate preventive measures are taken against pollution; the best available techniques are applied; the generation of waste is prevented in accordance with Directive 2008/98/EC; energy is used efficiently ► installations must comply with the emission limit values for critical substances and requirements for soil and groundwater protection prescribed by the Directive and by the competent authority in the country of operation; these limits must be determined, reviewed and adjusted regularly in accordance with technological advances and changes in scientific knowledge and understanding; strict monitoring has to be applied and compliance with the rules ensured, if necessary by way of inspections ► stipulates that the public concerned shall be given early and effective opportunities to participate in the permit procedures and get access to the relevant information

Directive on the landfill of waste

Directive 1999/31/EC of 26 April 1999 on the landfill of waste	
References	OJ L 182, 16.7.1999; Corrigendum: OJ L 282, 05.11.1999 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0031:EN:NOT
Main content / objective	The main objective is to prevent or reduce as far as possible negative effects on the environment from the land filling of waste, by introducing stringent technical requirements for waste and landfills.
Principal definitions	Defines the different categories of waste (municipal waste, hazardous waste, non-hazardous waste and inert waste), the permitted landfill types and emissions from landfill operations.
Key provisions	▸ lays down standard waste acceptance procedure and stipulates technical standards in order to ensure a safe deposition of wastes of different kind ▸ promote waste treatment before landfilling in order to exploit any options leading to a utilization of waste material and to reduce toxicity, hazardousness and volume of the material to be deposited ▸ prohibits mixing municipal waste or hazardous waste with inert waste ▸ promotes the need to have a system to identify and record information on waste to be deposited. ▸ excludes certain wastes from being landfilled ▸ provides for a schedule to reduce the organic matter on landfills and to exclude biodegradable waste from landfills on a long term perspective ▸ stipulates procedures for monitoring and recording of the waste deposited ▸ requires certain standards regarding the monitoring of operations and measurement of control parameters ▸ requires that landfills which do not conform to the set standards need to be reconstructed or closed within a certain period of time

Waste prevention

Introduction

Growth-oriented societies need and cause a tremendous resource consumption that is mostly higher than the limits set by the natural environment. After the (partially strongly shortened) usage phase of products, these societies generate an immense waste amount. Hence, a priority environmental goal should be to decouple the economic growth from the waste generation to meet the necessity of a sustainable development. In Europe, the decoupling was considered by implementing the waste hierarchy, whereby the waste avoidance is determined as the highest priority within a circular economy.

According to the Waste Framework Directive, waste prevention is defined as measures that are realised prior to the conversion of a material or product into waste. These measures shall

- reduce the waste amount by reusing products and materials / by prolonging their life span
- reduce the content of hazardous substances in products and materials and/or
- reduce harmful impacts of generated waste to the environment and human health3.

The integration of waste prevention into supply chains of economies needs initiatives from state and market. Both institutions can establish conditions and measures in their spheres that may influence each other (Figure1).

Legally binding prevention measures for economic actors and the market went already into force in Europe. The principle of producer's responsibility is one example (see the factsheet on "Waste stream related EU-regulations"), though the application is dependent on the economic and technical feasibility of the measure. This implies that voluntary measures and self-commitments ("soft" measures) of economic actors offer a broader range of possible actions. Moreover, waste preventing actions of consumers and public institutions (e.g. schools, authorities) play an important role. Essential contribution to waste prevention can be achieved by e.g. greener procurement of public institutions and deliberate consumption behaviours of consumers (e.g. use rather than own, repair, etc.).

In the frame of the German waste prevention programme several waste prevention measures are presented and recommended, which can be classified into following categories[4]

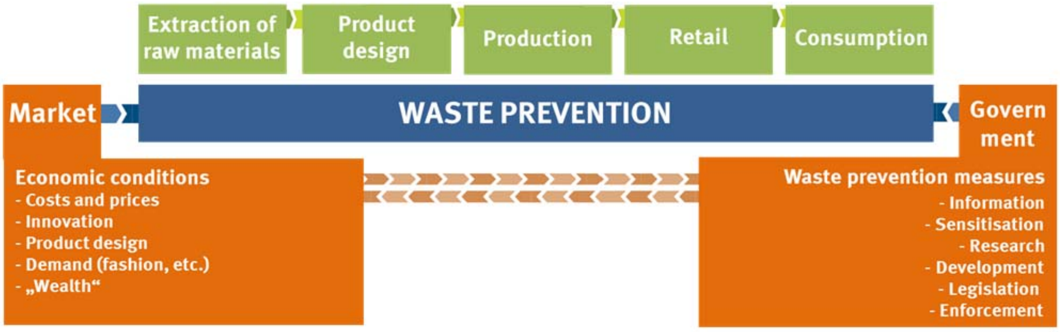
- Measures that could impact the framework conditions related to the generation of waste
- Measures that can affect the design, production and distribution phase
- Measures that can affect the consumption and use phase

Each category will be clarified with examples in the tables presented hereinafter.

[3] Article 3 (12) of Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

[4] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety: Waste Prevention Programme of the German Government with the Involvement of the Federal States, BMU, Division WA II 1, Bonn, July 2013

Figure 2: Target of waste prevention according to the German waste prevention program[4]



Measures that could impact the framework conditions related to the generation of waste

Measure of waste prevention	Initiators	Addressee of measure	Example of application
No. 1: Use of planning measures or other financial mechanisms to promote the efficiency of resource use			
Development of waste prevention strategies and approaches by local authorities	Local authorities (district and local governments)	Local residents, local government offices, companies	Integration of waste prevention strategies into official waste management plans of municipalities as well as providing online based information and offer telephone consultation about second-hand shops, waste preventing shopping and repair shops in the region Example: Waste management concept for the Mittelsachsen county 2014 - 2020
Cooperation with stakeholders	Government agencies, federal states	Representatives of value chains in selected sectors	The German food bank “Tafeln e.V.” cooperates with wholesaler Metro Group. Amongst other things, Metro Group is publishing a cookbook „Das gute Essen“ about sustainable cooking. The profit of the sale is donated to the food bank
Consideration of waste prevention aspects when reviewing the environmental impacts of existing subsidies	Government agencies, federal states	Producers, Consumers, Retailers	-
No. 2: Promotion of relevant research and development			
Research into waste-preventing technologies and utilisation concepts as an integral part of pre-existing support programmes and measures	Government agencies, federal states	*For technological development:* research institutions, industry and SMEs; *For utilisation concepts:* research institutions and stakeholders	In the area of plastics engineering an intense research about biological degradable materials took place. They consist of organic substances, which can be fully integrated in the environment after the usage phase. One research institute dealing with bioplastics is Institute for Bioplastics and Biocomposites of University of applied Sciences and Arts Hannover
Support programmes and measures to implement waste-preventing concepts and technologies	Government agencies, federal states, KfW group of banks	*For the application of technologies*: industry and SMEs; *for utilisation concepts:* retailers and stakeholder	The transfer of research results into applying economy is supported by following programs: Umweltinnovationsprogramm of BMUB KfW-Umweltprogramm der KfW Group
Nr. 3: Development of effective, meaningful indicators for the environmental pressures associated with the generation of waste			
Development and application of systems of indicators with the aim of benchmarking	Government agencies, federal states	Industry, public waste disposal agencies, statistical offices of Federal States, Federal Statistical Offices	Statistical data such as the waste generation per capita can be linked to measures in order to evaluate applied best-practices for waste prevention. For example data about waste generation in Germany can be obtained from the Federal Environment Agency: „Kartendienst Abfallwirtschaft“ or Statistical offices

Measures that can affect the design, production and distribution phase

Measure of waste prevention	Initiators	Addressee of measure	Example of application
No. 4: The promotion of eco-design			
Identification of product-specific requirements for clean product design within the context of measures to implement the EU Eco-design Directive (2009/125/EC)	EU Commission, coordination in Government agencies	Circulators of products	National debates about product specific requirements take place via the „EuP-Network“ initiated by the German Environmental Ministry
Provision of information and awareness-raising with regard to clean product design	Government agencies in collaboration with industry and environmental organisations	Product designers, product developers, product manufacturers and supply chains	The Environmental Ministry of Baden-Wurttem-berg honours companies that develop innovative technologies for material efficiency with the “Award for environmental technologies“
Measures aimed at producer responsibility (PR) for waste management	Government agencies	Manufacturers and distributors of certain products	PR is already applied for waste streams: Electrical and electronic waste, batteries and accumulators and packaging (see also factsheets on “Electrical and electronic waste”; “Batteries and accumulators”)
Standardisation in support of waste-preventing and resource-conserving product design	Government agencies, authorities represented in the CEN or DIN standardisation committees	Producers, retailers	Electronic and electrical devices that are labelled with the environmental sign “The Blue Angle“ are repairable to ensure a longevity of the product (e.g. RAL-UZ 78c: Requirements for monitors)
No. 5: Providing information to facilitate the use of best available technologies in industry			
Adapting the enforcement aids and guidance tools for installations subject to licensing in line with the best available technology on waste prevention	Government agencies	Licensing authorities; operators of facilities requiring a license	-
Advice to companies by public institutions on waste prevention potential	Government agencies, federal states, local authorities	Branches and SME in the manufacturing industry, especially companies that use large quantities of primary resources	In Germany, centres were established that offer consultancy services for companies and SME’s in the area of resource efficiency: Deutsche Materialeffizienzagentur VDI Zentrum für Ressourceneffizienz
Nr. 6: Training of competent authorities as regards the consideration of waste prevention requirements when issuing licenses			
Training licensing authorities to give better consideration to waste prevention aspects	Federal states, highest authorities	Licensing authorities of the Federal states	-
Nr. 7: Inclusion of measures to prevent waste production at installations			
Insisting on the uniform implementation of waste prevention obligations at installations requiring a license as well as those not requiring a license	Government agencies	Licensing authorities of the Federal states, installation operators	-
Nr. 8: Sensitisation measures and financial / decision-making support to businesses			
Establishment, continuation and interlinking of existing programmes to sensitise companies and advise them on waste prevention	Environment ministries and ministries of economics	Companies	The project “EffCheck” is a project of the Efficiency Network of Rhineland Palatine that offers consultancy services to SME’s about energy and resource efficiency
Nr. 9: Voluntary agreements.			
Waste-preventing cooperation among industrial companies	Governments with regional industrial companies as the operating force	Industrial companies, SMEs	In the frame of a project, companies of the industrial park of Henstedt-Ulzburg/ Kaltenkirchen concentrated logistics and occurring waste streams
Voluntary agreement with retail and gastronomy on training measures aimed at a more targeted supply of foodstuffs to shops and restaurants.	Government agencies and states in collaboration with public institutions and/or industry associations for retail and gastronomy	Retail	-

Measure of waste prevention	Initiators	Addressee of measure	Example of application
Agreements between industry / commerce and government agencies on waste prevention	Government agencies and states in collaboration with industry associations, logistic companies, trade chains etc.	Various types of companies	-
Nr. 10: Promotion of creditable environmental management systems			
Extending existing environmental management systems to include waste prevention aspects	Federal states, local authorities in collaboration with private consulting firms.	Companies	The „greentable“–certificate honours restaurants and catering firms that meet requirements in sustainable procurement, environmental protection and social engagement. To obtain and retain the label, compliance with set criteria must be shown, e.g. applying a waste management that includes food waste prevention

Measures that can affect the consumption and use phase

Measure of waste prevention	Initiators	Addressee of measure	Example of application
Nr. 11: Economic instruments			
The promotion of waste-preventing product service systems	Federal states, local authorities	Companies, associations, clubs, consumers	Car-Sharing (DriveNow): Support of car-sharing systems through the exemption of parking fees
Support of waste disposal structures and systems that encourage waste prevention	Local authorities, public waste disposal agencies.	Waste producers and owners	Waste fees can consist of a fix and a variable part. Latter one can decrease if less waste is generated /thrown away. Exemplarily, this fee system is used at Zweckverband Abfall- und Wertstoffeinsammlung für den Landkreis Darmstadt-Dieburg (see also factsheet on “Financing policies”)
Nr. 12: Sensitisation and information measures			
Strengthening the aspect of waste prevention in purchase recommendations	Consumer organisations as operational players, supported by the Government agencies or states	Consumers	The German Ministry of Food and Agriculture initiated the nationwide campaign „Too good for the bin!“ about food waste and its prevention. It sensitises consumers about their food habits, gives information and recommendations
Educational measures and public participation in waste prevention	Culture ministries of federal states in collaboration with Government agencies	Teaching staff, pupils, trainees	Consumer centres of Federal states offer several workshops and exhibitions about waste prevention
Practical introduction and implementation of sustainable, resource-conserving waste concepts in schools	Federal states ministries prescribe requirements, but individual schools formulate their own concepts	Local authorities, teaching staff at primary and secondary schools, pupils	Since 2000, the Secondary School of Dresden-Cotta carries out environmental education with waste prevention as a key issue
Encouraging local authorities and environmental and consumer organisations to develop waste prevention campaigns	Government agencies, federal authorities, local authorities	Companies, consumers	The Federal State of Saxony established the initiative „Food is precious“ to sensitise consumers about food waste
Nr. 13: The promotion of eco-labels			
Using product labels for resource-con-serving, “waste-preventing” products	Government agencies and federal states	Manufacturers, consumers, EU Commission	Awarding “The Blue Angle“-eco-label is bound on meeting certain waste prevention demands
Nr. 14: Agreements with industry			
Concerted actions to prevent food waste	Government agencies, federal states and local authorities; agriculture, food industry and retail sector representatives	Food industry, retailers	The grocery chain REWE Group established a comprehensive environmental system. Amongst others, food waste is prevented by applying efficient logistics like demand-driven supply to stores but also households

Nr. 15: Waste prevention and public procurement system			
Consideration of waste prevention aspects in public procurement	Government agencies, federal states	Awarding authorities at all levels, building authorities of federal governments /states, property developers	A guideline on the green public procurement of monitors published 2015 by the German Environment Agency contains recommendations for the procurement of energy saving, long lasting, low-emission, recyclable monitors
Nr. 16: Promotion of the reuse and repair of appropriate discarded products			
Promotion of the reuse or multiple use of products (second-hand merchandise)	Local authorities, public waste disposal agencies	Organisations and private trade structures for second-hand, public waste disposal agencies.	ReUse Computer e.V. is an association of companies, institutions and private persons that encourage the reuse of high-quality IT-devices
Support of repair networks	Federal states, local authorities	Private and charitable initiatives	SAPOS GmbH sells second-hand electronic devices, which are tested and, if necessary, repaired. The company is specialised to working and integrating socially disprivileged persons
Development of quality standards for reuse	Government agencies and states	e.g. Repair workshops	In the frame of the research project „Second life" technical criteria were determined for the reuse of electronic devices. Amongst others, it is recommended to rely on the VDI-guideline 2343, sheet 5 "Reuse"
Cleaner events at public institutions (reuse over disposal)	Federal states, local authorities	Public and private event organisers	Public events planned and conducted according to DIN EN ISO 20121. The guideline includes criteria for and demands on a sustainable event management. Additionally, the "Leitfaden für die nachhaltige Organisation von Veranstaltungen" of the German Environment Agency provides recommendations about a waste preventing, sustainable event management, too
Support of research and development into lifespan-extending measures	Government agencies and federal states	Research institutions, companies	The project „ProSensonet2" of Leibniz Institute for Agriculture Technology Potsdam-Bornim e.V. developed sensor-based solutions aimed at the reduction and prevention of food waste through an efficient transport logistic

Area adapted waste management planning

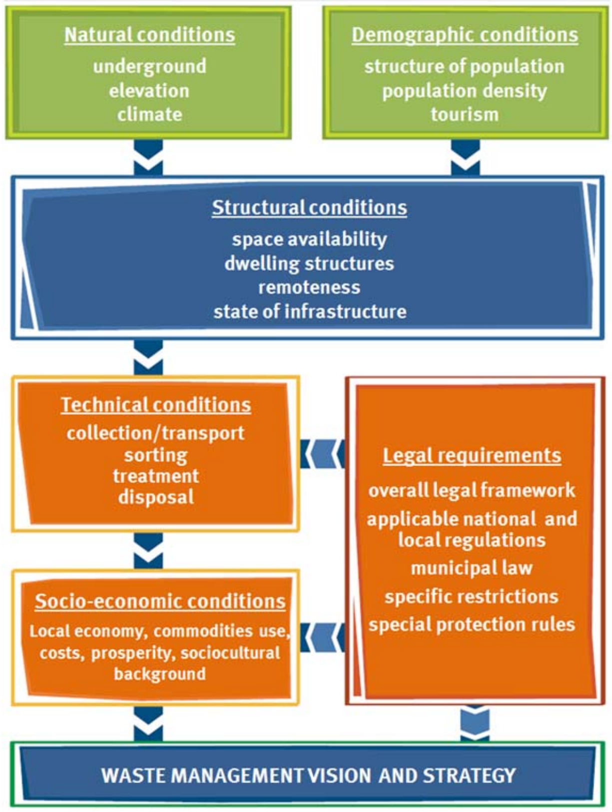
Background and methodical approach

An effective waste management and the area characteristics and structural conditions need to be seen in a context. Beside economic and infrastructural circumstances (e.g. number of inhabitants, accessibility, available transportation routes, economic diversity etc.) also the social and cultural framework are very influential. These factors have a defining impact not only on the wastes` qualitative and quantitative developments but determine as well the possible range and efficiency of individual techniques and waste management measures. The specific combination of various features in a given area determines which potentials and limits exists for waste management or where the practice from one place can be possibly adopted in another territory and where such strategy would probably not be that successful.

Waste management planners and decision makers need to be aware on these interrelations to be able to identify suitable waste management solutions. It is no surprise that waste management can take very different forms under different circumstances. The most accepted and sustainable waste management schemes as a simple rule-of-thumb are those which give high respect for local needs and conditions without compromising on the objectives of environmental and resource protection.

Planning waste management therefore must be understood and performed as a task which takes a holistic view on all components of the waste management system including their potential dependencies from external conditions. Only this way realistic visions and targets will eventually be formulated and the most appropriate combinations of waste management measures and technologies and ways for efficiently employing them be found. Good knowledge on local particularities and constrains is also what enables planners and decision makers to compare the approaches and results in areas with similar conditions and to seek strategic co-operations or undertake benchmarking initiatives with them in order to enhance effectiveness in their own places. It is for all these reasons that an effort to look onto the territorial features of the planning area (country, region, county) and identify those differences which impact on the applicability and functionality of certain waste management measures should always be part of the planning process (Figure 3).

Figure 3: The interrelation of structural conditions and waste management planning



This effort can be facilitated by adopting a stratification approach which leads to a clustering of areas with similar conditions and requirements for the practical implementation of waste management.

The stratification is offering a generalized, comprehensive picture of waste management related features and/or framework conditions based on which certain waste management problems and planning issues can be approached more efficiently. Such a consolidated view is especially helpful for developing a more uniform perception on diverse waste management aspects based on a set of common criteria for different territories. This facilitates the process of identifying locally feasible concepts for the integrated management of various waste streams based on the best available experiences and trusted (technical) components under certain conditions and to adopt solutions which do not discriminate the people in areas of high similarity.

Following here, a proven method for area stratification shall be briefly presented.

Criteria

For the stratification concept it is important to establish critical features and a number of parameters, which describe the area and local situation in a realistic manner and from which a relevant influence in particular with regard to the generation of waste and organization of waste management services can be derived. Single or multiple parameters (see Table 2) can be grouped together to, for instance, the following six guiding criteria used for area stratification (classification):

1. Dwelling structure
2. Structure of heating
3. Commercial structure
4. Transportation network
5. Industrial structure
6. Regional particularities

The relevance and describing character of the above selection for different waste management aspects derive from the following considerations:

Dwelling structure

Two main features may basically be taken into consideration: the population (number and density) and the building aspect. Both are seen to have a direct relationship (e.g. a large population and high population density implies a dense building structure) so that, depending on what information are actually available, they can be used both or substitute one for another.

The criterion 'dwelling structure' stands representatively for a multitude of spatial significant attributes like typical building types linked with typical building sizes. They are characteristic for a certain development of infrastructure leading to different accessibility and typical configurations of open spaces. There are also strong interrelations with other aspects, such as socio-economic ones. Amount and composition of the generated waste and the possible arrangements for its collection are largely determined by these combinations.

Further waste management relevant aspects linked to this criterion are for example:

- composition and volume of waste to be expected per structure unit,
- possibilities for source separation and home composting of waste,
- appropriate collection arrangements (pick-up or bring system),
- suitable waste container types and sizes,
- appropriate waste charging schemes and tariff models.
-

Structure of heating

The manner of heating (individual solid fuel firing versus long-distance or centralised district heating) is crucial as far as it concerns the possibility that households may use another way to get rid of their waste (i.e. by way of combustion) than thru participation in collection.

Moreover, this criterion has significant influence on the physical amount and properties of the waste forwarded to collection (e.g. seasonal presence of ashes) and therefore on the suitable types of collection receptacles and waste treatment.

Further waste management relevant aspects linked to this criterion are for example:

- composition and volume of waste to be expected,
- suitable waste container types
(e.g. waste containers made from plastic are generally unsuitable for collecting waste which may contain hot ashes from the combustion of solid fuels),
- applicable options for waste treatment
(e.g. large amounts of ashes in the waste may demand other waste treatment options to be used).

Commercial structure

The intensity of commercial activities and diversity of industrial branches largely influences the amount and types of the waste generated and provides, in combination with the characteristics of dwelling, quite a reliable indicator for the socio-economic status/conditions of an area (e.g. employment, income situation, development potentials etc.).

Waste management relevant aspects linked to this criterion are for example:

- the expectable composition and volume of waste,
- possibilities for separate waste collection,
- suitable collection arrangements (pick-up or bring system),
- appropriate waste charging schemes and fee models (e.g. system of differentiated tariffs and adapted to capability to pay).

Transportation network

State and diversity of the transportation infrastructure determine the possibilities and intensity by which an area can be served with waste collection and the means by which the waste can be shipped away for treatment and/or recycling. Any means and solution of transportation is worth to be considered (in particular motorways, railways and navigable rivers) as each can offer very specific advantages for waste collection and transports.

Waste management relevant aspects linked to this criterion are for example:

- suitable collection arrangements,
- type of suitable vehicles and transportation chains,
- need for local disposal solutions, temporary storage facilities and transfer stations.

Industrial structure

The existence of certain industries and industrial facilities (e.g. paper mills, cement kilns, etc.) determines the possibilities for the recycling of certain components of the waste and influences whether there are opportunities for other forms of disposal and structure developments (e.g. co-incineration of waste, development of abandoned mines into deposits for certain waste types). It has also a link to transportation aspects (e.g. using industrial transporters for waste shipments) and the generation of certain types of waste in an area.

Regional particularities

The main regional particularities that have to be considered from the waste management point of view are:

- Tourism areas: Diverging developments of waste generation and composition as compared to the areas of the surroundings give these areas particular meaning in the waste management context. Typical are the fluctuation of the waste volume by season and the concentrations of commercial and organic wastes. For locations with a mixed spectrum of activities (tourism, industry and administration) the superposition of waste flows, one constant flow of waste produced by the common activities and permanent residents, and one seasonal flow of waste produced during peaks of tourism activities, can be critical.

  Tourism demands for certain standards as regards cleanliness and waste disposal opportunities but also brings in different attitudes and behavioral customs as waste is concerned. Whilst domestic tourism is accustomed to domestic patterns of waste disposal, foreign tourists may likely be familiar with advanced segregation schemes and separate collection and disposal provisions already. Tourist and touristic infrastructure concentrations thus require and enable a different spectrum of adoptable waste management options, in addition they can also influence the socio-economic situation and statutory leeway of the area significantly.
- Protected zones (nature conservation areas, national parks, national heritage sites, military reservations, etc.): These are areas protected by the Ramsar Convention and/or other national regulations. Their relevance for waste management in particular derives from limitations as far as the options for managing the waste (e.g. restrictions as to the establishment of waste management facilities or special permitting conditions), spectrum of commercial activities and the general development potentials of the area are concerned. Usually these areas are not permitted for any major economic activities, especially commercial/industrial ones.
- Topographic particularities (extremely mountainous land, wetland areas, etc.): The relevance for waste management lies in possible limitations for the collection and management of the waste e.g. due to restricted accessibility, long transportation distances, climatic influences and other barriers hindering waste treatment and disposal operations in their common forms. Also impacts on the general development potentials of the area are often noticeable, i.e. there may exist fewer options where to locate a waste management installation and to create a functional framework (access roads etc.) can be extremely burdensome. Topographic features on the other hand can make an area attractive to certain commercial activities (tourism, fishery) which require the development of very specific waste management solutions.
- Special zones (specially promoted areas, border influenced zones, etc.): Areas under a special status are usually marked by different development potentials but can also indicate a concentration of rather unusual phenomena with particular impacts on the local organisation of waste management. Special legal mechanisms or funding applying to these areas can stimulate developments which influence very particularly the waste management activities. Practically this may comprise a rather quick growth of the population figures, industry and infrastructure development or the

concentration of people and activities which follow specific customs and traditions. All that impacts for example on the waste generation and composition which hence can be very different from that seen in other parts the country. An intensive transboundary traffic and trade of second-hand and waste items can also trigger completely different waste situations within confined areas and give rise for considering them as separate zones with specific waste management needs and challenges.

Eventually, one should take note that a stratification (cluster) approach based on territorial structure conditions cannot finally replace the accurate information and data needed on the quantity, the composition as well as the chemical and physical properties of waste materials. Both are important for effective waste management planning and to determine waste-processing options and facility design eventually in proper ways.

Experiences show that in the absence of concrete data, municipalities oftentimes solicit design bids for waste-processing facilities based on county-made averages. As result of that, considerable deviations frequently occur between the design and the actual processing capacity of a facility.

Local data on the waste volumes and composition are thus **an indispensable element in** a process of detailed, **sustainable waste management planning**.

Practical application

Local data availability for each criterion is often a limiting factor to undertake a plausible and robust area stratification. Statistic offices, regional cadasters and various other sources on the other hand often deal with information which alone or in combination with others have the potential to provide evidence for the existence of a specific situation and can thus be a good reflection for certain criteria used for the stratification. These information take the function of “proxy” indicators or parameters that describe directly or indirectly the different criteria (see Table 2). With them the need to have extensive local investigations for each criterion can be drastically reduced and a picture of sufficient accuracy for the general waste management planning obtained. Here and particularly where feasibility studies are concerned the change and/or evolution of the chosen parameters for several years (past and forward) are also of significant meaning.

Table 2: Examples of guiding criteria which can be used for a waste management-related stratification concept and the describing parameters

Lead criteria	Describing parameters/data
Dwelling structure	Population figures
	Density of population
	Building types / structures
Structure of heating	Dimension of centralized heating system/ number of payers to it
	Share / number of households using own stove heating or solid fuel firing
Commercial structure	Production-oriented activities (registrations/turnover/number of employees)
	Service-oriented activities (registrations/turnover/number of employees)
	Tourism-related figures (registrations/ stays/turnover/number of employees)
	Existence /number of fresh markets
Transportation network	First class roads
	Secondary class roads
	Railway lines
	Navigable waterways
Industrial structure	Existence of large industrial centres or industrial agglomerations
	Existence/ number of sites/facilities with waste disposal potential
Regional particularities	Existence of tourist areas
	Existence of isolated areas
	Existence of national parks/protected areas
	Existence of specially promoted zones
	Existence of areas with local border traffic

Different types of available maps (land use maps, population maps, etc.) may have the same or similar data/parameter like those being used for a waste management-related area stratification as their basis. They can hence be helpful for the characterization of local situations especially when large areas need to be covered and/or other data are scarce. Eventually a map/GIS tool can also be good instruments to visualize the outcome of the stratification on the basis of the chosen criteria and the data available. Maps provide an opportunity to obtain a holistic image of regional waste management-related particularities and at the same time underline the fact that neither national territories nor smaller territorial units can be considered uniform bodies when it comes to waste management implementation. Clusters of similar framework conditions for practical waste management implementation can be made visible with such instruments at one glance, however.

This kind of an insight facilitates responsible authorities to understand the need to identify their potentials and priorities in waste management planning in accordance with the specific structure conditions in their area. It also helps them to identify areas where, due to similar preconditions, the planning and strategic orientation can be the same as in other areas or where co-operations or the formation of associations for joint waste management implementation would be most useful.

In waste management planning information in relation to dwelling structure aspects (e.g. types of building) have special significance as building characteristics often stand representatively for many factors impacting on waste management (e.g. waste amount and composition, space availability, state of infrastructure, etc.). Similar to the area stratification which incorporates the dwelling aspect as one principal criterion it is possible and recommended to also differentiate (classify) an area according to its different building structures. Typical for many countries and quite comparable frameworks for waste management are the following building structure types (see Figure 4):

Building structure type I – Estates of high-rise multi-unit residential buildings:

Blocks of multi-storey apartment buildings accommodating numerous living units and usually offering limited space for individual households to store and forward their wastes individually to collection.

Building structure type II – Attached multi-unit residential buildings:

Larger formations of apartment buildings in inner-city locations with a lower height (typically 3-6) storeys and a smaller number of living units per entrance, limited available space to store and forward wastes individually to collection due to the small distance to adjacent buildings and to kerbsides. Courtyard plantings, small green spaces occasionally exist.

Building structure type III – Detached multi-unit residential buildings:

Single, multi-storey apartment buildings in less densely built-up areas with yet a good infrastructure, occasionally furnished with small gardens and green space, still in closer distance to kerbsides.

Building structure type IV – Detached and semidetached one or two family buildings:

One or two family buildings in the less densely built-up areas (city outskirts or rural areas), partly in greater distance one to another and occasionally with bad infrastructure access or rather distant to kerbsides (especially in rural areas). Oftentimes with garden land and own fireplaces.

Figure 4: Different type dwelling structures

By taking some of the essential parameters given in Table 2 and the guiding criteria ‘structure of dwelling’, ’heating structure’, ‘commercial structure’ and ‘transportation network’ as those of particular relevance into consideration, a simplified but sufficiently good overall clustering of larger territories for the purposes of waste management planning can be attained. With that the planning area can, for example, be split up into three major area types with each type being known for its own requirements and implications for practical waste management. Useful as a model for that case is the following classification:

Urban centre type area:

areas with a high density of population, good and diversified transportation networks, strong and diverse commercial structure, good structure of municipal utilities, predominantly enclosed multistorey types of building (building types I, II and III);

Suburban type area:

areas with a medium or low density of population but developing districts of larger residential buildings (building types II, III and IV), developing structures of municipal utilities and a present transportation network and commercial diversity;

Rural type area:

areas marked by a medium and low density of population, mainly separate residential houses (building types III and IV), largely poor structures of utilities and commerce and low infrastructural development and/or diversity.

Table 3: Urban centre, suburban and rural type area characteristics as summarized for a WM stratification

	Urban centre type area	Suburban type area	Rural type area
Dwelling structure	- large density of population, in connection with the structure of population large, strongly diversified and concentrated volumes of waste can be expected; - generally little available space for the temporary storage of the waste within the households as well as for collection; - predominantly building types I, II and partly III	- the structure of population large, strongly diversified and concentrated volumes of waste can be expected; - available space for the temporary storage of the waste within the households as well as for collection, - developing areas with infrastructure under construction; - mainly building types II, III and partly IV.	- low density of population, in connection with the structure of population small and less diversified volumes of wastes per capita can be expected (mainly organic wastes); - little spatial constraints for waste storage within the households as well as for collection, - predominant are detached, single family houses, with bigger yards, building types: III and IV.
Structure of heating	- significant residential sectors with centralized long distance heating systems and occasionally small apartment heating systems; - older cities have residential sectors or houses with stove heating or with solid fuel firing,	- significant residential sectors with long distance centralized heating systems and more frequently small apartment heating systems; - older cities have residential sectors or houses with stove heating or with solid fuel firing,	- predominantly stove heating or solid fuel firing system; - selected areas (e.g. tourist places) with houses using individual heating system.
Commercial structure	- large variety of commercial activities and large spectrum of industrial processing per unit of area, - large diversity of waste types and concentrated volumes of specific types of waste, e.g. organic wastes (in fresh market places), paper (in office areas), packaging (in commercial areas);	- Lower variety and intensity of commercial activities and lower spectrum of industrial processing per unit of area, - yet a large diversity of waste types and concentrated volumes of specific types of waste like in the urban centre type but with the highest amount being packaging	- predominantly agricultural activities with only occassionally other types of commercial activities (small size local workshops and industrial activities (repair agriculture equipments, shoes, etc.);
Transportation network	- good connection with the motorways, national and local roads and railways network; rather often connected with navigable waterways.	- good connection with the motorways, national and local roads and railway network; - occassionally connected with navigable waterways.	- Often bad and narrow access ways occasionally connected to the railway network, more seldom to navigable waterways.

The criteria and area classification presented above are most representative for European countries but may have to be modified for other regions. Generally valid for the stratification approach should be the conclusion that areas of the same type (strata) in principle offer similar opportunities for waste management planning and implementation.

Complementary components which deserve special attention after that point are the regional particularities which may lead to really distinct challenges for practical waste management implementation in areas even when they fall into the same category. These particularities of an area may create specific constraints (for example restrictions due to local climate) or render the place as particularly suitable for special technical applications and waste management measures (e.g. pneumatic system, lockhopper or chamber system for waste collection, varying cost recovery strategies).

Options for the treatment of principal fractions of the municipal waste considering the local framework

Introduction

It is a common practice and part of the concept to achieve a sustainable environmental management to plan the management of waste taking the local framework, present conditions and state with regard to waste management, formulated waste management objectives and the (technical) options available to achieve them as the main basis. Programmes and strategies which were developed for environmental protection and the waste sector at national level oftentimes provide the necessary information and entrance points for this task. The information tool presented here aims to support planners and decision makers in their search for the procedures and technical options available to design an integrated waste management system and realise the collection, transportation, utilisation and disposal of the waste in the most efficient and cost-saving manner. The information provided over this tool contain practical tips and remarks concerning the applicability of a certain process or technology in view of specific local requirements and limitations that might be imposed on them from certain regional particularities.

To obtain an overall picture and cover most of the aspects a good waste management planning would have to incorporate, some additional statements have been added on cost recovery issues and financing possibilities, possible measures to prevent the generation of waste and to optimize treatment needs and recycling. Application areas and suitability of approved technologies and equipment with regard to the management of different waste streams and existence of certain framework conditions are characterized at the entrance to the technical descriptions contained in each fact sheet. However, technologies and equipment are just parts of an overall system whose effectiveness and success needs to be guaranteed under varying environments and for a multitude of different waste material and sources of generation. It is therefore the greatest challenge in planning to come to a selection of the individual technical elements appropriate to achieve given waste management targets vis a vis the local conditions and needs and to fit them together to obtain a complete, integrated and functional management solution for all the different waste streams generated by society in a certain area. A waste management system deriving from such an approach would not only set a good example for the intelligent combination of information as provided in this documentation but should have all chances to be well accepted and successful in meeting the ambitious environmental objectives of a modern waste management policy.

Treatment options for the different fractions of the municipal waste stream

With examples of purposefully assembled waste management solutions that draw from the technologies and details described in the individual fact sheets and other technical sections, users are given more than just a pool of information from which the most interesting details can be chosen by them and set into a context to each other. The examples shall demonstrate how the data provided can be used in designing an integrated waste management system. A first step towards this goal is that different single options for the handling of the various waste fractions of the municipal solid waste are being explained whereby the incorporated technical components may get affirmed through links to the respective technologies.

The objectives and basic directions of the waste management legislation in Europe (see section on "Guiding principles of European waste policy") provided the principal orientation for selecting these technical options. They stand for European best practices in municipal waste management and the commitment of Germany and the EU member states to depart from the conventional route of waste disposal through landfills as the worldwide most widely availed waste management solution until to date. The wider spectrum and variability of *options* for one and the same fraction of municipal waste shall illustrate the existence of various alternatives to handle a waste and the possibilities this entails to make consideration of local conditions and particularities in the planning process. The necessity to dispose of different treatment options derives from the rising complexity of the waste at global scale and the ultimate goal that our natural resources must be saved and waste more effectively be collected and utilised for this. It is a very important fact in this respect that also the waste generated in the yet less developed regions of the world, including those in remote and very rural areas, tends to show material compositions and concentrations of hazardous substances now which have so far been typical for urban dwellings only. What however remains at the same time are the badly developed infrastructure and conditions for a proper waste management in these areas which obstruct the possibility for adequate reactions and precautions and lead to even new forms of environmental risks and destruction. When defining the different options for the treatment of different types of waste, a particular attention was paid on the material separation at source. In that way a good amount of awareness shall be created for the fact that waste separation at source is very often a pre-condition to avail of different treatment options and that already existing forms of waste diversion and material recovery still have their meaning and should be maintained and enhanced even where a modern waste management system is going to replace a rather outdated or traditional model of waste management.

The presentation of the different treatment *options* is taking its start from the main fractions which make up the municipal solid waste stream. By following this approach, the available alternatives within the scope of one specific waste stream, such as packaging waste can be described. A separate collection and transportation of each single material fraction in the municipal waste as the beginning of a material specific treatment won't be a feasible model though. While separate treatment schemes might indeed be applicable to specific waste fractions, one has to consider that a single technical option can serve different waste fractions at once and in this way most efficiently be employed. Waste incineration and mechanical-biological waste treatment are illustrative examples for this. Both technologies allow treating mixed household waste and bulky waste at the same time. Obtaining a profound knowledge of each treatment option is thus one part of the planning job. The other part is to get a complete picture on waste generation and develop a holistic view on the entire municipal solid waste stream and for the useful matching of the various options available to have this stream including its different components managed in the most efficient and environmentally-benign way. To facilitate both, treatment options for the different fractions of the municipal waste are first illustrated individually whereas examples of their useful combination to obtain integrated, all embracing waste management systems adapted to different local environments make up another section of this information tool.

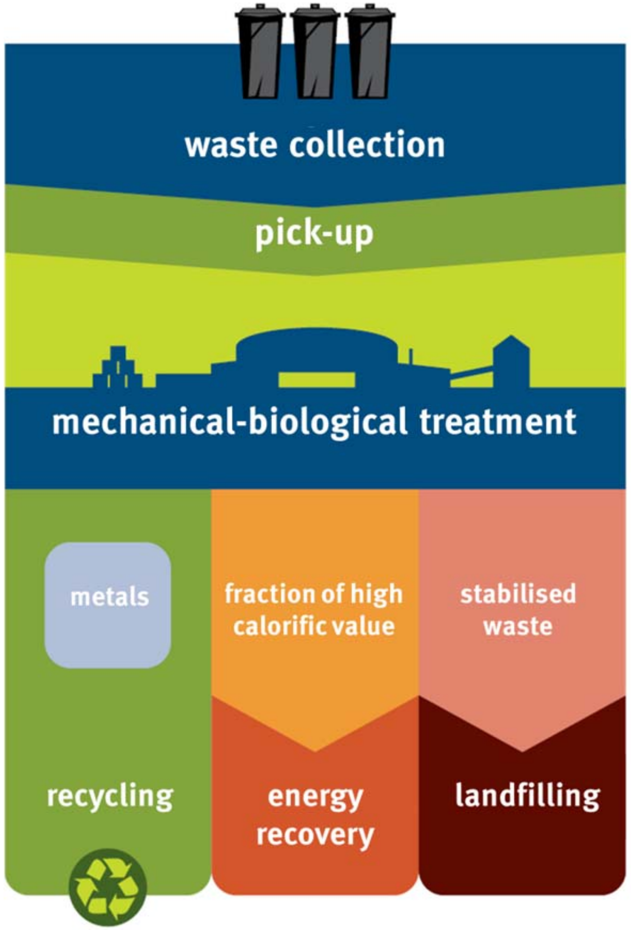
The compilation of these overall ***scenarios*** for an integrated waste management can be regarded as a final synthesis of the information provided over this tool. To follow the logic behind this synthesis it will be useful that users first make themselves acquainted with the description of technical options for the treatment of the single waste fractions of municipal waste. The links to these descriptions can be found in the last column of the following table and have been further integrated in the scenarios as appropriate.

Table 1: Overview of main technological options available for the treatment of municipal waste fractions

Waste fraction	Management options		Option
	Collection mode	Way of treatment	
Household waste	collected as mixed residual waste	sent to mechanical-biological treatment	1
	collected as mixed residual waste	sent to incineration	2
	collected as mixed residual waste	sent to mechanical-biological treatment via waste transfer station	3
	collected as mixed residual waste	sent to incineration via waste transfer station	4
	separate collection of the dry (recyclable) components and of the (wet) remainder	dry components sent to a sorting facility, remainder is forwarded to mechanical-biological treatment or to incineration	5
Organic/ bio waste	collected separately at source	sent to a composting facility	6
	collected separately at source	sent to a facility for biodigestion	7
Packaging waste	collected in a mix separately at source	sent to a sorting facility for the segregation and recovery of recyclables	8
	different material components collected separately at source	sent to different sorting facilities for a refining and processing for recycling	9
Bulky waste	collected in a mix separately at source	sent to incineration	10
	collected in a mix separately at source	sent to a sorting facility for the segregation and recovery of recyclables	11
	collected in a mix separately at source	sent to mechanical-biological treatment	12
C&D waste	collected in a mix separately at source	sent to sorting facility for segregation and generation of usable material fractions	13
	different material components collected separately at source	partly on-site processing and utilisation, remainder sent to external recyclers	14

Treatment option 1: Mechanical-biological treatment of household waste

Flow chart	Description

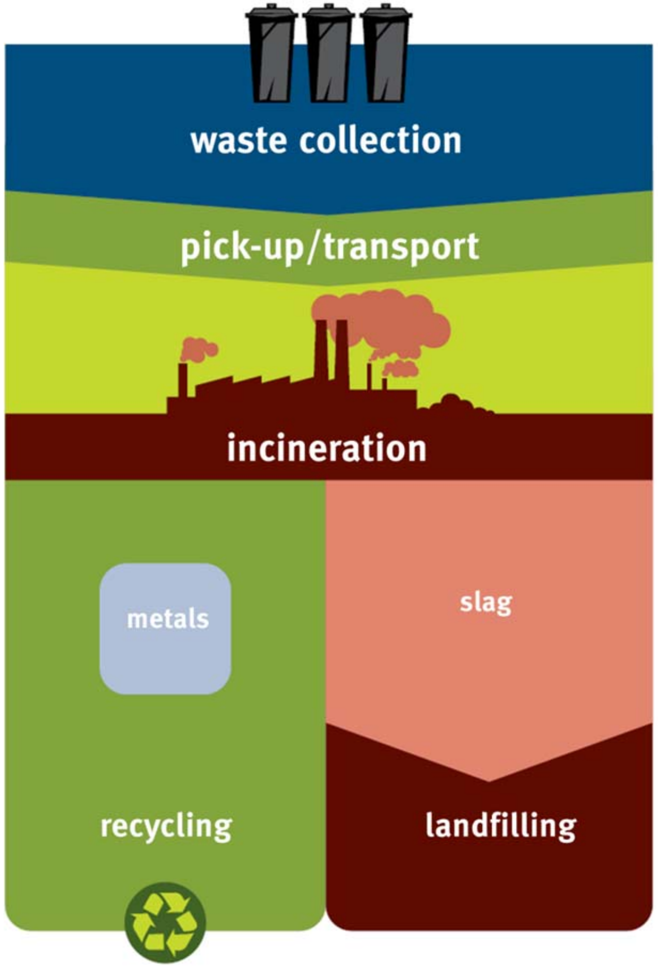


The household waste is collected as mixed residual waste from the waste generators in the receptacles provided for this purpose. These can be mobile waste containers and especially for smaller waste quantities, standardized bags and sacks, which are also suitable in cases of a system independent waste collection. Usually, the collected waste gets picked up by one of the different types of refuse collection vehicles, which are of rear end loaded, front loaded or side loaded type and available in various modified versions in order to fit to differing conditions. The delivery of the waste to the treatment facility by these vehicles can be done and is efficient as well, when the distances are rather short.

The waste is then treated by mechanical and biological processes in a mechanical-biological treatment facility. The goal is a reduction of the overall weight and volume as well as the stabilisation of the waste before its final disposal. During the treatment recyclable materials (mainly metals) and a combustible fraction are separated from the remaining waste stream by mechanical processes, while biological processes (either rottening processes or anaerobic digestion) achieve the drying and degradation of the waste material and thus its deactivation. Depending on whether a treatment (MBT)-scheme or a stabilisation (MBS-) scheme is pursued, a stabilised material suitable for landfilling or a dried material for combustion is the main outcome, respectively.

The recovered recyclables can be further processed by the respective recycling industries, the combustible fraction used for energy recovery and the stabilized residues deposited in a sanitary landfill.

Treatment option 2: Incineration of household waste	
Flow chart	Description

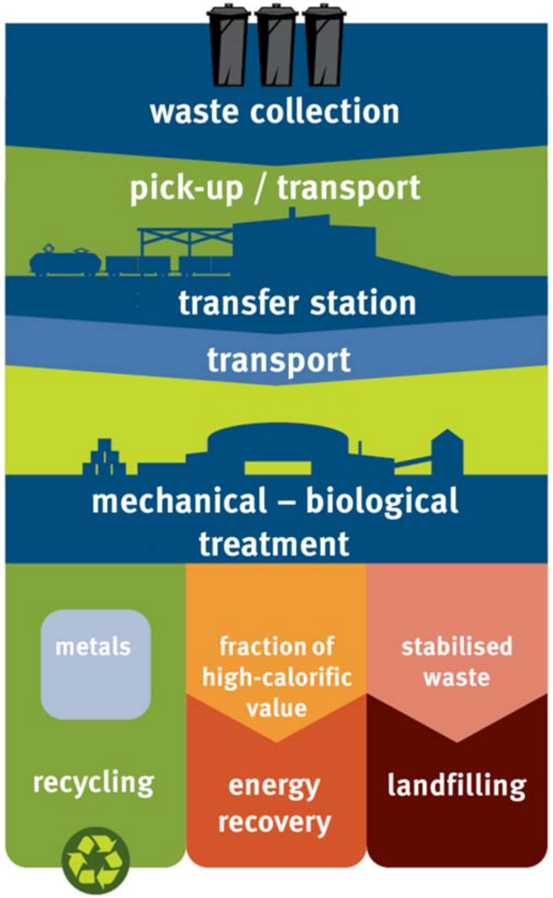


The household waste is collected as mixed residual waste from the waste generators in the receptacles provided for this purpose. These can be mobile waste containers and especially for smaller waste quantities, standardized bags and sacks, which are also suitable in cases of a system independent waste collection. Usually, the collected waste gets picked up by one of the different types of refuse collection vehicles, which are of rear end loaded, front loaded or side loaded type and available in various modified versions in order to fit to differing conditions. The delivery of the waste to the treatment facility by these vehicles can be done and is efficient as well, when the distances are rather short.

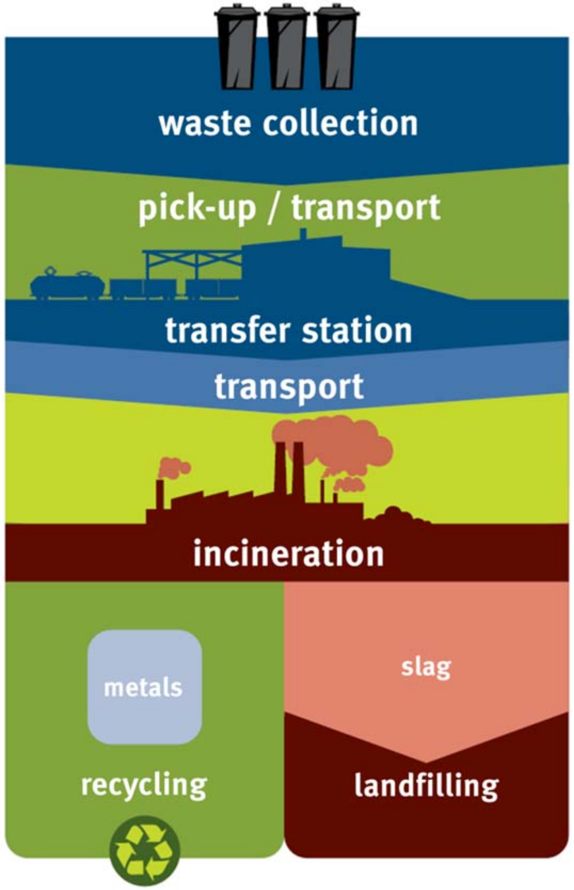
The waste is treated thermally in a waste incinerator. The incineration process aims at reducing the waste volume and risk potential through oxidation and mineralization, offering at the same time the opportunity of energy recovery (both energy and thermal). Various technologies for waste incineration are available; principal techniques are the grate combustion, fluidized bed combustion and the oscillating kiln. What technique will be selected is among others influenced by the waste composition and quantities. All technologies require installations for flue gas cleaning in order to ensure environmental protection standards to be met. Waste incineration is especially recommendable for places where large and steady amounts of waste of varying composition need to be treated and users for the generated energy exist (whereby the latter renders the incineration process to be economically more efficient). Also rather high investments must be considered.

Metals can be recovered for recycling from the ashes, the generated slag deposited at sanitary landfills whereas fly ashes and filter dust may have to go to hazardous landfills.

Treatment option 3: Mechanical-biological treatment of household waste after delivery via a transfer station

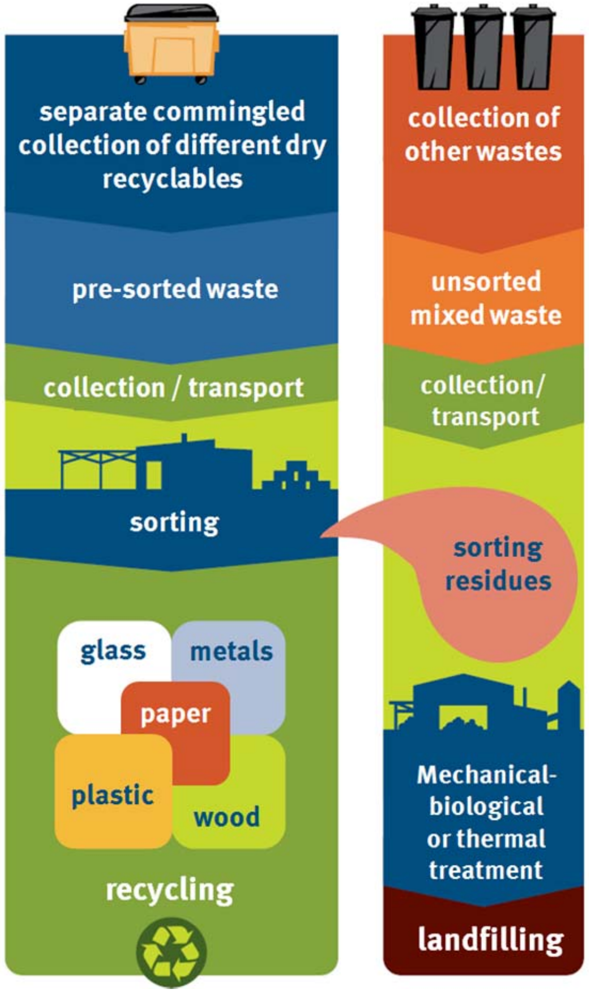
Flow chart	Description
	The household waste is collected as mixed residual waste from the waste generators in the receptacles provided for this purpose. These can be mobile waste containers and especially for smaller waste quantities, standardized bags and sacks which are also suitable in cases of a system independent waste collection. Usually, the collected waste gets picked up by one of the different types of refuse collection vehicles, which are of rear end loaded , front loaded or side loading type and available in various modified versions in order to fit to differing conditions. A transfer station ensures the accumulation, temporary storage and reloading of the waste delivered by the collection vehicles in view of the need for long distance transportation to the next available treatment facility. The transfer process may also include a treatment of the delivered waste in form of a volume reduction by compression aimed at the optimisation and lowering of the costs for the long distance transportation. Long distance transporters like semitrailer trucks with walking floor system or swap body (container) systems can be used in the extended transportation chain. The treatment of the waste is performed in a centralised mechanical-biological-treatment facility, which is located in larger distance from the original collection area. The process of the mechanical-biological-treatment itself has the same characteristics as outlined for option 1. Also the outcome and options available for the further use of the recovered materials and for the final disposal of the process residues are the same.

Treatment option 4: Incineration of household waste after delivery via a waste transfer station

Flow chart	Description
	The household waste is collected as mixed residual waste from the waste generators in the receptacles provided for this purpose. These can be mobile waste containers and especially for smaller waste quantities, standardized bags and sacks, which are also suitable in cases of a system independent waste collection. Usually, the collected waste gets picked up by one of the different types of refuse collection vehicles, which are of rear end loaded, front loaded or side loaded type and available in various modified versions in order to fit to differing conditions. A transfer station ensures the accumulation, temporary storage and reloading of the waste delivered by the collection vehicles in view of the need for long distance transportation to the next available treatment facility. The transfer process may also include a treatment of the delivered waste in form of a volume reduction by compression aimed at the optimisation and lowering of the costs for the long distance transportation. Long distance transporters like semitrailer trucks with walking floor system or swap body (container) systems can be used in the extended transportation chain. The treatment of the waste is performed in a centralised waste incineration facility which is located in larger distance from the original collection area. For the incineration process itself the same technologies and principal framework as regards incineration objectives, suitable location and costs as outlined in (option 2) apply. Also the outcome and options available for the further use of the recovered materials and for the final disposal of the process residues are the same.

Treatment option 5: Separate collection of the dry (recyclable) waste fraction followed by material separation in a sorting plant

Flow chart



Description

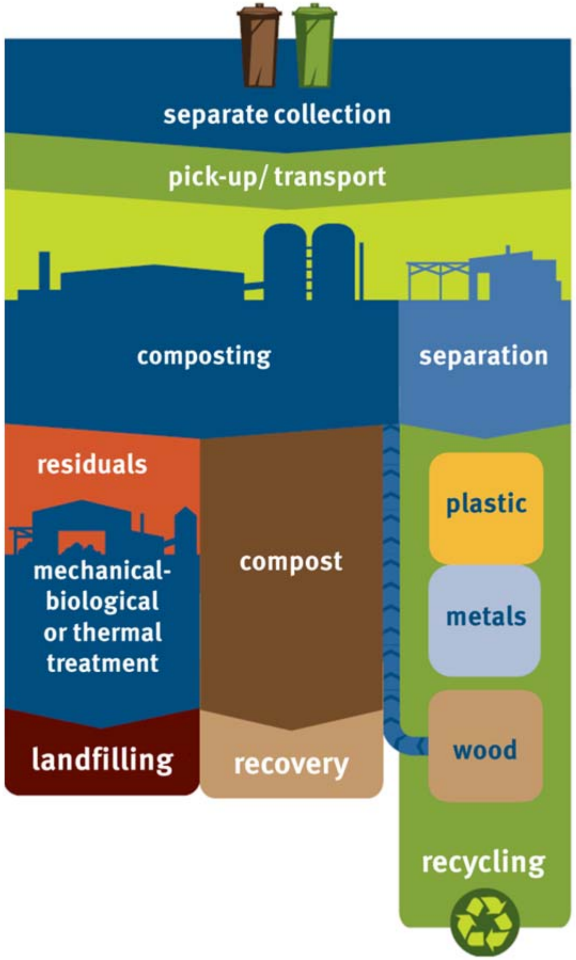
With a purposeful separation of recyclable materials from the rest of the household waste, a significant reduction of the quantity of waste requiring treatment and final disposal and a recovery of secondary raw materials can be achieved altogether. Demanding a too intensive waste segregation or extending the obligation for source separation to all recyclable materials in the household waste may not only reduce the acceptability of households to participate in source separation efforts but also increase collection costs. The concept of a separate "Bin for dry (recyclable) wastes" is a suitable and cost-efficient method for the collection and recovery of recyclable materials, however. The concept proposes that households split their waste into two separate fractions only. These are 1. Dry (recyclable) materials and 2. Other (mostly wet) wastes.

The collection of the two fractions can be realized via a pick-up scheme using different types of collection receptacles (e.g. <u>mobile waste container</u>, <u>standardized/non-standardized bags or sacks</u>) or with the help of a bring scheme mainly based on a system of <u>bring banks</u>. The pickup of the collected waste in both schemes can be done with <u>rear-end-loaded</u> or <u>side loaded</u> collection vehicles. The dry (recyclable) fraction would then go straight to a sorting plant whereby the collection vehicles also undertake the transport. In a <u>sorting process</u> involving mechanical processes including manual and/or automated sorting recyclable materials will be separated and processed into different fractions for recycling and further utilisation. The most prominent fractions are glass, paper/cardboard, wood, Fe and non-Fe metals and plastics. For the fractions paper/cardboard, non-Fe metals and plastics a sorting into different marketable grades is recommended. Sorting residues can be treated as described for <u>option 1</u> or <u>option 2</u>.

The fraction of other wastes is going to be separately collected and picked up in the same way like the dry (recyclable) waste. The treatment routes can be the same like those used for the sorting residues, i.e. <u>option 1</u> or <u>option 2</u> may apply.

Treatment option 6: Composting of separately collected biodegradable waste

Flow chart	Description



The separate collection of biodegradable waste at source can be done using mobile waste containers or standardized or non-standardized bags or sacks whereas latter are also suitable in cases of a system independent waste collection. Usually, the collected waste gets picked up by rear end loaded or side loaded refuse collection vehicles which are available in various modified versions in order to fit to differing conditions. The delivery of the waste to the treatment facility by these vehicles can be done and is efficient as well, when the distances are rather short. Larger amounts of biodegradable waste that arise for example in form of green cuttings, garden or kitchen waste can also be collected and transported in roll of or skip container types or directly loaded on semitrailer trucks with walking floor system.

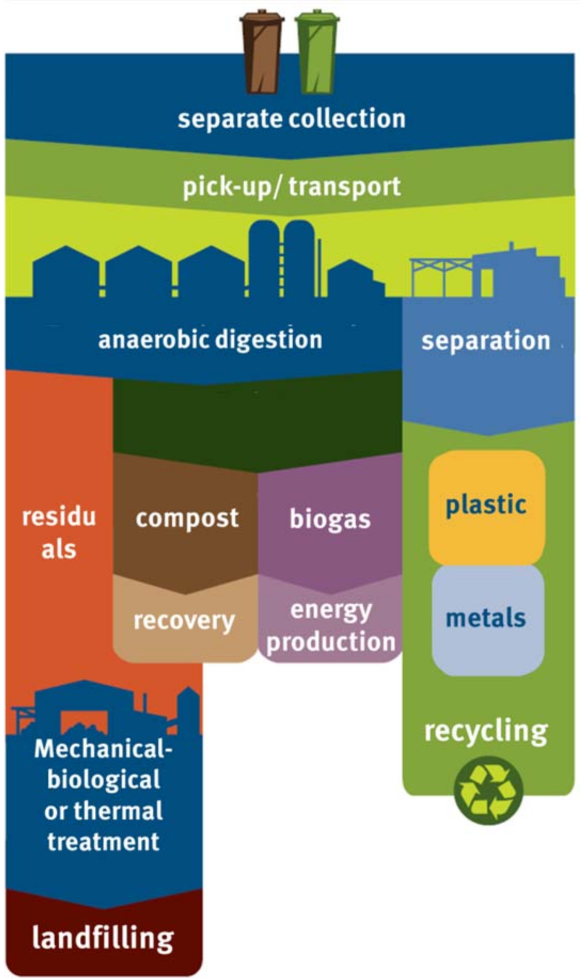
The biodegradable waste is delivered to composting facilities, where it is used for the production of a humus product that can be applied for soil improvement in agriculture and other sectors. In screening processes before and after the composting disturbing, non-biodegradable materials and remaining recyclables are being separated. Depending on the available space and other framework conditions windrow composting or encapsulated composting schemes can be used for the composting process itself.

Aside from the compost product as the main outcome, screening residues are being generated. These residues suit for an industrial co-combustion, however, further treatment by stabilisation or incineration before landfilling as described in option 1 or option 2 might apply as appropriate alternatives. The stabilised residues can be finally deposited at sanitary landfills or even utilised there as a material for a qualified landfill cover.

Umwelt Bundesamt

Treatment option 7: Treatment of separately collected biodegradable waste by anaerobic digestion

Flow chart	Description



The separate collection of biodegradable waste at source can be done using mobile waste containers or standardized or non-standardized bags or sacks whereas latter are also suitable in cases of a system independent waste collection. Usually, the collected waste gets picked up by rear end loaded or side loaded refuse collection vehicles which are available in various modified versions in order to fit to differing conditions. The delivery of the waste to the treatment facility by these vehicles can be done and is efficient as well, when the distances are rather short. Larger amounts of biodegradable waste that arise for example in form of green cuttings, garden or kitchen waste can also be collected and transported in roll of or skip container types or directly loaded on semitrailer trucks with walking floor system.

The biodegradable waste is delivered to facilities where its anaerobic digestion is undertaken in a dry or wet process scheme. The anaerobic digestion process decomposes the organic material in the relatively absence of oxygen, resulting in biogas, that can be used to generate energy.

Aside from biogas generation, the process must be combined downstream with a composting process, or a biological waste treatment (biological stage of a mechanical-biological treatment process only) in view of preparing the semi-solid residues that remain after the digestion for landfilling.

In screening processes before the anaerobic digestion, disturbing, non-biodegradable materials and remaining recyclables are being separated. The options available for the final disposal and/or utilisation of all residues remaining after these processes are principally the same as outlined in context with option 6.

Treatment option 8: Mixed packaging collection and subsequent separation in a sorting facility

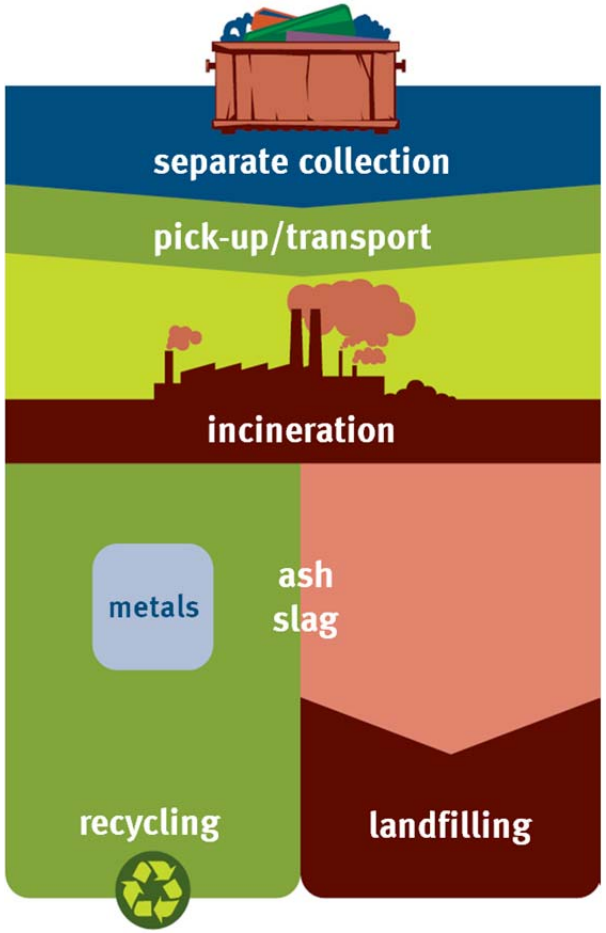
Flow chart	Description
	The amount of packaging waste generated is in continuous increase. The packaging fraction contains almost entirely materials that can be recycled. That's why packaging waste is being separately collected from other wastes. Sorting technologies which allow the separation of the different materials in preparation to recycling make the collection of mixed packaging possible. For the collection from households (pick-up system) mobile waste containers, standardized or non-standardized bags or sacks can be used, a bring system for collecting this waste can be implemented with special skip container systems, or by placing drop-off stations. The pickup from the households is done using the rear end loaded or side loaded type of refuse collection vehicles, the front loaded vehicle type can additionally be used where the large container types (>1000 ltr.) are used. All vehicle types are available in various modified versions in order to fit to differing conditions. Large container systems and drop-off stations are serviced from vehicles with the appropriate chassis and loading equipment. This can include trucks carrying swap bodies or semitrailer trucks with walking floor. The trucks forward the collected waste directly to a sorting facility. In a dedictaed sorting process the waste is separated by various mechanical processes, which may also include manual segregation, into the different material fractions as being demanded by the recycling industries. The output depends in quality and composition on the complexity of the sorting plant and actual market demands, whereby pure fractions of glass, paper, ferrous and non-ferrous metals and plastics are being most commonly generated for recycling. The residual components consisting of undesired and non-recyclable waste materials must be further treated as being indicated in option 1 or option 2.

Treatment option 9: Collection of source separated packaging waste with quality improvement in sorting facilities

Flow chart	Description
	The amount of packaging waste generated is in continuous increase. The packaging fraction contains almost entirely materials that can be recycled. That's why packaging waste is being separately collected from other wastes. In view of an optimised quality of the collected packaging material and to facilitate recycling and reduce sorting costs a separate collection of different, source separated packaging materials can be undertaken. For such separate collection specially marked respectively coloured mobile waste containers and bags or sacks can be used in a pick-up system or specially modified drop-off stations set up at centralized locations. Very efficient in this respect are also take-back or recycling stations where the delivered waste can be stored right away in roll of or skip containers. The pickup of mobile containers or sacks is done using the rear end loaded or side loaded type of refuse collection vehicles, the front loaded vehicle type can additionally be used where the large container types (›1000 ltr.) are used. All vehicle types are available in various modified versions in order to fit to differing conditions. Large container systems and drop-off stations are serviced from vehicles with the appropriate chassis and loading equipment. This can include trucks carrying swap bodies or semitrailer trucks with walking floor. The trucks forward the collected waste directly to material specific sorting facilities. The sorting processes separately for glass, paper and plastics consist of mechanical and opto-mechanical operations whose aim it is to clean the delivered materials from disturbing components and pollutants and sometimes to generate ready-to-recycle fractions. The residual component made up of undesired and non-recyclable waste must be further treated as being indicated in option 1 or option 2.

Treatment option 10: Incineration of collected bulky waste

Flow chart	Description



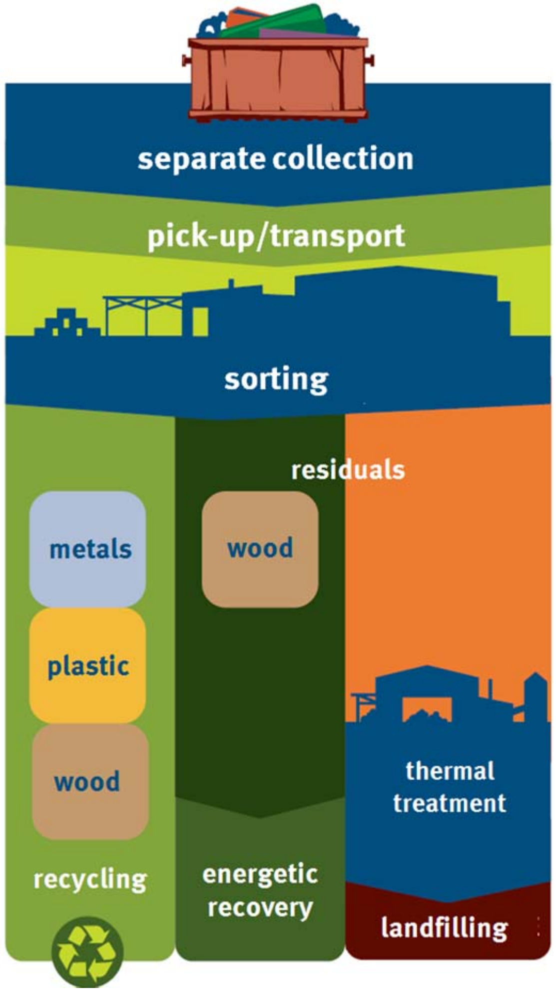
For the bulky waste generated by households and commercial agents, the most practical way of collection is the separate collection in a pick-up system. Considering the large volume that characterizes the bulky waste, roll off containers or skip container systems can be used for collection as well as for the direct transportation to the treatment facility. Also possible is a non-system dependent collection with the waste being forwarded loses to the kerbside or to central collection points. Very useful in this respect are collection yards/recycling stations.

For picking up the loose waste from the kerbside rear end-loaded vehicles can be used. Generally possible is the use of different platform trucks and of transporters with the chassis and equipment to carry the above specified container types, or trucks carrying swap bodies and semi-trailer trucks with walking floor, respectively.

Bulky waste contains combustible materials to a large proportion. This makes the incineration of this waste possible. Where incineration facilities are within reach, the collected waste can therefore be forwarded to an incineration facility for thermal treatment. Before being fed into the incinerator, the material mix has to undergo some mechanical processing in order to remove disturbing items (such as large metal items) and to make it fit for the incineration process (mainly through comminution). The principal technology used for the incineration of this waste type is the grate combustion. Producing RDF from bulky waste materials and using it in industrial co-combustion processes for energy generation is a preferential concept.

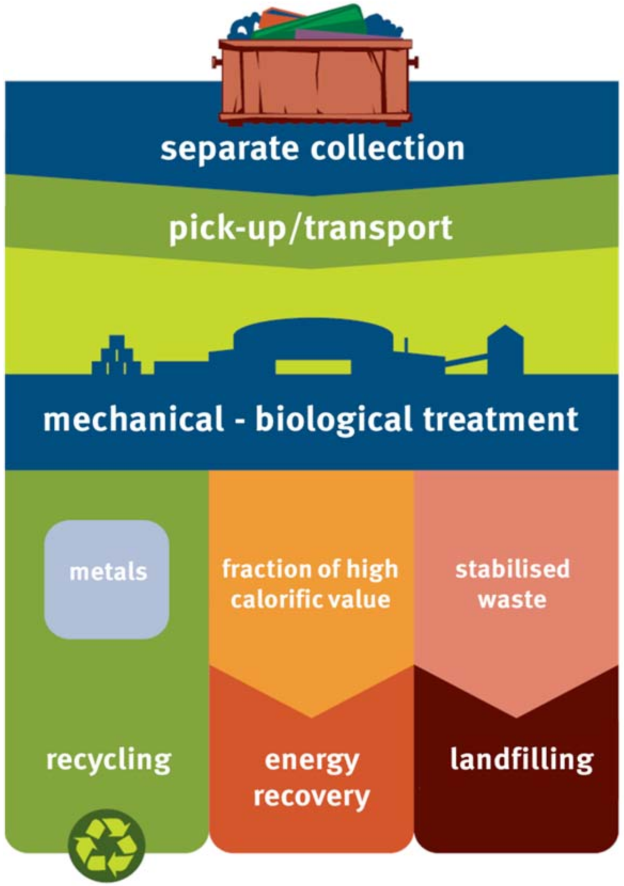
As far as all other aspects are concerned, the incineration process has the same characteristics as outlined in option 2.

Treatment option 11: Collection of bulky waste and subsequent sorting

Flow chart	Description
	For the bulky waste generated by households and commercial agents, the most practical way of collection is the separate collection in a pick-up system. Considering the large volume that characterizes the bulky waste, roll off containers or skip container systems can be used for collection as well as for the direct transportation to the treatment facility. Also possible is a non-system dependent collection with the waste being forwarded loose to the kerbside or to central collection points. Very useful in this respect are collection yards/recycling stations. For picking up the loose waste from the kerbside rear end-loaded vehicles can be used. Generally possible is the use of different platform trucks and of transporters with the chassis and equipment to carry the above specified container types, or trucks carrying swap bodies and semi-trailer trucks with walking floor, respectively. Sorting the waste will create the possibility for the recycling or a secondary use of certain materials, such as wood, metals, glass and certain plastics which are contained in this type of waste. The sorting operations consist of mechanical separation processes which may also include manual segregation. Comminution of the waste once freed from disturbing items at the beginning of the processing in sorting facilities supports the material recovery process. Metals, plastics and the wood fraction can be forwarded to material recycling (e.g. wood in production of particle board). Plastics, wood and other combustible components (e.g. leather, textile, cardboard) suit for the use as substitute fuel and for energy generation in industrial co-combustion. The residual component consisting of undesired and non-recyclable waste materials has to be further treated as being indicated in option 2 .

Treatment option 12: Mechanical-biological treatment of collected bulky waste

Flow chart	Description



For the bulky waste generated by households and commercial agents, the most practical way of collection is the separate collection in a pick-up system. Considering the large volume that characterizes the bulky waste, roll off containers or skip container systems can be used for collection as well as for the direct transportation to the treatment facility. Also possible is a non-system dependent collection with the waste being forwarded loose to the kerb-side or to central collection points. Very useful in this respect are collection yards/recycling stations.

For picking up the loose waste from the kerbside rear end-loaded vehicles can be used. Generally possible is the use of different platform trucks and of transporters with the chassis and equipment to carry the above specified container types, or trucks carrying swap bodies and semi-trailer trucks with walking floor, respectively.

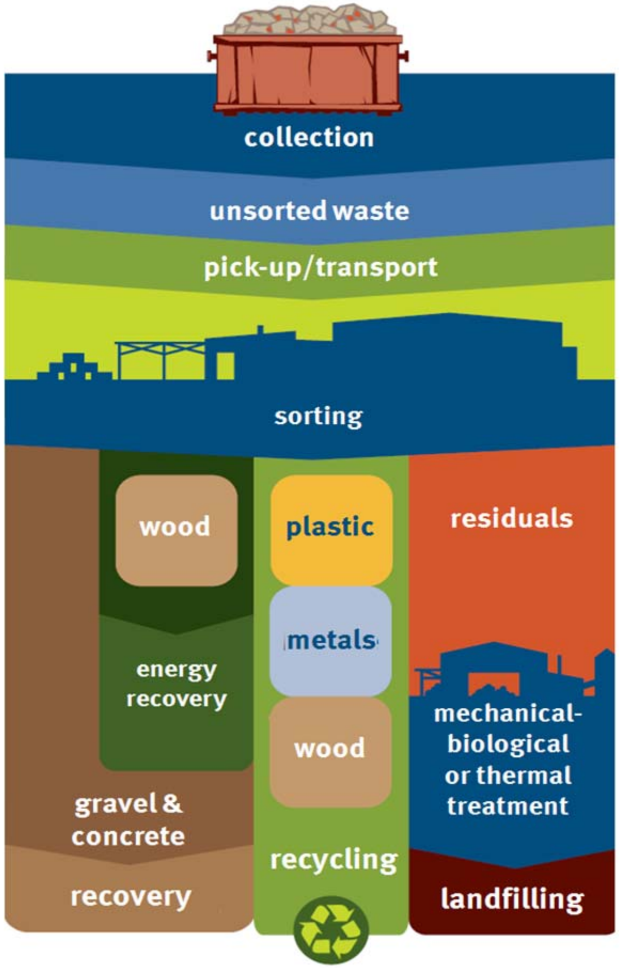
Mechanical-biological treatment plants which generate a refuse derived fuel (RDF) from their waste input, and especially those operated as a MBS-scheme, can handle bulky waste as well. The essential part for treating this waste type is the mechanical process, however. In this process stage, the waste is shredded and the non-combustible, recyclable materials (especially metals) are being separated from the waste stream. The remaining materials make up a high-calorific fraction that can be separated before the biological treatment stage as a refuse-derived fuel product. This fraction can also be used in mixture with the material which is being dried in a biological stabilisation process with the result that the calorific value of the output stream increases. The obtained material gives a refuse derived fuel product as well. RDF-products are used in substitution of conventional fuels for industrial co-combustion (for example in cement kilns and coal-fed power stations). For this the RDF-product is often compressed to pellets.

The recovered recyclables can be used by the respective recycling industries, stabilized matter and (inert) process residues residues can be deposited at a sanitary landfill.

Umwelt Bundesamt

Treatment option 13: Collection of mixed C&D waste and subsequent sorting

Flow chart	Description



The construction and demolition (C&D) waste is both bulky and heavy and usually generated by specific activities independent of other waste streams. The waste itself is usually made up of large portions of similar material whereby mineral substances (e.g. soil, bricks, concrete) and wooden components still form the largest parts, nowadays very much on the growth are composite materials. The conditions at the demolition site (available space, technical possibilities and time) are not always favourable enough for a separation of the different waste materials at source. Commingled collection of the material belonging to the two major fractions, e.g. mineral rubble on the one hand and the remaining materials on the other thus remains one way of handling C&D waste. Depending on the generated quantities and the space availability at the building site container with a large capacity, i.e. skip or roll off containers or big bags are used for the collection.

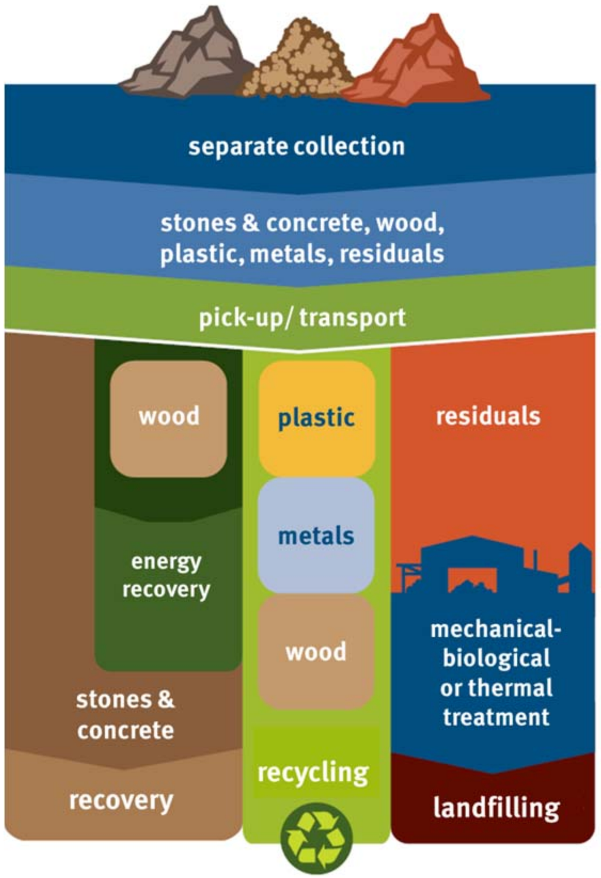
The pickup and transportation of the containers and/or big bags is done by transporters with the necessary chassis and loading equipment or any suitable platform truck. Swap bodies and semitrailer trucks with walking floor can be used as well.

The waste is received by sorting facilities, which can be mobile, semi-mobile or stationary aggregates in various configurations for the auto-mated sorting, crushing and screening of the waste. By means of these mechanical operations, the mixed input stream is being separated into different material fractions, such as wood, metals, plastics and mineral components of various size classes. Stone, soils and concrete can be used right away as secondary material in other construction activities. Parts of the wood and plastics which do not match the quality requirements for recycling can become fuel products for industrial co-combustion. The residues arising from the sorting process may have to be further treated (delivered to mechanical processing for RDF production) though incineration by grate combustion generally gives the more economical solution.

The final disposal of all ultimate process residues is done on sanitary landfills, purely mineral C&D waste is sent for storage or disposal to an inert landfill.

Treatment option 14: Separate collection of source separated C&D materials

Flow chart	Description



Construction and demolition (C&D) waste is usually generated by specific activities independent of other waste streams and made up of large portions of similar material whereby mineral substances (e.g. soil, bricks and concrete) and wooden components form the largest parts. Nowadays very much on the growth are also composite materials. To increase the recovery and recovered quality of secondary materials from construction and demolition waste and widen the possibilities for their utilisation (minimising down-cycling), a source separation of the different waste materials and their separate collection should be undertaken. A good management of the building site and/or a controlled dismantling are necessary pre-requisites for this.

Generally used for separate collection are container types with a large capacity, i.e. skip or roll off containers or big bags. The large capacity containers offer the possibility of stockpiling the wastes until they can be efficiently further transported. An advisable scheme for material fractions collected from building sites is to segregate treated (e.g. painted, coated, impregnated) from untreated wood, ferrous from non-ferrous metals, the separation of different mineral components (e.g. bricks, concrete, ceramics), plastics, combustibles, and a fraction of other inseparable components. Of utmost importance is the separation of contaminated material (such as materials with PAH concentrations) from the rest. In the demolition of industrial sites, various working materials (e.g. lubricants, fuels, coolants, etc.) must also be considered and kept separate.

The pickup and transportation of the collection receptacles is done by transporters with the necessary chassis and loading equipment or any suitable platform truck. Swap bodies and semi-trailer trucks with walking floor can be used as well.

The preferable way is the direct (re-)utilisation of the recovered material on-site or in other sectors with a minimum of processing. Processing for further use and recycling as well as the treatment of the residuals basically follow the same patterns as outlined post-sorting in option 13.

Application of waste treatment options in the local context

Possible scenarios for the handling of waste in typical area structures

With the scenarios following hereafter, examples of practical relevance have been constructed which shall give planners and decision-makers a feeling how local area characteristics and circumstances may influence the choice of applicable waste management schemes and technology. Starting from the different waste streams municipal waste management is usually tasked to handle, treatment options have been purposeful arranged with the aim to show what could be an integrated concept for the management of these wastes under the specific conditions of a certain type area.

The results are meant to provide guidance for those in charge for local waste management implementation on how to get local conditions and the needs arising from the national environ-mental legislation and waste management goals considered in a planning framework which eventually allows those structures and technical solutions to be adopted through which the generated wastes can be managed most effectively, at reasonable costs and in an environmentally benign way.

Purpose of this document is to provide scenarios one can consider applicable for some very common type areas, namely:

- **Scenario A** for a quasi-urban type of area marked by the presence of (a) medium sized cities and city-like agglomerations with some green/garden areas but limited agricultural activities in the surroundings,
- **Scenario B** for an urban centre type area as being found in large sized city/cities or urban agglomerations with high population density and mixed commercial activities,
- **Scenario C** for a quasi-urban to rural type of area with the presence of medium and smaller-sized towns and villages within an agriculturally dominated area, and
- **Scenario D** for an isolated rural type of area marked by small and dispersed villages and with occasional spots of tourism activities.

The scenarios presented hereunder in tabular style are model examples for an entire arrangement of ***waste management options*** so as to provide a consolidated picture on how waste management systems for the most essential municipal solid waste fractions can be shaped or may theoretically differ due to varying urban environments and conditions.

The descriptions delivered for each stage of the waste management process within a scenario point at certain particularities as the cause for significant differences in the handling of the waste and applicable technology options in dependence from the type of area.

The scenarios and specifications made therein take into consideration that some essential pre-requisites for an integrated waste management can already be found in a country. These are, among others, the availability of firms interested and capable for the recycling of packaging material, the existence of "public collection points" (kind of official or informal take-back or recycling stations) and scattered experiences with a selective waste collection. Upcoming waste management concepts should, wherever possible, build on such potentials and take pilot experiences as starting points or opportunities from where to proceed.

The history of successful schemes all over the world indicates that good knowledge of the local situation and potentials is essential and often the best entrance point to find viable and technically efficient solutions for a sustainable waste management in a specific area.

<table>
<tr><th colspan="2">Scenario A</th><th colspan="3">Quasi-urban type of area
Presence of medium sized cities and city-like agglomerations with abundant green/gardening but limited influence of farming in the surroundings</th></tr>
<tr><td>Household waste</td><td>Biological (garden/kitchen) waste</td><td>Packaging waste</td><td>Bulky waste</td><td>Construction and demolition waste</td></tr>
<tr><td colspan="5">MANAGEMENT CONCEPT (Combination of options)</td></tr>
<tr><td>1</td><td>6 and 7</td><td>5 or 8</td><td>11 or 12</td><td>14</td></tr>
<tr><td colspan="5">COLLECTION – Scenario A</td></tr>
<tr><td>Mobile garbage container/bin (MGB)
Waste bag/sack</td><td>Mobile garbage container/bin (MGB)</td><td>Waste bag/sack
MGB
Bring bank</td><td>Roll-off container
Skip container</td><td>Roll-off container
Skip container
Big Bag</td></tr>
<tr><td colspan="2">Explanatory notes:
- The high amount of organic matter becoming waste in this area, the existence of a potential market for compost and the moderate to good accessibility to most of the waste generators provide a sufficient basis for a separate collection and treatment of the organic waste. As for the residual household waste, mobile waste containers in appropriate size or alternatively plastic bags provided to each household can be used for collection. Sacks or backs with a limited durability might be problematic in areas which are less frequently served however. They are under the risk of destruction by wildlife and other animals, may cause hygiene and esthetic problems if it takes days before they are picked up from the collection trucks.
- Organic waste separation can be stimulated in that households have to pay lower charges per unit of organic waste forwarded to collection or by having the costs for organic waste collection fully included into the charge on residual household waste.
- Homes with garden have a chance for backyard composting, minimizing in this way the amount of biodegradable waste forwarded to collection and charges to be paid for that. The share of such households increases towards the areas with more detached building structures and rural character. The separate collection of organic waste may lose efficiency here as a result of significant amounts being home composted and used in other ways (e.g. garden fire, animal fodder).</td><td colspan="3">Explanatory notes:
- A separate collection of paper/board and of waste glass in bring banks set up at central points is undertaken. Alternatively, take back or recycling stations could be operated for these fractions so that sufficient amounts aggregate before pickup. The material is shipped to an appropriate sorting facility where a separation of the various materials in adaptation to the subsequent recycling routes is done.
- Other packaging materials should be separately collected as well, provided that larger amounts indeed accumulate in this area. In case of a lower overall generation of packaging and where must be considered longer collection distances and transports to get different fractions of source separated packaging treated the collection of packaging and other recyclables in a mix can be advantegous. Generally possible are bags or tearproof sacks that households can put out to the kerbside on specific collection days. In places with a higher population and concentrations of residential areas where the appropriate infrastructure is available, bring banks and mobile waste container might be used instead.
- Upon request, containers of the roll of or skip container type are being provided for the separate collection of bulky waste or C&D waste.</td></tr>
<tr><td colspan="5">PICKUP AND TRANSPORTATION – Scenario A</td></tr>
<tr><td>Household waste</td><td>Biological (garden/kitchen) waste</td><td>Packaging waste</td><td>Bulky waste</td><td>Construction and demolition waste</td></tr>
<tr><td colspan="2">Rear-end loader
Side loader</td><td>Rear-end loader
Side loader</td><td>Rear-end loader*)
Roll-off container
Skip container</td><td>Roll-off container
Skip container</td></tr>
</table>

Explanatory notes:

- Narrow streets in parts of the cities likely pose an obstacle for the use of other equipment than rear-end loaded collection vehicles for the pickup of containers Side loaded collection trucks might be an option for more accessible areas in the city outskirt.
- The rate of total waste generation in this area type should allow to establish appropriate waste management facilities economically and in not so far distance to the collection areas so that a direct delivery of the household waste by collection trucks could be feasible.

Explanatory notes:

- For transportation of bulky waste and C&D waste, trucks with the necessary chassis for containers of the roll of or skip container type are most suitable.

*) *where waste items are placed loose to the kerbside*

TREATMENT – Scenario A

Household waste	Biological (garden/kitchen) waste	Packaging waste	Bulky waste	Construction and demolition waste
Mechanical-biological treatment with a possible utilisation of the waste-derived fuel for Industrial Co-combustion	Composting Anaerobic digestion	Sorting of packaging	Bulky waste-sorting	Sorting and partly utilization on the spot

Explanatory notes:

- Mechanical biological treatment of the household waste due to space availability and generally higher acceptance as opposed to waste incineration is believed to be the most useful and easier to establish solution in the local context.

Explanatory notes:

- Existing experience and rather favorable conditions (demand, short distance to end users, acceptance) for the utilization of compost put a preference on composting and/or digestion technologies as options for treatment.
- The availability/combination with capacities for mechanical biological treatment is an asset for the subsequent treatment of residues left over by the aforementioned processes.
- The integration of anaerobic digestion in the biological treatment stage of the MBT opens up possibilities for a co-treatment with other waste streams (such as sewage sludge, liquid manure or -parts of- the biodegradable fraction) and thus to use their energy potentials jointly and generate power from the biogas obtained.

Explanatory notes:

- The mixed packaging waste is shipped to an appropriate sorting facility where a separation of the various materials in adaptation to the subsequent recycling routes will be undertaken. Existing recyclers (e.g. paper mills / glass factories) may process other source separated materials (e.g. separately collected paper / glass) directly.
- Bulky waste can be sorted to separate materials for which a demand exists or utilization will be possible in the area itself (e.g. metals for a steel plant, wood waste for the production of particle board), or the material is forwarded to the mechanical-biological treatment where its processing (separation of metals, RDF-production) is undertaken.
- To the extent possible C&D waste is sorted and used (for example as recycled aggregates or for backfilling) on-site. Space availability should be good enough to facilitate this by way of selective demolition and controlled dismantling procedures and with the help of mobile processing equipment (e.g. screen, crusher). Only amounts not being processed on-site are shipped to sorting facilities. Wood components are checked and sorted on site for reuse or any potential recycling options (e.g. wood chip production) or otherwise may go like other combustible and non-recyclable residues from these operations also to the MBT.

FINAL DISPOSAL – Scenario A

Residues from the treatment of

Household waste	Biological (garden/kitchen) waste	Packaging waste	Bulky waste	Construction and demolition waste
Landfill for non-hazardous waste Landfill for inert material				Landfill for inert material

Explanatory notes:

- All residues can be landfilled where preceding steps of treatment make sure that corresponding criteria are fulfilled. Residues from the mechanical-biological treatment usually require that a landfill site for non-hazardous waste should be in the closer surroundings, however due to the smaller amounts and fewer and more efficient transports required for them both these facilities should be serving for larger territories.
- Landfills for inert material are set up to avoid larger transportation and allow for the temporary storage of the mineral waste and excavated soil generated by construction works in the area until its treatment with mobile devices and further utilization.
- Hazardous wastes are kept in safe places (storages) until sufficient amounts accumulate to dispose them of via the nearest appropriate installation approved to handle the specific waste types.

Scenario B

Urban centre type area
within the area of (a) large sized city/cities or urban agglomeration with high population density, many high-rise buildings and commercial activities

Household waste	Biological (garden/kitchen) waste	Packaging waste	Bulky waste	Construction and demolition waste
MANAGEMENT CONCEPT (Combination of options)				
2		9	10	13
COLLECTION – Scenario B				
Mobile garbage container/bin (MGB) Ident-system	Not separated and thus jointly collected with the household waste in one sort receptacle	Bring bank MGB	Roll-off container Skip container	Roll-off container Skip container Big Bag

Explanatory notes:

- Given that incineration is an economically feasible treatment option and due to a low quality of separation that must be expected in such environment, spatial constrains which hamper temporary storage by the household and the setting up of further devices for separate collection, it is foreseen here to collect biodegradable waste together with household waste and not separately from the very beginning. A separate collection of certain organic waste fractions in sufficient quantities might work well on selected spots and the feasibility of a larger rollout should be regularly examined, however.
- Waste composition, hygiene and esthetic aspects put a preference on mobile waste containers for the collection of waste from households. In connection therewith, ident or ident-weighing systems can easily be introduced to facilitate a tour optimization and waste charging based on waste amounts and intensity of service availment (PAYT).
- Because of spatial constrains in the residential areas bring banks on central locations (big markets, parking areas, etc) as well as on accessible places where they can serve a greater number of units are most suitable for the separate collection of source segregated light-weight packaging, paper/board and for glass.
- Take-back centres and/or other types of recycling stations are set up to support source segregation and provide further possibilities for the separate collection of specific waste types.

Explanatory notes:

- Bulky waste and C&D waste are collected separately in a non-standardized scheme upon demand. Due to spatial constrains the use of big bags could be the best option for collecting these wastes. Where space allows, the collection from the kerbside with roll of containers or skip container can be an alternative. Controlled dismanteling of buidlings with source separation of the C&D waste is undertaken in house reconstruction, space constrains may limit this procedure elsewhere.
- Overall generation rates of C&D waste in the area require the establishment of centralized processing and sorting facilities where mixed material fractions can be separated subsequently.

PICKUP AND TRANSPORTATION – Scenario B

Household waste (including the biodegradable material)	**Packaging waste**	**Bulky waste**	**Construction and demolition waste**
Rear-end loader Side loader Front loading vehicle	Rear-end loader*) Roll-off container Skip container		Roll-off container Skip container

Explanatory notes:

- Generally town traffic in the dense urban areas is congestive during the day and there are restrictions for traffic (e.g. one-way routes, narrow streets in the historical quarters of cities) and as far as space availability on the kerbside is concerned. All that demands for refuse collection vehicles with a high flexibility for pickup operations, such as the rear-end loaded type. In the city outskirts, along linear developments and for large commercial compounds (malls) side-loaded vehicles, and as regards the latter also front-loaded trucks can be an option.
- All these vehicles can be used for transporting the waste to the treatment facilities as rather short distances to them can be assumed.
- For the transportation of bulky waste and C&D waste as well as for source separated waste collected in bring banks or at recycling stations, trucks with the necessary chassis for containers of the roll of or skip container type are most suitable.

*) *where waste items are placed loose to the kerbside*

TREATMENT – Scenario B

Household waste (including the biodegradable material)	Packaging waste	Bulky waste	Construction and demolition waste
Grate combustion Fluidized bed combustion *Alternatively:* Mechanical-biological treatment with a possible utilisation of the waste-derived fuel for Industrial Co-combustion	Waste paper sorting Waste glass-sorting Sorting of packaging	Bulky waste-sorting Grate combustion	Sorting or direct utilization

Explanatory notes:

- The composition and concentrated generation of waste renders the establishment of an incineration facility to be an economical option. The mixed household waste can be incinerated in a facility applying grate combustion. Dried sewage sludge, commercial waste and combustible material as well as most of the residues or resulting from treatment processes of other wastes give a suitable input for fluidized bed combustion. The generated heat can be used for district heating and to supply generated energy to the grid.
- Where special circumstances may have to be observed (e.g. strong people's opposition to incineration) a mechanical biological treatment with waste stabilization (MBS) may become an alternative. This solution can also come in the focus if adequate downstream utilization options exists (i.e. appropriate co-incineration facilities, e.g. in cement plants or power stations) in the closer surroundings.

Explanatory notes:

- The separate collection of different recyclable fractions in conjunction with the appropriate pre-treatment processes offers a great potential for the recycling industries to get supplied/established in the area. Due to the high intensity of commercial activities and consumption in the specified type of area a good market for recycled products can be likewise assumed. The non-usable residues generated in these processes can be incinerated.
- To the extent possible C&D waste is sorted and used on-site with the help of mobile processing equipment (e.g. screen, crusher). Amounts not being processed on-site are shipped to sorting facilities. Combustible and non-recyclable residues from these operations may go to incineration.

FINAL DISPOSAL – Scenario B

Residues from the treatment of			
Household waste (including the biodegradable material)	Packaging waste	Bulky waste	Construction and demolition waste
Landfill for non-hazardous waste Landfill for hazardous waste			Landfill for inert material

Explanatory notes:

- Even though the waste that need to be landfilled should have been drastically reduced by recycling and preceding treatment operations, a landfill for non-hazardous will be required for the area to safely store the residues from the treatment of the own waste and those amounts delivered by others (such as the quasi-urban type areas in the surroundings) to this treatment facility. Located somewhat outside the highly urbanized structures this could become a centralized waste management spot combining treatment and disposal facilities to serve a large territory.
- In addition to this type landfill, some further landfill capacities will be needed to manage the amounts of inert waste material

(coming from construction activities) as well as hazardous residues generated in the area. In this way, a safe disposal for ashes and filter dust from the waste incineration can be also ensured without the need of larger transportation.

<table>
<tr><th colspan="2">Scenario C</th><th colspan="3">Quasi-urban to rural type area
High presence of medium-sized towns and villages marked by a dominance of detached building structures and within an agriculturally dominated area</th></tr>
<tr><th>Household waste</th><th>Biological (garden/kitchen) waste</th><th>Packaging waste</th><th>Bulky waste</th><th>Construction and demolition waste</th></tr>
<tr><td colspan="5">MANAGEMENT CONCEPT (Combination of options)</td></tr>
<tr><td colspan="2">3</td><td>8</td><td>11 or 12</td><td>14</td></tr>
<tr><td colspan="5">COLLECTION – Scenario C</td></tr>
<tr><td>Mobile garbage container/bin (MGB)</td><td>Not separated and thus jointly collected with the household waste in one sort receptacle</td><td>Waste bag/sack
MGB
Bring bank</td><td>Roll-off container
Skip container</td><td>Roll-off container
Skip container
Big Bag</td></tr>
<tr><td colspan="2">Explanatory notes:
- Aside from a greater proportion of households having the possibility to make use of individual backyard composting as alternative for the disposal of their organic waste, separate collection of biowaste due to its specific logistic challenges (provision of separate bins, separate pickup) would be difficult and expensive in the specified area. With mechanical-biological treatment systems a good solution for the treatment of household waste with higher organic content is available. A separate collection of certain organic waste fractions in sufficient quantities might work well on selected spots and the feasibility of a larger rollout should be regularly examined, however.
- Given the high specific gravity of the household waste in result of the high proportion of organic material remaining for collection, the use of sacks/bags for collecting the household waste may not be recommendable (danger of destruction by weight or rodents) unless short collection intervals can be ensured. Also the existence of solid fuel firing in a greater number of households and the occurrence of hot ashes in the waste speak against this option and for waste containers (MGB) from heat resistant materials.</td><td colspan="3">Explanatory notes:
- A separate collection of paper/board and of waste glass in bring banks set up at central points is undertaken. Alternatively (and especially in more remote places), take back or recycling stations could be operated for these fractions so that sufficient amounts aggregate before pickup. The material is shipped to an appropriate sorting facility where a separation of the various materials in adaptation to the subsequent recycling routes is done.
- The generally lower overall generation of packaging and the longer transport distances that must be assumed to get different fractions of source separated packaging treated individually suggest the collection of packaging and other recyclables in a mix. Generally possible are bags or tearproof sacks that households can put out to the kerbside on specific collection days. In places with a higher population and concentrations of residential areas where the appropriate infrastructure is available, bring banks and mobile waste container might be used.
- Upon request, containers of the roll of or skip container type are being provided for the separate collection of bulky waste or C&D waste.</td></tr>
<tr><td colspan="5">PICKUP AND TRANSPORTATION – Scenario C</td></tr>
<tr><td colspan="2">Household waste
(including the biodegradable material)</td><td>Packaging waste</td><td>Bulky waste</td><td>Construction and demolition waste</td></tr>
<tr><td colspan="2">Rear-end loader
Side loader
Waste transfer station</td><td>Rear-end loader
Roll-off container
Skip container
Swap body container</td><td>Rear-end loader*)
Roll-off container
Skip container
Walking floor transporter
Swap body container</td><td>Roll-off container
Skip container
Walking floor transporter</td></tr>
</table>

Explanatory notes: - In as much organic waste can be separately collected, it is rather easy to establish treatment installations (such as composting plants or digesters) adopted to the available quantities and close to the place of generation. Then this waste can be directly forwarded to the composting facility by the collection trucks. This however does not apply for mixed (residual) household waste. Effective and cost-efficient operations require treatment installations for this waste stream to have a certain capacity and permanent throughput rate. That is why setting up such facilities is usually done to serve larger territories. In that case a network of waste transfer stations is useful to reload the waste from smaller-sized collection vehicles to transportation means for longer distance transports.	***Explanatory notes:*** - For the transportation of bulky waste and C&D waste as well as for source separated waste collected in bring banks or at recycling stations, trucks with the necessary chassis for containers of the roll of or skip container type are most suitable. Where larger amounts of these wastes (with the exclusion of mineral C&D waste) need to be transported over long distances, walking floor systems may come in use as well. - Ship and railroad transportation may gain a significant meaning in the transportation concept for waste amounts in this specific type of area *) *where waste items are placed loose to the kerbside*

TREATMENT – Scenario C			
Household waste (including the biodegradable material)	**Packaging waste**	**Bulky waste**	**Construction and demolition waste**
Mechanical-biological treatment	Waste paper sorting Waste glass-sorting Sorting of packaging	Bulky waste-sorting Mechanical-biological treatment	Sorting or direct utilization

Explanatory notes: - The mechanical-biological waste treatment of the household waste is undertaken at a centralised facility. Depending on the options available for the downstream utilisation of the treated material, this can take either the form of an MBT (with subsequent landfill disposal) or an MBS (with subsequent thermal processing or industrial co-combustion of the waste derived fuel material). Broader experiences with composting, the availability of space and some of the required technical equipment (e.g. wheel loader) in the area may render a mechanical biological treatment with intensive rottening in the biological stage as the most approriate solution. - The integration of anaerobic digestion in the biological treatment stage of the MBT might be adviseable in places where a potential user for energy generated from biogas exists, and where larger amounts of sewage sludge are generated (e.g. an area with larger urban structures or with larger animal farms in place). - To create economies of scale and erect and/or operate waste processing facilities of sufficient capacity in the area it makes sense to enter into co-operation with adjacent areas and perhaps participate in or even found waste management-oriented associations. Also waste infrastructures elsewhere can be used when sufficient capacities and prices can be negotiated and necessary transports (perhaps via transfer stations, ship or railroad) arranged economically.	***Explanatory notes:*** - The mixed packaging waste is shipped to an appropriate sorting facility where a separation of the various materials in adaptation to the subsequent recycling routes will be undertaken. Existing recyclers (e.g. paper mills / glass factories) may process other source separated materials (e.g. separately collected paper / glass) directly. - Bulky waste can be sorted to separate materials for which a demand exists or utilisation will be possible in the area itself (e.g. metals for a steel plant, wood waste for the production of particle board), or the material is forwarded to the mechanical-biological treatment where its processing (separation of metals, RDF-production) is undertaken. - To the extent possible C&D waste is sorted and used (for example as recycled aggregates or for backfilling) on-site. Space availability should be good enough to facilitate this by way of selective demolition and controlled dismantling procedures and with the help of mobile processing equipment (e.g. screen, crusher). Only amounts not being processed on-site are shipped to sorting facilities. Wood components are checked and sorted on site for reuse or any potential recycling options (e.g. wood chip production) or otherwise may go like other combustible and non-recyclable residues from these operations also to the MBT.

FINAL DISPOSAL – Scenario C			
Residues from the treatment of			
Household waste (including the biodegradable material)	Packaging waste	Bulky waste	Construction and demolition waste
Landfill for non-hazardous waste Landfill for inert material Temporary storage			Landfill for inert material

Explanatory notes:

- All residues can be landfilled where preceding steps of treatment make sure that corresponding criteria are fulfilled. Residues from the mechanical-biological treatment usually require that a landfill site for non-hazardous waste should be in the closer surroundings, however due to the smaller amounts and fewer and more efficient transports required for them both these facilities should be serving for larger territories.
- Landfills for inert material are set up to avoid larger transportation and allow for the temporary storage of the mineral waste and excavated soil generated by construction works in the area until its treatment with mobile devices and further utilization.
- Hazardous wastes are kept in safe places (storages) until sufficient amounts accumulate to dispose them of via the nearest appropriate installation approved to handle the specific waste types.

Scenario D

Isolated rural type area
Presence of small and dispersed villages in mountain areas and wetland zones with seasonal influence of tourism and spotted tourist facilities

Household waste	Biological (garden/kitchen) waste	Packaging waste	Bulky waste	Construction and demolition waste
MANAGEMENT CONCEPT (Combination of options)				
3 or 4		**5 or 8**	**12**	**14**
COLLECTION – Scenario D				
Mobile garbage container/bin (MGB) Waste bag/sack	Not separated and thus jointly collected with the household waste in one sort receptacle	Waste bag/sack Bring bank	Roll-off container Skip container	Roll-off container Skip container Big Bag

Explanatory notes:

- Spread up houses and villages, long distances between them and limitations as to the accessibility by road make waste collection services difficult. Waste management planning must therefore give a high attention on a.) the promoted schemes of consumption, b.) a thorough separation of what can be reused at source and what not, and c.) the optimization as to the services offered. In practical terms this may for example imply a.) the use of compostable and re-usable products to be promoted, b.) the establishment of local composting schemes and take back, c.) the joint collection of fractions with similar processing needs and where possible via centralized collection points rather than house to house collection. For all this, information on best practice must be provided and shared.
- Although it is to be expected that most of the waste is of organic nature, no separate collection of this waste shall take place because of the logistic challenges and the good possibilities for having organics composted individually/locally. Residual waste from households is collected in mixed form, for this the use of tearproof and durable bags can be an advantage where pickup is just in time and wildlife allows for it.
- A network of bring banks and/or recycling stations in appropriate locations is preferably to be used for collecting mixed packaging waste, additionally the collection in bags which can be taken away by various supply vehicles could be offered. Also bags of various colours for the different recyclable packaging materials could be used in combination with centralized collection points.
- In places with higher tourist concentrations, separate collection can be intensified to the extent local disposal options allow for it (e.g. biowaste collection if composting/anaerobic digestion facilities can be used or set up), or such is reasoned by the generated amounts and for steering purposes (e.g. for different types of packaging – treatment option 8).
- basically procedures that are identical with those mentioned for scenario C should be preferred for all other waste management operations in the area.

PICKUP AND TRANSPORTATION – Scenario D

Household waste (including the biodegradable material)	**Packaging waste**	**Bulky waste**	**Construction and demolition waste**
Rear-end loader Waste transfer station Walking floor transporter Swap body container	Rear-end loader Roll-off container Skip container Swap body container	Rear-end loader*) Roll-off container Skip container Walking floor transporter Swap body container	Roll-off container Skip container Swap body container Walking floor transporter

Explanatory notes:

- In order to allow for an appropriate treatment and avoid ineffective investments into own treatment facilities, most of the collected waste will have to be sent to transfer stations before being finally shipped to the processing and disposal facilities.
- Further procedures are basically identical with those mentioned for scenario C
- Waste collection in bags or another non-standardized manner (e.g. loose for C&D and bulky waste) and infrastructure constraints may allow simple truck transport systems or even traditional techniques (like horse-drawn wagons) to be used for pickup in remote or badly to reach places. Long distance transportation to processing/treatment facilities is then done by various means with appropriate equipment whereby ship and railway transportation might be playing a significant role, too.

*) *where waste items are placed loose to the kerbside*

TREATMENT – Scenario D

Household waste (including the biodegradable material)	**Packaging waste**	**Bulky waste**	**Construction and demolition waste**
Mechanical-biological treatment *or* Grate combustion	Sorting of packaging	Bulky waste-sorting	Sorting or direct utilization

Explanatory notes:

- Treatment in principle must be realized by way of delivering the waste to a centrally located waste treatment facility of the appropriate size and type – therefore procedures are basically identical with those mentioned for scenario C
- To form or join specialized associations for efficient waste management solutions and cooperation models is adviseable.

Explanatory notes:

- The procedures are basically identical with those mentioned for scenario C

- The need to minimize waste transportation calls for any efforts to avoid as much as possible waste and use whatever possible options for a decentral utilisation of waste materials. To promote home composting by way of adequate education, information and support, impose certain waste separation models and rules in tourist destinations and invest into small-scale installations for waste processing (e.g. balers and compaction containers, waste digester or compost yards) can quickly pay off.

FINAL DISPOSAL – Scenario D

Residues from the treatment of

Household waste (including the biodegradable material)	Packaging waste	Bulky waste	Construction and demolition waste
Landfill for inert material Temporary storage			Landfill for inert material

Explanatory notes:

- All residues can be landfilled where preceding steps of treatment make sure that corresponding criteria are fulfilled. Central facilities which receive the waste for treatment via transfer stations have their own capacities for final waste disposal, hence no other local capacities must be created for that.
- Only landfills for inert material are set up to avoid larger transportation and allow for the temporary storage of the mineral waste and excavated soil generated by construction works in the area until its treatment with mobile devices and further utilization.

Financing of waste management and options for cost recovery

General introduction

Waste management comes at its costs. Solid waste management is an indispensable but expensive service that consumes a large proportion of available operational budgets for municipal services. The financing of waste management implementation is thus a critically important issue for the sustainability of the operations and the economic flexibility of the municipalities. Improving waste management by enhanced technology is always associated with additional costs for which appropriate ways of financing need to be found.

The responsibility for the financing of waste management should be shared between the state and the municipalities. State policy must govern the enforcement of environmental objectives also by financial means whereas financial organization of the actual waste services be given in the hand of the municipalities.

At the level of the municipality one has to distinguish between the financing of the services citizens receive for their waste, and the financing of municipal investments into improved waste management solutions.

Waste management related services citizens wish to receive or have to use include, for example, the provision of waste containers, their emptying and the transportation of the collected waste to the disposal facilities. These services should be levied to the citizens by the way of dedicated fees or charges stipulated in municipal waste ordinances or waste statutes.

Investments of the municipality into the appropriate waste management infrastructure comprise, among others, the purchase of waste collection equipment (e.g. containers, dustbins) and devices (e.g. street cleansing and collection vehicles, etc.), and the establishment, operation and aftercare of waste deposits and treatment facilities. For these expenses the municipalities have to employ adequate financing models which take account of all the advantages and risks associated with the respective application and investment.

In regard of the fact that environmental protection is of importance for the national economy, also the financial instruments of the state need to be considered.

Governments can influence the impacts of society on environmental developments by means of different policy instruments at their disposal. These can for instance be geared to the goal of:

- limiting resources consumption for example thru the introduction of a commodity tax;
- limiting the release of undesired material into the environment or a disposal via certain unwanted pathways for example thru special levies, taxation of landfills or mandatory environmental licences;
- promoting certain environmental benign measures such as recycling thru a specialized taxation or charging system (e.g. mandatory waste disposal charge) in order to close the loop from the waste generation to secondary material production.

A coarse overview of the most common financing instruments in the waste sector is given in Table 1.

Some brief explanations of the different financing instruments and practical information regarding the ways to implement them in practice shall be provided in addition.

Table 1: Most common instruments used at different levels for the financing of waste management

Options of waste management financing								
at the municipal level						at the state level		
Financing of public waste disposal services		Financing of investments				Financing instruments of environmental policy		
Waste charge		Loan financing	Shared financing	Operator model	Other instruments	Environmental / Eco taxes	Levies / 'Fines'	Environmental licences
Single component / one-tiered model	Multiple component/ multi-tiered model							
	Service independent (basic) fee	Public sector loans	Other public body involvement (joint associations)		Fund financing	Waste disposal tax	Pollution levy/fine	
	Service-dependent fee		Third party participation (Public-Private-Partnership)		Factoring	Packaging tax	Product levy	
	Rental fee				Leasing	Commodity tax	Landfill levy/tax	

Financing options of the municipal sector

Financing of public services

Waste fees / waste charging

A basic principle should be that the costs caused by the management of waste should be borne (recovered) from those who generated the waste and benefited from the disposal efforts („polluter pays principle"). That's why charges should in particular be levied for the services offered to and availed of by the public.

Ideally would be to charge the entire waste service in the form of cost-covering fees to each individual user. That would represent a truly fair allocation of the financial burdens for collection, treatment, disposal as well as the aftercare of waste and for the prevention or restoration of the environmental damage done to the waste generator.

A key element in here is that of "willingness-to-pay". If people are willing to pay for the full costs of a particular service, then it is a clear indication that the service is valued and therefore will most likely be used and maintained. Hence it will be possible to generate the funds actually required to sustain the service and the state of the environment. However, the extent to which an individual is willing to pay for a hypothetical service also depends on how much he or she can afford. Therefore, next to the willingness-to-pay, the affordability-to-pay is a key element in the marketing of solid waste services. Not knowing the affordability to pay implies the danger of a failure of recovering the full costs of solid waste management. Intelligent charging mechanisms and models are therefore indispensable.

Waste management involves a large spectrum of services of different intensity and for different materials and the borders set between them and other public services can be varying and even overlapping. Costs for waste management are in general related to the following types of services:

- the disposal of the various types of collected waste and recyclables, whereby disposal includes waste collection, transport, treatment and/or the safe storage or depositing of the waste;
- the operation of special recycling programs (e.g. take back schemes, etc.);
- the provision of waste consultation and public information;
- the corresponding administration.

The costs reflect the actual or estimated price of these activities. This price has to be charged to the waste generator for a service based on the expenses of providing and performing it. The minimum requirement in this respect should be the recovery of the share of the inevitable or fixed costs for the collection and management of the collected waste independently from the actual use of the provided services.

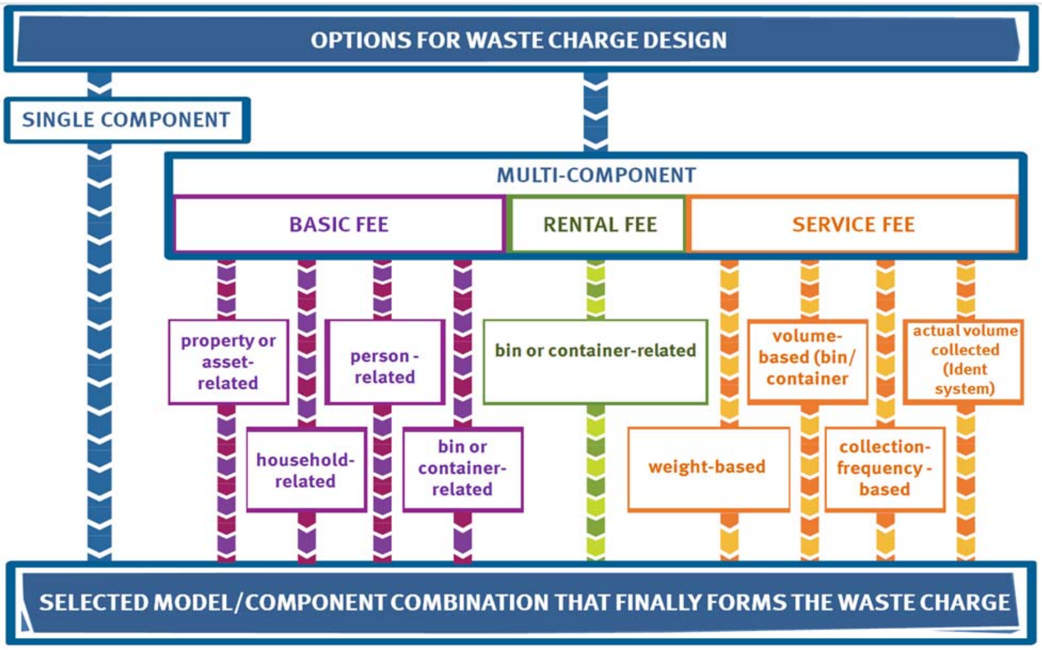
The *fixed costs* in conjunction with waste management can be described as those expenses incurring independently of the amount of collected waste and extent of real use of waste disposal services, i.e. mainly by creating the conditions to provide the respective service. Expenses incurred in conjunction with the actual performance of the service and hence in dependence on the waste amount and actual range and intensity of disposal activities shall be considered as *variable costs*.

Fixed and variable costs cannot be differentiated always very clearly. The allocation of single expenses to fixed or variable costs is done very differently by the municipalities. As a rule of thumb it can be said that the costs considered as the fixed part make up a proportion of 60 to 80 % of the total costs whereas the variable part very seldom goes higher than 20% to 40%.

Waste charging schemes should for these reasons consider to split up the calculation of the overall chargeable amount into one, non-service dependent part plus another, service dependent part and further fees for various surplus services. A waste charging scheme should in any case make sure the full coverage of the waste management related costs and the fair allocation of these costs to the population as beneficiaries of the services.

Possible components and models to create a waste charge are shown in Figure 1.

Figure 1: Suitable models and components for designing a waste charge



One-tiered charge system

The single-component (one-tiered) charge system represents the simplest charge model. It consists of only one type of fee. Classical example is the flat rate scheme. It consists of a fixed fee which is being established via a certain calculatory algorithm and charged independently of the actually generated waste amount or availed services as a lumped sum which is supposed to cover fixed and variable part of the waste management costs. The estimated total amount of these costs is divided among all recipients (households) of the waste management services. This model guarantees a known quantity of revenue but the fixed charge does not reflect the individual amount of waste produced. It therefore doesn't provide for any incentive to reduce the amount of generated waste or to engage in source separation activities.

Multi-tiered charge system

General cost structures and practical experience suggest waste charges to be levied on the basis of a two- or multi-component (multi-tiered) waste charge system. As a basic component a fixed fee is levied from each household. This fee is either unified (e.g. a certain annual amount) or non-unified (according to specific criteria, e.g. a function of the surface of the real estate). Further charged is a variable fee component which is in relation to the collection service actually availed, for instance for each unit of waste set out for collection, and may be combined with other cost components. Multi component waste charge models are best suited to realise the polluter pays principle.

The implementation of waste charging by the way of *pay-as-you-throw (PAYT)* schemes must be considered as the most suitable option to ensure fairness in paying for waste management services and moreover proved to be very efficient for promoting the reduction of disposable waste in providing incentives for source separation and home composting.

The approach of pay-as-you-throw is to realise the polluter pays principle in a fair manner by charging people in accordance to the actual quantity of waste generated by them and the corresponding service they obtained for its disposal. Such direct form of unit pricing for their waste aims at stimulating households to divert an increased portion of their discards away from traditional means of disposal mainly to recycling. Pay-as-you-throw sets a contrast to the yet common approach of waste charging where waste collection services are invoiced in form of a fixed recurring payment and/or by means of a flat rate calculated on the basis of living space, the number of household members or as a certain percentage of other supplies. With PAYT, services related to waste management are treated just like any other utility. To implement such form of variable waste charging requires:

- the measurement of the generated amount of waste and/or services obtained for it;
- a kind of identification for reasons of accountability to the waste generator, and
- the unit pricing for individual charging according to collected amount or availed services.

Although a fully variable waste charging model seem to be possible to realise PAYT, it has to be noticed that multi-component waste charge models offer indeed the more suitable solution here. Such model should however make consideration only to the indispensable costs for delivering the waste service in its fixed part whereas a sufficient variable part must be maintained to keep the incentive for waste reduction and diversion. Also a minimum mandatory charge can be included for reasons of revenue security. More detailed information about PAYT are available at the website www.payt.net or through the English "Handbook for the implementation of pay-as-you-throw as a tool for municipal waste management" which is introduced on this website.

The components for multi component waste charge models will be described hereafter and further explanations regarding their suitability provided.

Basic or flat fee component

The determination of a fixed basic fee shall reflect that certain expenses are already incurred with the installation of a system whether a household is going to use them or not (fixed costs). The fee thus does not serve as a payment for availed services but as a compensation for the provided opportunity to do so. A basic fee should be justifiable through the provided waste management infrastructure and thus also applicable to vacant premises and flats which do not actually avail of the collection services.

While calculating this fee component only the fixed cost positions should be accounted for and no other non-system immanent costs included, however. To the eligible costs belong, for example, costs for the accounting and billing, the service routing and the fleet, for the purchase and supply of waste containers, personnel and maintenance costs, rents, capital and depreciation costs. It is recommendable to charge the basic fee in the form of a flat amount if there is a need to consider services of general nature such as could be the collection of bulky waste together with the fixed costs for the individual services.

There are various ways to define a basic fee. The most applicable solutions are shown in the following table.

Table 2: Common options to determine/arrange a basic fee

Basic or flat fee arrangements	
Person-related	***Bin or container-related***
- charging a unit price per recipient of the service i.e. the fee increases proportionally to the number of the persons living in the household or on the property	- charging a fee for each provided bin/container in relation to their volume
Property or asset-related	***Household-related***
- charging a fee per property including the possibility of a differentiation based on certain parameters (e.g. size of the property, type of property, i.e. private, commercial or mixed utilisation, first or second home, permanent or temporary occupation)	- charging a unit price per household or for each household established on a property without consideration of its actual size or the number of persons belonging to it

A bin or container-related arrangement combines with the need to have the containers registered. This can be achieved thru the assignment of the container to the waste generator or a subscription.

A person and household-related arrangement in combination gives more respect on that waste generation generally goes up with a growing number of household members. However, a degressive calculation model must be applied here.

Advantages and disadvantages of the different arrangements are summarised in Table 3.

Table 3: Advantages and disadvantages of different arrangements for basic / flat fee components

	Person-related (basic) fee	Bin or container-related (basic) fee	Property or asset-related (basic) fee	Household-related (basic) fee
Advantages	- Reliable and transparent calculation - To a certain extent polluter-pays-principle applies as costs for other waste fractions, e.g. bulky waste or hazardous waste, are usually covered by this fee and their arisings are more or less person-dependent	- Reliable and transparent calculation - Handling is rather simple - Low administrative effort required - With possibility to choose the size of bin/container a financial incentive for waste avoidance and waste separation is created	- Handling is rather simple - Low administrative effort required	- Relatively low administrative effort required after the introduction
Disadvantages	- High administrative expenses for the introduction and for the data administration due to rather high fluctuations of household size - Disregards the fact that there are certain waste fractions where no relationships between the individual number of persons and cost arisings can be established (e.g. waste paper, where amount and costs arising are rather household-dependent)	- Bin size for residual waste is no suitable criteria to account for the costs arising for other waste fractions like bulky waste and waste paper because there is no direct relationship between the generated volume of residual waste and the amount of bulky waste and waste paper forwarded to collection	- No equality of treatment where flat amounts per property are charged - Size of the property is no suitable criteria to account for the costs arising for other waste fractions like bulky waste and waste paper because of no direct relationship between these parameters	- High administrative expenses for the introduction - Number of households is no suitable criterion to account for the costs arising for other waste fractions like bulky and hazardous waste because these costs are dependent on the number of persons in a household

Service-dependent fee(s)

The charging of service fees requires for an unambiguous perpetuation of evidence on the extent of the services availed by the payer of the charge. The most applicable ways of defining service related fees are shown in Table 4.

Underestimated capacities in the volume-based arrangement are by far the largest problem since the arrangement usually offers the households freedom of choice for the container size used. That’s why such arrangements should normally be offered in combination with the determination of a minimum chargeable volume per person.

The prescription of a fixed frequency of emptying (which might also be chosen individually from the user of the service in adavance) does permit the regular pickup of the waste and helps thus to avoid the development of odour nuisances and health risks. Such measure is most suitable for the collection of biowaste and other biologically or chemically active wastes.

Table 4: Common options to determine/arrange a service fee

Service fee arrangements	
Volume-based (bin volume)	***Pickup frequency based***
- charging for the collection service based on the provided container volume and frequency of emptying. The frequency of emptying is fixed. In support of revenue security and a regular utilisation of the system by the citizens, such arrangements could include the determination of a minimum chargeable volume per person.	- charging in dependence from the actual number of emptyings for a standard bin or other receptacles of a defined size. The frequency of emptying is optional. In support of revenue security and a regular utilisation of the system by the citizens, such arrangements could include the determination of a minimum chargeable number of pickups.
Weight-based	***Volume-based (actual volume collected)***
- charging per unit weight of collected waste (typically applying to residual and biowaste collection). Accountability of the collected waste to the generator is a precondition. A weight based service fee can be charged in combination with a fee per emptying.	- requires to know the actual volume of the waste inside the receptacle in the moment of pick up. Aside from a few solutions where the waste container‘s filling level is measured, this typically applies to pre-paid arrangements, e.g. prepaid sack or tag-a-bag scheme.

Pickup frequency based arrangements can be best realised with the help of bin-identification systems (see factsheet ‘bin-identification systems’). Identification systems make sure the accountability of the collected waste to the waste generators. This is a precondition for weight-based arrangements as well. As an incentive for households to render containers for emptying only when they are full, an extra fee for each pickup can be charged together with the weight based service fee.

Advantages and disadvantages of the different arrangements are summarised in Table 5.

Arrangements with a prescribed minimum of chargeable services have a special status within the charging regime in that they fulfill a steering function and take the character of a basic fee. This mandatory fee is charged independently from the actual availment of the waste collection services. The arrangement should safeguard the proper waste disposal which is endangered by littering and the illegal depositing of waste or the pollution of waste fractions which are collected at lower or no charges at all. It isn't a disincentive for individual waste avoidance efforts if households get charged a minimum payable container volume or number of emptyings well below the average of actual service intensity.

Table 5: Advantages and disadvantages of different arrangements for service-dependent fee components

	Volume-based (service) fee	Pickup frequency based (service) fee	Weight-based (service) fee	Actual volume-based (service) fee
Advantages	- provides an incentive for waste avoidance and waste separation - calculation reliable and transparent - well acceptable by the citizens if applied in conjunction with a flexible choice of bin size	- provides an incentive for waste avoidance and waste separation - collection becomes transparent to citizens and waste collection company	- provides a high incentive for the avoidance and separation of waste, especially heavy one, hence best applied in conjunction with separate biowaste collection - perfectly producer oriented - collection becomes transparent to citizens and waste collection company - allows the permanent monitoring of waste flow developments (i.e. the effectiveness of certain waste management measures can be detected immediately)	- provides a high incentive for the avoidance and separation of waste, especially spacious one, hence best applied in conjunction with separate collection of packaging and bulky waste - no accounting of the unused volume of the bin - billing becomes transparent for the citizen (price per volume unit)
Disadvantages	- limited acceptance if applied without freedom in the choice of bin size - danger of bypassing in the absence of provisions for a minimum chargeable volume per household or capita - tendency to subscribe for small sized bins which goes along with higher disposal costs and increasing amounts of materials forwarded to bulky waste collection or compressing of waste	- danger of bypassing in the absence of provisions for a minimum chargeable service - high administrative effort required - arbitrary frequency of emptying can be associated with hygienic problems and the use of undesired forms of waste disposal - possibility of additional logistic expenses	- investment intensive - higher expenses for system maintenance - danger of bypassing in the absence of provisions for a minimum chargeable mass per household or capita - discriminates households with conventional coal firing and such who do not have the possibility for backyard composting	- high costs for measuring equipment, its calibration and maintenance - sensitiveness of measuring and proneness to errors - incentive for illegal dumping/littering or pollution of the recyclable fractions

Rental fee

A rental fee is meant to cover the costs for the provision of a waste collection container by a public authority or any other body in charge for waste related services different from the waste generator. The fee varies in dependence from the container size or volume. Alternatively, these costs can also be accounted as part of the basic fee or included into a service-dependent fee.

Crediting this fee as a separate accounting position has the advantage of a higher calculatory safety and leads automatically to an optimised container allocation.

Waste charging policy

The waste charging policy (WChP) determines the calculation mode of the service level to be charged and may be one of the three following types:

- *Linear or neutral WChP*: Each collection unit costs the same for the citizen, regardless of the number of units set out for collection.
- *Degressive or passive WChP*: The second collection unit set out from the same waste producer costs less than the first, the third less than the second, etc.. The scheme can also be transferred on

the bin size, i.e. the price of larger bins is comparatively lower than that for smaller bin sizes.

- *Progressive or active WChP*: The second collection unit set out from the same waste producer costs more than the first, the third more than the second, etc..

The reason of the different types of waste-charging policies varies in dependence from social and policy concerns.

The first type (neutral) does not take into consideration any factors in waste production or different disposition and strain of the waste services. It treats every citizen and every excess production the same way. This policy is the easiest to implement and renders charges' calculation easier. It also appears to the citizens as it doesn't make any discriminations which, however, is not true if one considers the real cost development and common mode of billing.

The second or passive type seems more 'favorable' to producers of greater amounts of waste, as opposed to the third or progressive where these producers are penalized more than in the other charging strategies

By taking actual cost structures and the common methods of billing into account, degressive charging policies are however those which approximate best the real situation in terms of different strains of the urban waste management system. Hence they are a very suitable solution for the practice. An explanation for it can be found in the facts that for example driving distances in the inner urban areas are often shorter and pickup efficiency higher due to the larger waste bins which are normally being in use here. In comparison one will see higher costs for the pickup of smaller waste amounts which are dispersed over a larger area requiring also longer travel distances.

Options for the financing of investments

Loan financing

The classical way of a long-term financing of public investments is the financing with outside capital or availment of so-called local authority loans. These can be loans on public assets or loans of money. The usual procedure for waste management investments are loans of money. A suitable way are bonded loans. In this case, the municipality is not bound to a certain financial institution but free in the choice of its creditors.

Depending on the agreed manner of repayment, one can distinguish the following types of bonded loans:

- *Closed-end loans*: The loan is due in one sum at the end of the agreed timespan. This provides for a clear running time and fixed date of repayment.
- *Fixed-rate loans*: The repayment of this loan is done on the basis of previously agreed repayment rates. The running time of the loan is thus dependent from the height of the rate.
- *Annuity loans*: An annually payable amount (annuity) made up from the sum of annual repayment plus interest is to be agreed beforehand. Whereas the annuity remains constant over time, the ratio between the share of repayment and interest alters continuously throughout the running time (decreasing share of interest).

The advantage of local authority loans lies in the favorable conditions which can be obtained due to the higher solvency and creditworthiness public enterprises supposed to have. Latter derives from the lower risk of failed repayments since public bodies are not at danger to go bankrupt and dispose of the means to secure the credit rates thru the power to impose charges.

Shared financing

- *Participation of public bodies (municipal joint purpose associations)*: The creation and participation of public bodies in target-oriented municipal associations (administrative unions) is a common and very useful way of inter-municipal cooperation. By enlarging the jurisdiction area for waste management optimal structures and investments can be achieved and positive cost effects obtained from task sharing and the possible rationalization of the operations.
  The administrative union is taking responsibility for the waste management operations in all participating municipalities. Depending on the specific circumstances these can also be single tasks, such as the operation of a larger waste treatment facility like a waste incineration plant, only.
  A municipal association should enjoy financial autonomy, meaning that it can also impose special levies or even charges for its services. Are the proceeds obtained in this way not enough to cover all costs, rules have to be established which ensure that the members of the association have to a share into the cost recovery.
- *Third party participation*: With a liberal legislation, municipalities are free in choosing the organizational form for their waste management operations. The municipalities may decide for

themselves (according to their political and economic preferences), if and to what to degree they want to privatize or not. In this case there are no central specifications for the so-called "delegation of duties to a third party". Complete privatization, however, may only be permitted in selected cases and under considerable stipulations. The most common organizational forms are as follows:

1. *Municipal department (Regiebetrieb)*: operated by the municipality within the scope of the regular municipal administration;
2. *Municipal utility (Eigenbetrieb)*: operated by the municipality in a separate capacity with independent book keeping.
3. *Municipal company (Eigengesellschaft)*: private entity company in the hands of the municipality.
4. *Joint venture*: Municipal utility with the involvement of a private firm.
5. *Management and service contract*: The plant property belongs to the municipality, but the operations and any further management tasks are delegated to a private firm.
6. *Operator model*: Delegation of the plant operations to a private firm, whereas the responsibility for the fulfillment of tasks remains with the municipality.

- *Third party participation (Public-Private-Partnership)– PPP):* Partnerships with the private sector - better known as Public-Private Partnerships (PPP) - describe a rather new model for development cooperation. Public private partnerships are a generic term for the relationships formed between the private sector and public bodies often with the aim of introducing private sector resources in order to help provide and deliver public sector assets and services. The term PPP is used to describe a wide variety of working arrangements from loose, informal and strategic partnerships to design build finance and operate type service contracts and formal joint venture companies.

  Private Finance Initiatives are a form of PPP but is also, principally, a form of contracting or procurement which can integrate the following features:

1. a long term service contract between a public sector body and a private sector operator,
2. the provision of capital assets and associated services by the operator,
3. a single ‘unitary’ payment from the local authority which covers investment and services,
4. the integration of design, building, financing and operation in the operator’s proposals,
5. the allocation of risk to the party best able to manage and price it,
6. service delivery against performance standards set out in an ‘output specification’,
7. a performance related payment mechanism,
8. an ‘off balance sheet treatment’ for the local authority so that any investment delivered through the project does not count against borrowing consents,
9. support from central government delivered through special loans.

A suitable arrangement for waste management purposes is the establishment of joint venture companies from the public body organisation and a private disposal company which are set in charge for the waste management operations. Alternatively, the public body organisation can found its own municipal company and set her in charge for the waste management. In a second stage, shares (usually up to 49 % of the value) on this company are being sold to a private enterprise with the consequence that from this moment on the operations are performed by the joint venture.

PPPs are of special interest for municipalities because of the savings that can be achieved on the side of the municipal budget in parallel with private capital investments, but also because of the existing expertise on the side of established private enterprises and the higher flexibility and efficiency of these partners.

PPPs come especially under scrutiny when there is assurance of the fact that the need for investment greatly exceeds the likely level of conventional resources (e.g. taxes, charges) likely to be available. Still there is the need to be certain on how services are delivered and whether such services are high quality and good value for money for the local community. A PPP should not be seen as the financier of last resort because there is unlikely to be a benefit to the public, if PPPs deliver more expensive services. The challenge for municipalities is to develop PPPs that give good value in their own right. PPPs must be able deliver significant performance improvements and efficiency savings.

PPPs cannot be justified by crude claims that the private sector is better at managing and providing assets and services than the public sector; this is clearly not always the case. A PPP must be tested in practice through a realistic project appraisal and the preparation of a robust business case. There are circumstances though, where value is more likely to be added through a partnership scheme. Proper risk assessments and rules must therefore govern such process.

More information about the PPP approach and links are supplied on the website of the PPP Infrastructure Resource Center (PPPIRC)
http://ppp.worldbank.org

Operator models

Operator models are very complex arrangements of organisational and financing schemes which include interrelations between public body organisations and the private sector in financial matters and the provision of services. In the waste management sector these models are commonly found for the establishment and operation of landfill sites and in the area of waste water treatment.

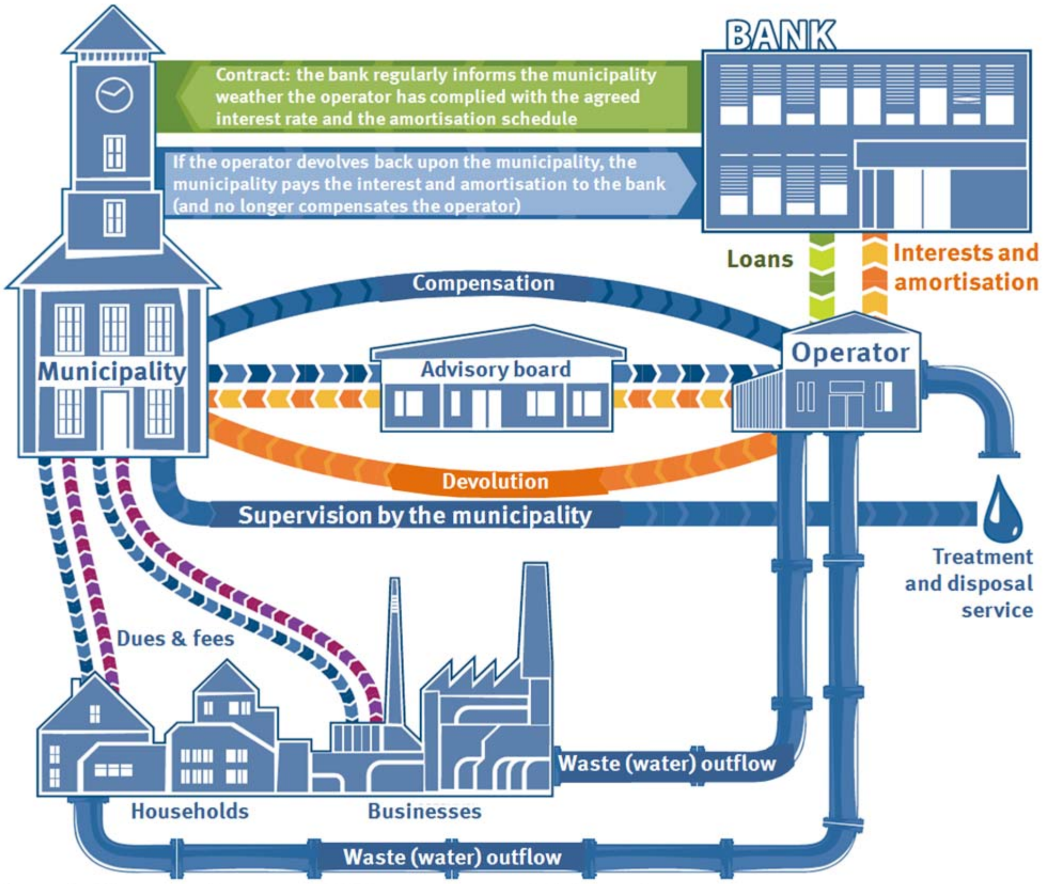
The basic idea of such model is that a private enterprise takes over the financing, establishment and operation of a disposal facility on public ground. This is done in due consultation with the responsible waste management authority who establishes the waste management needs according to which the waste disposal installation is being planned, build and operated.

The selection of the future operator is done thru a public tender procedure. The waste management authority then uses the facility to meet the waste management needs of the respective area and pays the operator a remuneration for the provided services. Basis for all that are contracting arrangements of a complex and long lasting (up to 30 years) nature

Not neglected should be the risk that the entire facility and all corresponding obligations (financial as well as organisational) will fall back to the public authority given the possibility that the commissioned operator of the facility can fail to comply with his duties or get bankrupt. To have a private financing and the appropriate expertise bound is thus of great advantage here.

The principal design of an operator model and the way it functions are shown in Figure2 on the basis of a typical arrangement found in the waste water sector.

Figure2: Arrangement behind an operator model (BOOT) on the example of waste water services



Other financing options

Fund-financing

Fund-financing is an instrument particularly for capital-intensive investments, such as the establishment of a facility for waste incineration. From the technical point of view it takes the form of a promissory note bond on a private capital collection instrument (realty fund).

The capital collection is achieved in two principal ways, namely:

a. by the sale of share certificates (which means also the creation of an own capital stock which is a precondition for option b),

b. the acquisition of additional outside capital.

The investment objects financed in this way become a property of the realty fund. The object is then given for the long-term utilization to a public body organisation (e.g. municipal association), usually by means of a leasing contract. The advantage for the public body organisation arises from the private capital collection, the saving of investments from the own budget and the integration of private expertise. Attention has to be paid to the fact that the investment risks are often entirely a liability of the public body organisation.

Factoring

Factoring involves the purchase of commercial customers' accounts receivable on an ongoing basis. Under such model, a contract is concluded between a pivate waste management company and a public body organisation (municipality) on the provision of a certain waste management service. The public body organisation pays the pivate waste management company for the availment of this service a remuneration which gets its financing from the collected charges. The private company on his part sets up a waste management facility after due consultations with the public body. The outside capital need for the investment is acquired by selling the rights on the receivable amounts (accounts) to a third party. The proceeds made in this way are usually high and the financial conditions under which the money was obtained favorable, given the fact that public bodies are not at danger to go bankrupt and the claims are backed by their power to impose charges. The advantage are the savings made on the own budget, a disadvantage is that the public body organisation renounces from insisting on its claims, i.e. the public body organisation has to continue with its payments even in case of a failing performance of the private company. A prerequisite is therefore the actual delivery of the goods or services on which the factoring agreement is based. Moreover, such arrangement has a long running period and is thus diminishing the public bodys‘ flexibility to react on a changing situation accordingly.

Leasing

Leasing has become a popular method of financing various goods and investments. Leasing means the renting of fixed assets including the option of a later purchase of these assets. Leasing contracts do not necessarily entail a change of ownership, this is just one of the possible options. Leasing is nowadays a common way to tap private capital resources for the long-term financing of public investments, so called financial leasing. Under such model, leasing companies take the investment into a specific asset with outside capital. The public body uses the asset on the basis of a contract with the leasing company. In the waste management sector, the leasing rates are getting paid from the charges collected from the citizens for the provided waste management services. While almost any fixed assets can be leased, usually no lease financing will be provided on current assets such as unsold inventory, raw materials or unfinished goods.

Again, savings made in the own budget are the main advantage of such models. Leasing contracts, however, transfer the entire risk from the leasing company to the lessee. This can cause problems when the conditions for which the asset was created do not hold true, e.g. a facility that was erected under the provision that it will intensively be used over a long time span does not meet the demand that was foreseen or suffers from decreasing rate of availment. In the extreme case the reasons why the facility was rented do not exist any longer whereas the public body is obliged to continue with the payment of the leasing rates.

Financial instruments of environmental policy governed by the state

The financial instruments in state environmental policy have the function of creating incentives and to provide the financial resources needed to meet certain environmental objectives. The prices for using the environmental resources are determined by political decisions. They are made to simulate market-like processes for the production factor 'environment' which would not exist otherwise. The costs arising thereof make the use of certain environmental resources more expensive. This creates an incentive for the sparing use of these resources and the application of environmentally benign technologies.

As of yet there is no uniform application of the terms used for the various financial instruments governments employ by to raise the funds and exercise steering functions for environmentally related actions. The instruments for which a description will be provided hereafter are therefore characterized in accordance with a differentation given by Ekins and Speck (1999):

- *cost-covering charges*, whereby those making use of the environment contribute to or cover the cost of monitoring or controlling that use. The level of a cost-covering charge is determined by the service it is intended to deliver or the other purposes which the revenues will support.
- *incentive taxes*, which are levied purely with the intention of changing environmentally damaging behaviour, and without any intention to raise revenues. Indeed, the success of such a tax may be judged by the extent to which initial revenues from it fall, as behaviour changes.
- *revenue-raising taxes*, which may influence behaviour but still yield substantial revenues over and above those required for related environmental regulation.

Clearly these three types of environmental taxes are not mutually exclusive: a cost-covering charge may have incentive effects like a revenue-raising tax, or the revenues from a revenue-raising tax may be partially used for related environmental purposes. This is where to distinguish taxes and charges becomes really difficult[1].

Environmental taxes / Eco-taxes

Opposite to environmental charges which are levied directly on environmentally relevant activities, revenues from these taxes are included in the general budget and not directly or automatically earmarked for the specific area under which they were collected. Their character is that of revenue-raising and incentive taxes, and the money a contribution of the citizens to the public budgets needed to finance collective services provided by public authorities.

Revenue-raising taxes

- *Commodity tax (Resource consumption tax)*: This tax is aimed at the sparing use of certain resources and intended to promote the development of product saving processes and technologies. A well known example is the tax on mineral oil or fuels.

Incentive taxes

- *Tax on waste disposal:* Taxes on waste disposal are employed with the intention to strengthen waste avoidance efforts. They should encourage the production of products which have a long life span, are reusable, can be recycled and generate little waste and environmental impacts during disposal. The aim is a closed loop economy with a minimum of negative impacts to the environment.
- *Packaging tax:* The packaging tax is a local purchase tax, that can be collected upon the sale of non-reusable, non-recyclable packaging products, such as one-way dishes. The application of this tax has spatial limitations and may not be enforceable because of legal biases, however. (Remark: The implementation of the tax has been legally stopped in a number of European countries).
- *Tax on municipalilties:* A special instrument imposed by state authorities is a tax on municipalities for exceeding waste amounts[2]. This instrument is applied on municipalities if the total amount of household waste collected by the municipalities exceeds an amount that has been legally determined.
  This tax shall force the municipalities to improve their waste management systems, to raise the general awareness of waste minimization among their population and thus to limit as much as possible the quantity of waste produced. Every ton of waste that exceeds the allowed level will be charged with a special tax that has to be paid by the municipalities to the authority who imposed the tax. The basis of assessment for the application of the taxation is the total quantity of household waste collected within one year. Some kinds of wastes may not be taken into account when calculating the yearly allowed amount of wastes. This are the reusable fractions, like paper or glass, etc. which are collected through specific collections and any material that still could be eliminated, segregated, or recycled from the household waste after the collection, whereas recycling could also include thermal waste reuse. This amount is excluded from the permitted quantity and not at all subject to the tax, in order to support waste recycling.

[1] See also: Study on Environmental Taxes and Charges in the EU. Report of ECOTEC and others, April 2001

[2] The instrument is for example known from the Walloon Region of Belgium where it was imposed in 1999

Environmental charges

Environmental charges shall have an incentive function and likewise raise the money needed to finance the respective environmental services. The proceeds are being used to recover the costs and to invest into the specific sectors through which they were obtained.

Charges for waste material management

The charge is levied together with the price for a product or availed service. In this way the consumer of the product/service bears for the costs which incur from the disposal of this product or from the service' impact on the environment. EU provisions on extended producer responsibility has for example led to a number of arrangements where charges for waste material management being levied, e.g.

- The *"green-dot"*-scheme for packaging waste. A license fee imposed on packaging authorises for the use of the "Green Dot" which indicates to the consumer that collection and sorting is financed by producers and retailers (http://www.gruener-punkt.de/en.html; http://www.pro-e.org).
- *Take back arrangements* for e.g. WEEE, end-of-life vehicles and batteries. Legal regulations foresee the cost for the take back and disposal service to be borne by the producers and retailers who - similarly to the packaging sector- will add them to the product price at the moment of sale.

Charges for waste material management can also be applied sector-specific, examples are:

- charges levied *from tourists* as part of the price for accommodation or included into the visitor's or any special local tax collected from them.
- *Ships* may have to pay such a charge in order to avoid the disposal of their waste to be done at sea. The charge is due when they enter a port and provides for the opportunity to get rid of the waste at the appropriate facilities in the port area.

Product charges

Product charges are specially levied to minimize for environmental and other reasons the use of a certain type products and/or material compositions. Examples are the charge on cans (formerly imposed in Denmark) or mandatory deposits (such as have to be made on one-way bottles and cans in Germany).

Waste treatment charge / tax

This type of charge exists in many European countries where it is levied in conjunction with different options for waste treatment as a landfill tax, incineration tax or waste treatment charge in order to promote a more environmentally benign waste disposal behavior and direct waste streams into the most appropriate facilities and collection systems. Most widely applied are:

- The *landfill tax*. It is imposed on waste amounts sent to landfills. In order to take a steering function as regards the diversion of the waste to recycling and other appropriate treatment facilities, a differentiated levy in dependence from the waste material and the state of the facility must be applied. The revenues should flow into a special trust fund from where it is especially used to finance the sanitation and remediation of older landfills. To prevent the waste from being shipped to less developed landfill sites or abroad a harmonized framework must be created.
- The *incineration tax* is imposed on waste amounts sent to waste incinerators. Through a differentiation of the levy in dependence from the kind of waste and the type of facility a steering effect can also be achieved with regard to the supply of the waste to facilities with a higher environmental standard (i.e. from the pure waste incinerators of the older type to facilities with energy recovery or modern waste-to-energy plants). Generally such a tax is meant to ensure that waste management will not simply shift from being a landfill dominated system to an incineration-centred one. It helps to shift waste management thinking from end-of-pipe solutions to materials recovery.

Environmental license and certificates

Environmental licenses and certificates form a financial instrument of environmental policy in that governments are selling rights for the release of emissions to the environment in order to provide an incentive for the reduction of these emissions to those generating them and reward those investing in clean technologies.

A license issued to an industrial operator deals with emissions to all environmental media, in addition to the environmental management of the facility. All related operations carried on by the operator in, on or adjacent to the facility are taken into consideration. The facility operator can release emissions only with such license and up to the amount for which he has obtained them, however, those who generate lower emissions can trade in their surplus licensed amounts to those who exceed the limit of their own license. A limitation of the tradable licenses provides for the margins in which the pollution of the environment can take place. Such limitation can however impair the competitiveness on the market in that monopolies could be created and hurdles for the access of newcomers to the market erected by the hoarding of licenses.

Waste management related licenses could be useful for the limitation of one-way packaging and the integration of any harmful substance in products becoming waste at the end of their life.

Under emissions trading schemes an overall limit is set on the greenhouse gas (GHG) emissions that the installations falling under the scheme are allowed to emit. This cap is distributed amongst the participants in the form of allowances, or permits to emit. The participants may then choose to use their assigned allowances to cover their emissions or to some degree reduce their emissions and sell excess allowances to other participants. Up to now the scheme adopted in the EU covers five main sectors, namely power and heat generation, iron and steel, mineral oil refineries, mineral industry (cement, glass, ceramics), and the pulp and paper sectors. Especially the use of waste derived fuels for energy production in industrial co-incineration processes (see factsheet "industrial co-combustion") can be a way to spare CO_2-certificates in case that waste with high biodegradable content is being used. However, mass-burn waste incinerators are by and large excluded from the emission trading until today.

Emission trading is done under the supervision of special authorities. They are the one responsible for the allocation and issuance of allowances, monitoring and control tasks, the administration of the national registry as well as national and international reporting. The issuance of allowances for new installations considers the application of the best available techniques for the minimization of GHG emissions. This is meant to work as an incentive for the operators to invest in ecological benign technology and to use fuels with a low potential for CO2 generation. The German Emissions Trading Authority (DEHSt) has been established at the Federal Environment Agency.

Industrial installations that are successful in reducing their GHG emissions beyond their target generate a surplus of allowances and can sell them to companies that do not meet their targets. In addition, companies are able to purchase Certified Emission Reductions under the regulations of the *Clean Development Mechanism (CDM)* and, from 2008 onwards, also Emission Reduction Units from *Joint Implementation (JI)* in order to achieve their targets. This has been implemented via separate EU legislation known as the 'Linking Directive.'

The introduction of Clean Development Mechanism (CDM) goes back to the United Nations Framework Convention on Climate Change which was formulated with the objective to stabilize GHG concentrations in the atmosphere at levels that would prevent dangerous human interference with the climate system. To further the goals of the Framework Convention on Climate Change, the Kyoto Protocol was adopted

Both JI and CDM are 'project-based' mechanisms which involve developing and implementing projects that reduce greenhouse gas (GHG) emissions, thereby generating carbon credits that can be sold on the carbon market.

JI is a mechanism that allows the generation of credits (known as Emission Reduction Units) from projects within industrialized countries, whereas the CDM allows the generation of credits known as Certified Emission Reductions from projects within developing countries.

Such emission reductions can also be generated in waste management upgrading projects, for example the transformation of an uncontrolled landfill into a landfill site with waste pre-treatment, gas collection and gas-to-power generation (see factsheet "non-hazardous waste landfill"). The category of waste handling and disposal CDM projects can also include liquid industrial waste such as waste water from palm oil or starch producers or animal farms. Methane is extracted from the waste streams and used as a biogas to supply heat and/or electricity on- or off-site, or simply burned (i.e. flared) in order to reduce its GHG potential.

In order for a project to generate Certified Emission Reductions, it must undergo a rigorous process of documentation and approval by a variety of local and international stakeholders, as specified under the CDM Modalities and Procedures. For this all CDM projects must satisfy certain requirements specified in either the Kyoto Protocol or the Marrakesh Accords. The revenues coming from such deal might be used for financing further waste management measures and investments.

A CDM guidance has been produced by UNEP and is accessible at:
http://www.cd4cdm.org/Publications/FinanceCDMprojectsGuidebook.pdf

Collection, pick up, transfer and transportation of municipal solid waste

Introduction

In addition to reuse, recycling and energy recovery as the primary targets of handling generated wastes, a good waste management framework should also prescribe that all waste disposal shall incorporate the treatment and storage of waste as well as all necessary measures of collection and transportation. In order to facilitate this, waste must be made collectable at its source. If an adequate waste treatment or processing is not possible close to the place of its generation, waste need to be transported, either directly or after reloading at a transfer station, to a specialized facility for the processing, material recovery, or for the final disposal of these waste.

The collection and transportation stage includes:

1. the collection of all household, industrial, and commercial waste including the collection of recyclable waste as much as possible separately from other waste types and the picking up of these wastes from the place of their collection;
2. the transportation of the collected waste to processing and disposal facilities including the necessary transfers or intermediate storage.

The stage of waste collection and transportation plays a central but often underestimated role in the waste management system. After all, it accounts for 60 - 80% of the total cost of waste disposal and thus any improvement in its organization and implementation would result in considerable savings. The type, size and combination of the receptacles used for collection, and the collection frequency furthermore influence the composition of household waste as well as the quality and quantity of the separately collected recyclables, and thus demands and costs for the subsequent treatment. All this shows that the opportunity to influence the amount and composition of the waste stream is given at the very beginning of the waste management process already.

An efficient and optimal implementation and organization of waste collection must take the following factors into account:

- dimension of the collection area,
- its structural, economic and social settings,
- area specific legislative stipulations,
- user demands, and
- the spectrum of appropriate collection systems and technology.

Essential details concerning the above factors are part of the information compiled in this section and have as well been included in the characterization of the application framework and technical descriptions forwarded in the various factsheets on appropriate collection systems and technology.

Waste collection

The process of waste collection begins when the generated waste is thrown into appropriate receptacles and ends when these receptacles are picked up and emptied by collection vehicles. A collection system is therefore defined as a combination of technology and human activities, and characterized by:

- the receptacles used for collection ,
- the applied method of setting them out and picking them up,
- the collection vehicles.

In a community with a variety of residential, commercial, and industrial developments it is impossible to collect waste with only one system. A variety of collection systems has to be used that are best suited to address the local waste arising and meet specific needs and spatial requirements.

Different collection arrangements and options for picking up the waste will be described in the following text. Details concerning the receptacles and vehicles used for collection are contained in the Factsheets enclosed to it. Hyperlinks and references included in this text provide for the link between the general descriptions and specific technical information in the factsheets and facilitate easy access to them

Collection arrangements

The means (receptacles) used for collection and the manner in which they are handled during the pick up operations is largely determined by the collection arrangement. The collection arrangement has to orient on the specific settings of the area, the collected waste types and other logistic aspects. Generally, two arrangements can be distinguished, the pick-up and the drop-off arrangement/system (Figure 1).

Pick-up arrangement/system

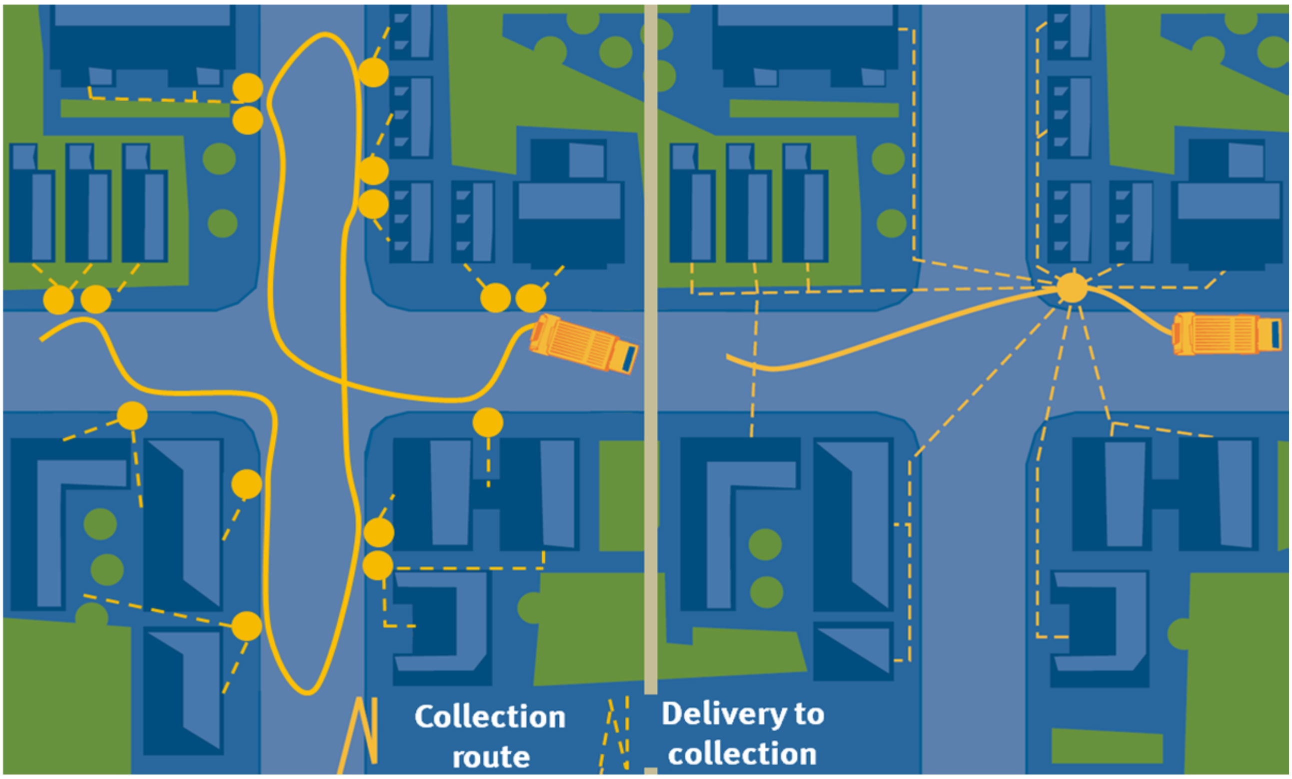
Residual waste from households and commercial sources and wastes which require special care (e.g. bio-waste, hazardous wastes) or would add extraordinary burdens to the waste generator (e.g. bulky waste, C&D waste) are usually collected in the pick-up system. In this system, the receptacles or containers are usually installed/ set up for collection close to the houses of the waste generators. From there they are set out to the kerbside either by the waste generator or by the collection crew for emptying. That's why the system is also referred to as kerbside collection.

The collection vehicle then passes by each container and picks up/empties its content. Each point where the vehicle has to stop for emptying (a) container(s) can be called a collection point. The use of specially assigned containers simplifies the work and allows the identification and individualised charging of the waste generator with the help of bin identification. 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.

Drop-off arrangement or bring system

In the drop-off system, accumulated waste amounts are taken by the waste generator to a central location and are being dropped into containers specially set up for this purpose. For the most part, drop-off stations or bring bank type of waste containers are used. The containers should be emptied regularly or as needed. Contrary to the pick-up arrangement the collection vehicles must go to central sites only and not pick up the waste from the kerbside in front of each house. 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 integrated into the local environment and reach area wide coverage. Successful locations have a high visibility and a high frequency of people's traffic such can be sites near shopping centres or at parking areas. Special care must be given to the regular cleansing of these sites.

Figure 1: Schematic drawing of pick-up (left-hand side) and drop-off arrangement (right-hand side) for waste collection



A particular component in a bring system are public recycling stations or civic amenity sites. These are operated bring sites for various types of (mainly recyclable) wastes generated by households. Households may be permitted to bring certain amounts of specific wastes to these sites free of charge, for other types a special levy might be charged or the disposal at such sites must generally be paid. The first option applies especially for source separated recyclable waste and in cases where the general waste charge already includes part of the operating costs for the recycling station

Collecting recyclables via such stations normally results in a better quality (purity) of the recovered material due to the direct gate control (especially observed for waste paper, see Table 1).

Table 1: Differences in the collection costs and quality of separately collected graphical paper in dependence from the employed collection system (data from Germany, Intecus GmbH, 2005)

Collection arrangement	Separate bin, pickup	Drop-off station bring bank	Recycling station
Collection costs	~100 EUR/Mg	~70 EUR/Mg	~110 EUR/Mg
Share of impurities in the collected material	~ 18 % (of which 2% non-paper material)	~ 3.5 % (of which 0.4% non-paper material)	~ 0.5 % (of which 0.1% non-paper material)

The higher proceeds that can consequently be made from selling these materials can (partly) compensate the high costs of operating such stations. However, often the purpose of such stations is also to offer a possibility for the collection of environmentally particularly sensitive wastes such as batteries, old paint and lacquer and other potentially hazardous wastes and thus to ensure their controlled disposal. Recycling stations can be well combined with social support programmes and charity activities in the frame of immediate on-site recycling schemes. Disabled, jobless or otherwise handicapped people can be involved, for example in the dismantling of electronic and household appliances for the recovery of spare parts and valuable materials, or in the refurbishment of old furniture for second-hand sales, and in this way economically or socially benefit from this waste management solution.

Methods for picking up waste

There are three different methods used to pick up the waste:

- simple container emptying,
- container exchange or
- one-way.

In addition, a non-systematic collection can be performed for picking up bulky waste and other particular items (e.g., furniture, WEEE, hazardous materials). Each collection method has compatible or dedicated container systems and vehicles with the appropriate loading technology and crew arrangement.

Simple container emptying

This method is primarily used for the pick-up of household and small quantities of commercial waste and uses a variety of standardized containers. The content of the container is emptied mechanically into the collection vehicle and then the container is returned for refill. Emptying of the containers is performed by different types of collection vehicles. For the mobile waste containers, rear-end, front or side-loaded collection vehicles are most common. For drop-off stations vehicles with open swap body containers are most suitable.

Container exchange

The exchange method is suitable for waste of high density, e.g. C&D waste, as well as for low-density waste from sources that generate large quantities of waste, e.g. manufacturing or industrial sites, hotels, offices, or multi-story buildings. In this method, full containers are exchanged with identical but empty containers at their place of installation. The full containers are taken along, get emptied at a treatment facility and can then be used elsewhere. For economic reasons, these containers (roll-off container, skip container system) have generally larger capacities but can be carried by a multitude of vehicles with the respective superstructure.

One-way method

In the one-way method, waste is picked up lose or in receptacles such as bags or sacks of different or big bags which get disposed of together with the waste. The collection process is rather easy because there are no emptied containers to be returned and the receptacles don't need to be cleaned. However, to get these receptacles into the collection trucks usually involves much of manual work which places considerable physical demands on the collection personnel. Because of this and due to limited strength of the material, quite small volumes can be forwarded with these receptacles only; moreover they become a waste themselves. Rear end-loaded collection vehicles and vehicles with open skip container systems suit best for this method.

Non-systematic and other special methods of collection

The non-systematic method applies to waste which is picked up on request from the kerb-side without specific container arrangements. Depending on the type of waste the material can be set out loose as it is or in different kind containers. Rear end-loaded collection vehicles, vehicles with walking floor or open skip container systems can be used here but also simple platform trucks can make it.

Another special but more investment intensive collection method is the vacuum system. It combines collection and to a certain extent transportation of the waste. It is particularly suitable in densely built-up urban areas, areas with special constraints in terms of accessibility and aesthetic value and for high rise apartments and larger building complexes, such as hospitals. This method replaces the internal collection and storing of the waste and the need of setting out the waste in special receptacles for pickup.

Transportation of waste

After the collection and pickup, the waste materials need to be transported to the facilities for waste treatment and disposal. This could entail transportation over short or long distances. With an increasing centralization of waste processing facilities and disposal sites, waste transfers and long distance transportation are gaining more and more importance.

For transportation over short distances the same vehicles that picked up the waste should be used. To use these vehicles also for the long-distance transportation is however not economical since they are optimised for the pick-up processes and do have rather limited loading capacities and usually additional personnel on board.

Are the appropriate facilities for waste treatment and disposal far off or difficult to reach (distance or expensewise), a long-distance transportation might become an option. For that different means for long-distance transportation can be employed, including various container systems and vehicles. Under certain circumstances, this requires a reloading of the waste from the collection vehicles to long-distance transporters at a waste transfer station. To employ waste transfer stations and long-distance transportation causes additional costs that, in order to render the process in an economic way must in total be lower than the costs that would accrue if collection vehicles would undertake the transports.

Short-distance transportation can be accounted as part of the process for picking up the waste. It is therefore more comprehensible to refer with the term "waste transportation" to long-distance transportation conducted by adequate means only. A distinction of waste transportation can be done in the following ways:

- by the kind of the employed transportation vehicle, i.e. truck, train or ship;
- by the kind of container system or truck body used, i.e. open or closed, exchangeable or fixed;
- transporting the waste material in a compressed or non-compressed state.

Waste transfer stations have to be planned and designed in accordance with these criteria.

Truck, train and ship transportation

For waste transportation a network of road, railway and waterway connections from the collection area as the place of waste generation to the waste management facility as the place of disposal is required. Unlike in road traffic where alternative routes are generally available, the limited coverage or lack of railroads and waterways within an area poses a principal limitation for waste transportation by train and ship. To consider a connection to these specific transport routes during the erection of a waste transfer station and/or disposal facility just to facilitate waste transportation is all but economically irrational. If there is no direct connection of this kind already existing, transport by train and ship can however become a part of the transportation chain at the expense of further costs for the additional reloading procedures. In this case one speaks of a combined transportation.

Further disadvantages of the combined transportation, aside from incremental costs, are the relatively low flexibility in case of changing conditions and the rather high quantities of waste needed to ensure an economically efficient transportation. Transports by ship may also suffer from periods where navigation is impossible due to low water levels, flood or ice drift so that additional capacities for intermediate waste storage or alternative transportation need to be planned. Railway and ship transportation of waste furthermore require enterprises with a certain experience in waste disposal logistics in order to ensure the transportation chain to be closed and necessary capacities to be provided just in time.

The advantages of ship and railway transportation as opposed to road traffic are the significantly higher loading capacity (maximum load: truck 25 t, train about

1000 t, riverboat 500–3000 t), thus a lower overall emission rate and environmental impact, lower specific energy consumption and a higher level of transportation safety.

Road, railroad and waterway transportation can all be adjusted to the to-be-transported waste amounts quite easily. There could however also be problems with the available capacities due to high demands and traffic movements in all three sectors including at the waste transfer stations.

Given the potential disadvantages of ship and railroad transportation in essential aspects, road transportation is still the dominant solution for waste transportation. Ship and railroad transportation is especially advantageous where wastes are generated in large amounts and where the place of generation and the disposal facilities have a direct connection to waterways or the railway network.

Fixed body transportation

Waste transportation in fixed bodies of long- distance transporters starts with an open loading of the waste into the body by means of conventional loading equipment such as, e.g. wheel loader, crane, over a dumping ramp, etc. at a waste transfer station. For the transportation of waste in a compressed state, large semitrailer trucks with a closed body are normally used. At the waste transfer site, these trucks are loaded with the waste which then gets compacted inside the body with the help of stationary compactors or thru a compacting mechanism integrated into the semitrailer itself.

For the transportation of waste in a non-compressed state, large semitrailer trucks with an open body are generally the choice. These bodies can be emptied via a tipping mechanism or have a walking floor system which can be used for the discharge of the waste. Transportation in open bodies by ship and railroad is common for inert waste material such as scrap metal and mineral C&D waste to a larger extent.

Swap body transportation

As the best way to avoid emissions during the reloading and transportation processes, exchangeable or swap body container systems are the preferred solution for the transportation of other than the above mentioned solid waste material per ship or railroad.

The advantage of this system lies in the exchange of full container bodies against empty ones as the only operation during the reloading. For a number of systems, there is even no need for additional reloading equipment such as cranes. In these cases technology allows the exchange to be performed by the transporters themselves and hence in a very cost efficient manner. Emissions during the reloading can be reduced to a minimum this way, a fact which can also mean a great advantage in the necessary permitting process for a waste transfer site. To have this benefit already when the waste gets transferred from waste collection to long-distance transportation, the use of collection vehicles with swap bodies is becoming more and more important.

For source-separated solid waste materials such as waste paper and glass which collection vehicles normally carry in a non-compressed state, the use of open roll-off containers as a kind of swap body on collection vehicles has already become a common solution.

Latest developments in the fabrication of collection equipment also allow collection vehicles to get equipped with closed swap body systems with an integrated compressing. Appropriate truck-trailer combinations can do the transportation of two to three swap body containers at once and often have the capacity to perform the container exchange on their own. Also available are railroad wagons for sets of two to three swap bodies. Likewise possible is the transportation of swap bodies by ship. Loading and reloading in both cases is done by cranes, direct reloading from trucks to train and vice versa is yet rather seldom.

Remark: Detailed descriptions of the technology and equipment referenced in the text are provided with the following factsheets.

Table 2: Overview of related factsheets

Subarea	Factsheet specification
Collection	Roll-off container Skip container Mobile waste container Bring bank Collection sack/bag Big Bag
Pick-up	Rear-end loader Front loader Side loader Vacuum Collection Waste Bin Identification
Transportation	Walking floor system Swap body container Transfer station

Umwelt Bundesamt

ROLL-OFF CONTAINER

APPLICATION OBJECTIVE	- To facilitate the collection, pick-up, storage and transportation of various types of waste in a system with container exchange

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	X
Lamps		Textiles		Electrical and electronic waste	X
Scrap metal	X	Wood waste	X	C&D waste	X
Waste oil		Old paint & lacquer		Waste tyres	X
Hazardous waste					
Branch specific waste					
Other waste materials	X	For all types of solid waste, accruing in high amounts in smaller areas within a shorter period of time			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
not necessary, except of size reduction for oversized items to fit container dimension

Options for the utilisation of the generated output:
unlimited, no dependencies from type of container used

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
The container system is especially useful in areas offering sufficient space and if set up at centralised locations with good access. They are perfectly suited to serve at bring stations/public amenity sites where bulky items, such as household devices, old furniture etc., and mass materials from households with a high density, like glass culets or graphic waste paper are collected.
The site should have a paved, compacted or otherwise stabilized surface in order to prevent the containers from sinking into the ground once they are getting filled.

Climatic conditions:
danger that container may sink into the ground in areas with soft soil and excessive rainfall or get frozen on the ground in cold climates

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	The roll-off container system is the most widely spread standard container for collection and transportation as regards the specific manner in which the container is picked up and fixed at the transportation vehicle (DIN 30 722). It is the most simple and most frequently used container version for the collection and transport of single large waste quantities in an exchange system (i.e. full container is exchanged against an empty one and then carried away). Beside vehicles with the appropriate chassis, there can also trailers be used for the transportation. There are various versions available, among others such that can very well be used in a bring scheme to collect solid waste items from households which are bulky (household devices) or highly compacted (glass, graphic paper). Frequently used for this purpose are multi-compartment or segmented container versions with flexible partition walls that allow different material fractions to be separately stored in one and the same container.
BASIC REQUIREMENTS	- A plain and easily accessible space of appropriate size to set out the container and a suitable truck/trailer chassis with roll-off tipper for the transportation are needed

SPECIFIC ADVANTAGES

- Interchangeability of the container
- wide spectrum of applications for various types of goods to be transported
- can be used during different waste management stages (from collection to storage container for waste processing, but most particularly for transport)
- many compatible versions
- reasonable in price due to a high degree of standardisation

SPECIFIC DISADVANTAGES

- no compression within the container possible, except for special (press container) versions
- there are more suitable solutions for long-distance transportation (see fact sheet "walking floor system")

APPLICATION DETAILS

TECHNICAL SCHEME

The roll-off container system (Figure 1) does comprise the container and a special superstructure on the truck/vehicle (Figure 2) that carries the container. There are many modifications and special versions (e.g. multi chamber system) of the container body depending on its specific application.

Figure 1: Roll-off container at recycling centre (left) and multi chamber system for separate collection of recyclables (right) (picture source left: Harald Heinritz, www.abfallbild.de / Picture source right: Intecus)

Modified special versions of the container system may include tipping and compressing installations for the mobile or stationary collection, versions with fixed or removable covers, stackable container versions, versions with foldout side- or back walls, rotting containers with ventilation systems, changeable superstructures for vehicles with rear or front loading inlet, ACTS-approved.

Figure2: Loading and Unloading of roll-off containers using a superstructure system (picture source right: Intecus GmbH/ picture source left: Harald Heinritz, www.abfallbild.de)

QUANTITY ASPECTS

The carrying capacity is limited by the allowed total load of the vehicle and the container type (permitted container load).

SCALE OF APPLICATION

The Volume of different roll-off container has a range of 5–40 m³.The total length varies between 4,000 and 7,800 mm with the width being normally 2,320 mm. The container height depends on the specific version, for the basic version it is between 500–2,500 mm. The container weight is in the range of 1,300–3,300 kg, depending on the specific version (light, stable or heavy) and use. The height of the handle for pick up is 1,570 mm according to DIN 30 722.

INTEROPERABILITY	Special container versions can be attached to external, stationary or on-board compressing units or allow the subsequent integration of a compressing device into the container body itself in order to increase the container's carrying load. Examples are: - container versions for stationary compressing: - versions for mobile compressing on board of the collection vehicle - container-integrated solutions Roll-off container can also be used for railway transportation (having received a special certificate (ACTS-Certificate). Furthermore, special tipper installations are offered for emptying two and four-wheelie waste bins into roll-off containers (See fact sheet „Mobile Waste Container"). Beside a direct transportation on trucks there is also the possibility to put roll-off container on trailers. In this case, loading and unloading is normally done from the trucks. However, there are also trailers with their own lifter system so that the roll-off container can be transported with, for example, a tractor as well.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
HUMAN RESOURCES	1 truck driver (who executes also all necessary operations such as, e.g. loading/unloading).
AIDS AND ADDITIVES NEEDED	Trucks need to have a roll-off tipper to transport these containers. For a roll off container with integrated compressing unit a heavy current connection is needed.
SPATIAL NEEDS	A roll-off container requires a space of 4,400 mm (max. 7,800 mm) x 2,320 mm, depending on the specific version. Additional space is needed to give access to the truck and to temporarily set out another container in exchange. A plain, solid ground with a maximum inclination of 5 % is needed to set a roll-off container out and pick it up.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- 1 truck with superstructure (3 axes, 20 Mg carrying capacity): ~ 90,000–130,000 Euro - Container (basic version): ~ 3,500–7,000 Euro
OPERATING COSTS	- repair and maintenance: per annum 11 % of the initial investment - personnel: 1 person (2 in maximum, depending on the operation mode)
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES	Roll-off container systems are a well proven technology for waste collection and transportation with a large scale application and references worldwide.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Truck superstructure: - F.X. Meiller Fahrzeug- und Maschinenfabrik GmbH & Co KG, München www.meiller.com - Hüffermann Nutzfahrzeuge GmbH, Wildeshausen www.hueffermann.de - PALFINGER GmbH, Ainring, www.palfinger.de Container - Laudon GmbH & Co. KG, Weilerswist www.laudon.de - Werner & Weber Deutschland GmbH, Oberhausen, www.werner-weber.com Compacting systems - Avermann Maschinenfabrik GmbH, Osnabrück www.avermann.de - Husmann Umwelttechnik GmbH, Dörpen www.recycling-umwelt-technik.de
REMARKS AND REFERENCE DOCUMENTS	

Reference for applicable norms/standards in Germany:
- **DIN 30722-1 to 4**: Roller contact tipper vehicles, roller containers
- **DIN 30730:** Mobile waste packer - Multi-bucket system vehicles and roller contact tipper vehicles

SKIP CONTAINER SYSTEM

APPLICATION OBJECTIVE	- to facilitate the collection, pick-up, storage and transportation of various types of waste in a system with container exchange

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	X
Lamps		Textiles		Electrical and electronic waste	X
Scrap metal	X	Wood waste	X	C&D waste	X
Waste oil		Old paint & lacquer		Waste tyres	X
Hazardous waste					
Branch specific waste					
Other waste materials	X	for all types of solid waste, accruing in high amounts in smaller areas within a shorter period of time			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
not necessary, except of size reduction for oversized items to fit container dimension

Options for the utilisation of the generated output:
unlimited, no dependencies from type of container used

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
The container system is especially useful in areas offering sufficient space and if set up at centralised locations with good access. They are perfectly suited to serve at bring stations/public amenity sites where bulky items, such as household devices, old furniture etc., and mass materials from households with a high density, like glass culets or graphic waste paper are collected.
The site should have a paved, compacted or otherwise stabilized surface in order to prevent the containers from sinking into the ground once they are getting filled. To set a skip container out and pick it up, a maximum ground inclination of 5 % should not be exceeded.

Climatic conditions:
Danger that container may sink into the ground in areas with soft soil and excessive rainfall or get frozen on the ground in cold climates.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	The skip container system is one of the most widely used standard containers for collection and transportation as regards the specific manner in which the container is picked up and fixed at the transportation vehicle. Similar to the roll-off container system (see fact sheet ”Roll-off Container“), this is a simple and very frequently used container version for the collection and transport of single large waste quantities in an exchange system (i.e. full container is exchanged against an empty one and then carried away). Beside vehicles with the appropriate chassis, there can also trailers be used for the transportation. Loading and unloading is normally done by the trucks.
BASIC REQUIREMENTS	- a plain and easily accessible space of appropriate size to set out the container and a suitable truck chassis with skip handler for pickup and transportation

SPECIFIC ADVANTAGES

- interchangeability of the container
- wide spectrum of applications for various types of goods to be transported
- can be used during different waste management stages (from collection to storage container for waste processing, but most particularly for transport)
- many compatible versions
- reasonable in price due to a high degree of standardisation

SPECIFIC DISADVANTAGES

- no compression within the container possible, except for special (press container) versions
- there are more suitable solutions for long-distance transportation (See fact sheet "walking floor system")

APPLICATION DETAILS

TECHNICAL SCHEME

Figure 3: Stacked skip containers (left) and loading process of a skip container (right) (picture sources left, right: Intecus GmbH)

Further modifications of the container system may include tipping and compressing installations for the mobile collection, stackable container versions or versions with foldout side- or back walls.

Figure4: Skip containers for the separate collection of waste (picture source left, right: Petra Hoeß, FABION Markt + Medien, www.abfallbild.de)

QUANTITY ASPECTS

Carrying capacity is generally lower than capacity of roll-off container. The carrying capacity is limited by the allowed total load of the vehicle and the container type (permitted container load).

SCALE OF APPLICATION

The Volume of different skip containers has a range of 5–20 m³ according to standardised norm. The total length varies between 1,500 and 4,800 mm with the width being normally 1,520 mm. The container height depends on the specific version, for the basic version it is about 1,500 mm. The container weight is in the range of 300 kg–1,500 kg, depending on the specific version (light, stable or heavy) and use.

INTEROPERABILITY

In addition to a number of special container versions with integrated functions there can also be a compacting unit attached to this container system to increase the carrying mass over volume. Further to a direct transportation on trucks there is also the possibility to put skip container on trailers. In this case, loading and unloading is normally done from the trucks.

OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
HUMAN RESOURCES	1 truck driver (who executes also all necessary operations such as, e.g. loading/unloading).
AIDS AND ADDITIVES NEEDED	Trucks need to have a skip handler to transport skip containers. For a skip container with integrated compressing unit a heavy current supply is needed
SPATIAL NEEDS	A skip container requires at least a space of 3,000 x 1,900 mm, depending on the specific version. Additional space is needed to give access to the truck and to temporarily set out another container in exchange.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- 1 truck (3 axes, 13 Mg carrying capacity): ~ 75,000–120,000 EUR - Container (basic version): ~ 1,500–3,500 EUR
OPERATING COSTS	- Repair and maintenance: per annum 11 % of the initial investment - Personnel: 1 person (2 in maximum, depending on the operation mode)

MISCELLANEOUS

MARKET INFORMATION	
REFERENCE FACILITIES	Skip container systems are a well proven technology for waste collection and transportation with a large scale application and references worldwide.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Truck superstructure: - F.X. Meiller Fahrzeug- und Maschinenfabrik GmbH & Co KG, München www.meiller.com - PALFINGER GmbH, Ainring, www.palfinger.de Container - Laudon GmbH & Co. KG, Weilerswist www.laudon.de - Sirch GmbH & Co. KG, Kaufbeuren-Neugablonz www.sirch.com - Werner & Weber Deutschland GmbH, Oberhausen, www.werner-weber.com - Husmann Umwelttechnik GmbH, Dörpen www.recycling-umwelt-technik.de

REMARKS AND REFERENCE DOCUMENTS

Reference for applicable norms/standards in Germany:
- **DIN 30720-1 and -2:** Containers for multi-bucket system vehicles; sizes, materials, performance
- **DIN 30723-1 and -2:** Multi-bucket system vehicles, swivelling device - Dimensions, requirements
- **DIN 30730:** Mobile waste packer - Multi-bucket system vehicles and roller contact tipper vehicles
- **DIN 30735:** Containers with a maximum width of 1520 mm for multi-bucket system vehicles

Umwelt Bundesamt

MOBILE WASTE CONTAINER

APPLICATION OBJECTIVE	- collection of waste materials from the municipal solid waste and certain commercial/ industrial waste arising in small amounts in the pick-up system

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Wood waste		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste materials	X	all kinds of non-hazardous solid waste materials, which are continuously generated from a specific source in a smaller amount			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
not necessary, except of size reduction for oversized items to fit container dimension

Options for the utilisation of the generated output:
unlimited, no dependencies from type of container used

Protective needs:
To minimize the risk of accidents, 4-wheel container versions have to be equipped with parking breaks in order to prevent the container from rolling away on an inclined surface. Cover lids shall allow the opening also from inside the container (see RAL GZ 951/1 and 2 for reference). Only containers which are free of any cracks or damages shall be used in order to avoid containers to suddenly break and release their content during operations. No plastic containers shall be used in areas with frequent arising of hot ashes from solid fuel firing in households. Specially-shaped openings in the top lid or modifications of the throw in slot may guarantee that no other waste items than those for which the container is provided will be inserted

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
Mobile waste containers are suitable for use in any kind of building structure; the location of the container shall ensure that moving them from the place of collection to the point for pickup is possible on a plain ground. The container site should have a paved or compacted surface to give the container a good foothold

Climatic conditions:
Where there are high proportions of biodegradable material in the waste or where kitchen/bio waste are collected via such containers, a frequent emptying (usually several times a week) should be ensured. This is especially applicable in areas with stable outside temperatures of 20 °C and higher. In cold climates there might be occasions that cover lids or the entire container gets frozen and hence cannot be opened or moved for a while.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	The mobile waste container system is the most widely used system for the collection of solid waste from households. These mobile waste containers are wheeled receptacles with volumes between 80–390 litres (2-wheelie bins) or 500-5,000 litres (4-wheelie container). Mobile waste containers are especially suited for pickup arrangements (kerbside collection) from households using a reloading procedure. In this procedure the content of the filled container is transferred (“reloaded”) into the storage body of a collection vehicle (see also fact sheets “Rear-end loader“, “Side loader“) whereby the container remains (empty) at the point of pickup/ container site.

BASIC REQUIREMENTS

- For picking up the waste collected with these containers, a collection vehicle usually with a lifting device (comb or Diamond type) and compaction mechanism will be needed
- For emptying, containers must be exposed at a location accessible to the waste haulers or even for the vehicle itself (kerbside)

SPECIFIC ADVANTAGES

- Possibility to interchange container
- Broad spectrum of applications for different waste materials collected from households in the pick-up system
- reasonable in price due to a high degree of standardisation
- compatible special versions for different applications, e.g. biowaste
- available in various colours for an easy differentiation of separately collected waste fractions

SPECIFIC DISADVANTAGES

- no possibility for the compaction of the waste, except for some special applications in the commercial sector
- risk that containers be set to fire from hot ashes or quickly igniting matter
- comparatively small carrying capacity for bulky or voluminous material
- emptying problems due to easy freezing of wet waste in the bin during winter season
- not optimised allocation resulting in excessive number of small sized containers that leads to inefficient collection

APPLICATION DETAILS

TECHNICAL SCHEME

The applications most frequently used in the pick-up system in Germany are those with a volume of 120, 240 and 1,100 litres. Standardized containers have a special fringe to permit emptying them by means of a standard lifting device attached to the collection vehicle.

Figure 5: Mobile waste container for residual waste (right), paper and paperboard (centre) and biowaste (left) (picture sources left, centre: Intecus GmbH, picture source left: Harald Heinritz, www.abfallbild.de)

4-wheel waste containers may additionally have a wheel/locking break. Moreover, containers are available with an arrestable lid to prevent an illegal use.

Figure 6: Waste container with locking break (left) and container version with arrestable lid (picture source left, right: Harald Heinritz, www.abfallbild.de)

Other modified versions of mobile waste container include: versions made from galvanised iron sheets, with domed or flat lid, special versions for biowaste collection with aeration system, containers to be used as moveable device for manual street cleansing.

QUANTITY ASPECTS

Depending on the size of the collection area, the to-be-collected material, the vehicle and the container type used, about 250 to 900 mobile waste containers can be emptied from one collection crew during an ordinary shift.

SCALE OF APPLICATION

Mobile waste containers are suitable for use in any kind of building structure. Common sizes for these containers are within in the range of 80-390 litres volume (2-wheelie bins) or 500-5,000 litres (4-wheelie container) volume. In order to use European standard lifting devices attached to a collection vehicle for emptying, mobile waste container must have a comb fringe. A special version of lifting device, which is hardly in use, exists with the Diamond type and is used from front and side-loaded collection vehicles. Plastic containers should not be used in areas where hot ashes from solid fuel firing are usually disposed of as a waste.

INTEROPERABILITY

Emptying of mobile waste containers always requires a collection vehicle with the corresponding lifting device. The emptying of these containers with special constructional mechanisms into a roll-off or skip container is very seldom. For emptying containers of the mobile waste container type, the following lifting devices are offered in the market:
- one-sided or double sided lifting mechanism for 2-wheel containers only,
- lifting mechanism for 2 and 4-wheel containers up to 1,100 litres,
- lifting mechanism for large container 1,100 up to 5,000.

OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION

HUMAN RESOURCES

The emptying is done from the crew of the collection vehicle which is usually of rear end-loaded type (see fact sheet "Rear-end-loader") and staffed with 1 driver and up to 4 haulers (1+4). In an optimised collection, crew arrangements of 1+1 are possible. In areas with a lower density of waste containers side and front-loaded collection vehicles (see fact sheets, "Side-loader", "Front-loader") are also often in use. Here emptying of the waste container can be done from the truck driver alone.

AIDS AND ADDITIVES NEEDED

Emptying can only be done by means of a collection vehicle with the corresponding comb lifting device.

SPATIAL NEEDS

Space requirements are low for containers of the type 80–240 litres. For 4-wheel containers, special attention has to be paid that the container site allows sufficient manoeuvrability. The site should be close to the kerb, be on plain, solid ground and without stairs.

Figure 7: Example of a site for mobile waste container in a densely built-up area (right) and in front of a school (left) (picture source left: Intecus GmbH, picture source right: Reinhard Weikert, www.abfallbild.de

Table 1: Dimensions of the most common mobile waste containers

Container (l)	Height (mm)	Width (mm)	Empty weight (kg)	Max. carrying capacity (kg)
120 litre type	930	480	11	48
240 litre type	1.070	580	15	96
1,100 litre type	1.450	1.210	69	440

OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	Investment costs for mobile waste container can range between: - 80-120 litre type: 15–35 EUR - 240 litre type: 22–45 EUR - 1,100 litre type: from 160 EUR The presented prices can only be provided if a minimum order of 10,000 pieces of 2- wheel or 1,000 pieces of 4-wheel containers is assured. Die dargestellten Preisspannen setzen eine Mindestabnahmemenge von mehreren 1.000 Stück voraus. The costs for gravity locks are at about 25 Euros for a 2 wheel bin and 55 Euros for a 4 wheel container, respectively.
OPERATING COSTS	- repair and maintenance (cleansing) services: 11 % of the investment/a - other specially requested services, such as subsequent modifications

MISCELLANEOUS

MARKET INFORMATION	
REFERENCE FACILITIES	Mobile waste containers are the most widely applied type of receptacles for the collection and temporary storage of solid waste materials from households before pickup and disposal. They are in worldwide use. In Germany, mobile waste containers with a volume of 80, 120, 240 and 1,100 litres are most common.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Manufacturers/suppliers for these type containers exist in Germany in a larger number. Some of the most prominent are for example: - SULO Umwelttechnik GmbH & Co. KG, Herford, www.sulo-umwelttechnik.de - ESE GmbH, Neuruppin www.ese.com - SSI Schäfer- Fritz Schäfer GmbH, Neunkirchen www.ssi-schaefer.de - Paul Craemer GmbH, Herzebrock-Clarholz www.craemer.de

REMARKS AND REFERENCE DOCUMENTS

Further information and a list of firms concerning the different applications, the use and necessary precautions to be made for this type containers can be obtained in Germany from:

- Gütegemeinschaft Abfall- und Wertstoffbehälter e.V., Siegburger Straße, Köln www.ggawb.com

Reference for applicable norms/standards in Germany:

- **DIN EN 840-1 to 6:** Mobile waste containers - dimensions and design, performance requirements and test methods, safety and health requirements
- **DIN 30760:** Mobile waste containers – Waste containers with two wheels with a capacity from 60 l to 360 l for diamond lifting devices
- **RAL-GZ 951/1 –** Waste and Recycling Material Containers made of Plastic Material Quality Assessment
- **RAL-GZ 951/2 –** Waste and Recycling Material Containers made of Metal Quality Assessment
- Introduction of quality label **RAL-GZ AWB**
- **VDI Guideline 2160:** Waste management in building and on ground - Requirement for bins, locations and transportation routes

Umwelt Bundesamt

DROP-OFF STATION/BRING BANK

APPLICATION OBJECTIVE	- Collection of waste materials (mostly source separated recyclables) from the municipal solid waste and certain commercial/industrial waste arising in small amounts in the bring system

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packages	X	Biowaste	
Paper/paperboard	X	Mixed household waste		Bulky waste	
Lamps		Textiles	X	Electrical & electronic waste	
Scrap metals		Wood waste		C&D waste	
Waste oil		Old paint & lacquer		Waste tires	
Hazardous waste					
Branch specific waste					
Other waste materials	X	all kinds of solid waste materials, which are continuously generated from adjacent sources in smaller amount			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:

Not necessary, except of size reduction for oversized items to fit dimension of feeding slot* (* in order to obtain a high purity of the collected material feeding slots of special shape corresponding to particular features of the wanted materials, e.g. small round hole shape for glass bottle banks, flat slit for paper banks are often used for these installations)

Options for the utilisation of the generated output:

Unlimited, no dependencies from type of receptacle used

Protective needs:

Noise might develop for certain bank types during throw-in and emptying due to the materials collected and the falling height. Noise absorbing installations or linings may therefore become necessary in noise sensitive areas.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:

Setting up bring banks is possible in all locations with the required space availability and accessibility, that is why central places (larger squares, parking areas) and the city margins are preferred areas for using these installations. There are also subterrestrial versions existing that allow the application also in areas with larger space constrains and a good visual integration into the cityscape. Using the system in residential areas must be accompanied by certain precautionary measures such as for example noise protection and limitation of operating hours in order to avoid nuisances and ensure acceptance of these systems among the population.

Climatic conditions:

no limitations but possibility to freeze on the ground in areas with cold temperatures

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	Drop-off stations/bring banks are receptacles in form of medium-sized containers which are usually set up at centralised locations for the collection of (mostly source separated recyclable) waste materials from households in the bring system. A particularly important special modification of the bring bank are the sub-surface systems. These are drop-off stations put under the ground with only a feeding slot appearing at the surface. These systems are highly relevant in densely built-up environments, in places with particular cultural-historical or otherwise representing function and in case of missing space for containers. Bring banks for glass collections often have an additional noise absorbing liner inside.

The emptying of drop-off stations is done either with the help of a crane aboard of a collection truck with roll-off container body, or with a special lifting device attached to a rear-end loaded or front-loaded collection vehicle. To discharge the waste material from the drop-off station a double hook or Kinshofer-system is being used.

BASIC REQUIREMENTS

- availability of trucks with crane to empty/transport the containers
- to be set up only at places that can be accessed from the collection truck

SPECIFIC ADVANTAGES

- possibility to interchange container
- broad spectrum of applications for different waste materials collected in the bring system
- reasonable in price due to a high degree of standardisation
- facilitates a logistically and cost efficient collection

SPECIFIC DISADVANTAGES

- only self-compaction of the waste possible
- risk that containers in public locations become subject of vandalism or be set to fire (especially when used for paper collection)
- comparatively small carrying volume for corrugated and board material
- limited feed openings at sub-surface installations

APPLICATION DETAILS

TECHNICAL SCHEME

Figure shows bring banks for glass and old textiles as well as feeding slots for public underfloor containers set up at a central location (bring station).

Figure 8: Bring bank for glass separated by colours (left-hand picture, Picture source: Harald Heinritz, www.abfallbild.de); Bring bank for textiles (centre) and bring station with underfloor container (right-hand picture, Picture source centre and right-hand: INTECUS GmbH)

A vehicle with installed crane system is used to pick up and empty bring banks and underfloor containers (Figure2).

Figure 9: Underfloor container in full size (left), a drop-off station is emptied (right; all pictures: INTECUS GmbH)

Figure 10: Scheme of drop-off station with drop down deceleration and noise absorber lining (Picture source, right: Harald Heinritz, www.abfallbild.de)

QUANTITY ASPECTS	Depending on the dimension of the collection area, the to-be-collected material, the vehicle and the container type used, about 50 to 100 drop-off stations can be emptied from one collection crew during an ordinary shift.
SCALE OF APPLICATION	Ordinary bring banks do range in size between 3–18 m^3 carrying capacity. A benchmark for the number of connected inhabitants per each bring bank in Germany is 500 capita.
INTEROPERABILITY	Drop-off stations can be (and are very useful as) an integrated part of a comprehensive waste collection system with differentiated material recovery. However, they are technically not compatible to other systems, i.e. they are suited to bring schemes only and emptying them must be done separately from other containers.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
HUMAN RESOURCES NEEDED	1 person (usually the driver of the collection vehicle does the emptying)
AIDS AND ADDITIVES NEEDED	Emptying can only be done by means of a crane or special lifting devices attached to the designated collection vehicles.
SPATIAL NEEDS	The emptying by a crane reduces the space needed for a drop-off station to a minimum. The underground should be solid. Sub-surface versions (underfloor containers) allow the drop-off stations to be set up also in areas with a limited number of suitable places.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	The price for a drop-off station can vary greatly due to the vast spectrum of different versions and the possible adaptations that have to be made to meet different local needs (design, material, protective measures etc.). The price range can be described as follows: - Bring bank 3 m^3, standard version — from EUR 450 to more than EUR 1,000 - Sub-surface installation, 5 m^3: — from EUR 4,000 inclusive assembly
OPERATING COSTS	- repair and maintenance: 11 % of the investment per annum - necessary modifications - cleansing of the bring bank site Introducing bring bank systems may incur additional costs for cleaning up the container sites from lay-bys or waste that are set out in these places due to the fact that they are consisting of similar materials like those collected there but which are not actually wanted in these collection systems (e.g. bulky waste). Using these systems on the other hand doesn't automatically mean to obtain highly polluted fractions, instead the increase of impurities and unwanted material is often proportional to the increase of totally collected recyclables.

MISCELLANEOUS

MARKET INFORMATION

REFERENCE FACILITIES	Drop-off containers are used in many European states and elsewhere in the world for the centralised collection of source separated recyclables. They are the most widespread solution for the realisation of waste collection in the bring system. Many waste service providers in Germany make use of such installations for the collection of certain types of waste (most especially waste glass and old textiles).
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Equipment and installations for drop-off stations/bring banks and underfloor systems are produced from a larger number of companies in Germany. To this spectrum belong for example: *Drop-off stations/bring banks:* - SULO Umwelttechnik GmbH & Co. KG, Herford, www.sulo-umwelttechnik.de - ESE GmbH, Neuruppin www.ese.com - Schletter GmbH, Kirchdorf/Haag i.OB www.schletter.de - Kinshofer Technik, Miesbach www.kinshofer-technik.de - SSI Schäfer- Fritz Schäfer GmbH, Neunkirchen, www.ssi-schaefer.de *Underfloor systems:* - SULO Umwelttechnik GmbH & Co. KG, Herford, www.sulo-umwelttechnik.de - ESE GmbH, Neuruppin www.ese.com - SSI Schäfer- Fritz Schäfer GmbH, Neunkirchen, www.ssi-schaefer.de - Bauer GmbH, Südlohn, www.bauer-suedlohn.de - Unterflur-Container & Projektierung Uthof www.uthof.de - SUBFLOORCON GmbH, Münster www.subfloorcon.de

REMARKS AND REFERENCE DOCUMENTS

Reference of applicable standards:
- **DIN EN 13071** part 1–3: Stationary waste containers up to 5000 l, top lifted and bottom emptied

NON STANDARDISED RECEPTACLES FOR WASTE COLLECTION - BAGS AND SACKS

APPLICATION OBJECTIVE	- Collection of municipal solid waste and small amounts of commercial waste for a one-way pick-up or non-systematic waste collection

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	
Lamps		Textiles	X	Electrical and electronic waste	
Scrap metal		Wood waste		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste materials	X	principally any type of solid waste that arises continuously or discontinuously at a specific place in rather small amounts			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
not necessary, except of size reduction for oversized items to fit bag dimension

Options for the utilisation of the generated output:
unlimited, no dependencies from type of container used

Protective needs:
- Storage of filled bags must take place in places sheltered from strong wind and access of scavenging animals.
- there could be health dangers during collection and transport caused by the uncontrolled discharge of sharp pieces into these receptacle
- easy to destroy (e.g. by vandalism and animals), quick disposal advisable

Limitations in use:
the kind of receptacle is not suitable to capture liquid, hot, especially bulky or heavy wastes

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
unlimited use, sometimes not suitable due to aesthetic reasons in certain environs and urban settings (e.g. tourism spots, historical areas)

Climatic conditions:
partly/not weatherproof

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

Non-standardised receptacles are still a common solution for the waste collection in many countries. In Europe, the collection of packaging is often done with 80 l-sacks. They can be used for the non-systematic collection, as a complement or to provide surplus amounts in a system using pick-up methods for standardised receptacles such as mobile waste containers (See fact sheet "Mobile waste containers"), but also form a collection system on their own. A distinct feature is that these receptacles are given away for disposal together with the waste they contain.

The following criteria were specified for the collection of lightweight packaging via the dual collection system „Green Dot“ in Germany:

	- material: LDPE foil - colour: yellow-transparent - thickness: 22 µm - strain: at least 15 Mpa - volume: 90 l
BASIC REQUIREMENTS	- No special truck technology is necessary. As a rule, a rear-end loader with internal press and low-lying slot is used.
SPECIFIC ADVANTAGES	- very low investment needs - very flexible in terms of deliverable waste amount - no specific requirements for collection vehicles - easy implementation of the pay-as-you-throw principle by the use and sale of specially marked sacks
SPECIFIC DISADVANTAGES	- prone to damages, burning or destruction by extern force or improper use - usually not weather proof and resistible to external forces - negative influence on the aesthetic appearance of the area, higher risk of injuries and adverse health effects when placed at the curb - very labour intensive during collection - additional expenses from the organisation of the sale or distribution - exact amounts of the forwarded waste hardly measurable
APPLICATION DETAILS	
TECHNICAL SCHEME	Common types of sacks have a volume of 50 litres to 120 litres and consist of materials PE-LD, PE-HD and rather seldom kraft paper. In recent years, biological degradable bags are used for collecting biowaste by private households. The biodegradability of the bags allows a collection of these bags in the biowaste container. Figure 11: Supply of bags for separate collection of light-weight packaging (right), kraft paper bag for green waste (centre) and biological degradable bag (left) (picture source right: Intecus GmbH, picture sources centre, left: Harald Heinritz, www.abfallbild.de) 
QUANTITY ASPECTS	Depending on the dimension of the collection area, the to-be-collected material, the vehicle and the type, about 2,400 waste sacks can be picked up from one collection crew during an ordinary shift. Is the sack used as a complement for surplus amounts to the collection with the mobile waste container system, a number of less than 10 sacks picked up during a tour for container emptying is usual in Germany.
SCALE OF APPLICATION	All types of solid waste, which may be filled into the foreseen sacks/bags.
INTEROPERABILITY	not bound to any system

OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
HUMAN RESOURCES	The pick-up is usually done from the crew of the collection vehicle which is usually composed of 1 driver and one or more additional haulers.
AIDS AND ADDITIVES NEEDED	none
SPATIAL NEEDS	The space requirements are very low. Receptacles of that kind should however be protected from weather and animals and placed safely on the curb or elsewhere.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	The costs for waste sacks are very low, for other receptacles used they may even be zero. A sack costs between 0.16–0.50 Euro depending on the quality and number of pieces ordered. There are racks for these sacks available. The prices are very variable, a durable and high quality rack in Germany can cost up to 60 Euros. Compared to the collection with bins, extra costs for the sale/distribution of the sacks might occur. This relevant if levying of fees is foreseen.
OPERATING COSTS	- no running costs for repair and maintenance - sale of waste sacks (in Germany): about 0.05 Euro per sack

MISCELLANEOUS

MARKET INFORMATION	
REFERENCE FACILITIES	The use of non-standardised receptacles for waste collection is yet a common phenomenon throughout the world. In Europe, the collection of residual waste as well as for light-weight packaging waste is yet very often performed in that way.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Production and retail of waste sacks can be done from various, particularly small and medium-sized enterprises. In Germany, such are for example: - TransPak AG, Solms www.transpak.de - WBV Eselgrimm GmbH und Co., Oelde www.wbv-worldwide.com

REMARKS AND REFERENCE DOCUMENTS

Reference for applicable norms/standards in Germany:
- **DIN EN ISO 527 1-4:** Plastics - Determination of tensile properties

Umwelt Bundesamt

FLEXIBLE INTERMEDIATE BULK CONTAINER – BIG BAG

APPLICATION OBJECTIVE	- Facilitating the collection of larger single amounts of dry solid, bulky or very small-sized waste (especially in places with limited space availability)

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X[1]
Paper / paperboard	X	Mixed household waste	X[2]	Bulky waste	
Lamps		Textiles	X	Electrical and electronic waste	
Scrap metal		Waste wood	X	C&D waste	X
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste	X[3]	e.g. waste containing asbestos, that has to be collected and transported in consideration of security rules as emerging dust may risk the environment and persons,			
Branch specific waste	X				
Other waste material	X	Basically, Big Bags can be used for every kind of solid and dry waste, if security rules are met.			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
Not necessary, except of size reduction for oversized items to fit bag dimension

Options for the utilisation of the generated output:
Unlimited, no dependencies from type of receptacle used

Protective needs:
There could be health dangers during the filling and transportation process caused by developing dusts, by the uncontrolled discharge of sharp pieces and/or uncontrolled discharge of the content through tears in these receptacles. Persons involved in collection/pickup operations have to keep distance and wear helmets when the receptacles are lifted by crane.

Limitations in use:
Special versions of this receptacle are needed to capture liquid and sharp wastes

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
Big Bags are easily to position, but transportation after filling can be done with technical help only. The technical means used can be forklift or crane, thus sufficient space is required for them.

Climatic conditions:
No limitations but possibility to freeze on the ground in areas with cold temperatures

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[1] Separate collection of green waste, gardening waste, park waste and leaves using Big Bags
[2] only if a very low moisture content is provided
[3] only usable as collection device for hazardous waste types, if the collection and transportation is not causing any risk to the environment and humans and if security rules are met

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

Big Bags are receptacles made out of reinforced fabric for the collection and temporary storage of small dimensioned solid waste materials that arise at specific places in quantities larger than mobile waste container can carry but well below the capacity of large sized containers such as roll-off or skip container. They are also a good alternative for the collection of certain waste material in areas with limited available space, i.e. places where large sized containers such as roll-off or skip container cannot be used.

BASIC REQUIREMENTS

- loading tor moving filled bigbags normally requires additional hoisting technology (in form of a crane or forklift)

SPECIFIC ADVANTAGES

- little capital intensive
- little space demanding when stored or used
- can easily be kept in reserve and used for strongly varying waste amounts
- no specialized waste collection trucks are required

SPECIFIC DISADVANTAGES

- except of dry and small-sized materials, less suitable for other wastes
- difficult to empty after compaction

APPLICATION DETAILS

TECHNICAL SCHEME

Big Bags are especially suitable for waste materials of mineral type such as C&D waste. A basal area of 900 x 900 mm is most common for big bags. Aside from that they differ especially in height, which leads to different carrying capacities (300 kg–1,500 kg). They are sold as one-way version or for multiple use. The image below shows a big bag that is filled with waste containing asbestos. The big bag is equipped with an inscription that warns of health risks coming from dusts and refers to security rules. The print of the notice in different languages permits the international use of the receptacle.

Figure 12: Big Bag with waste containing asbestos (left) and warning notice about health risks and security regulations on Big Bag (right) (Picture source: Harald Heinritz, www.abfallbild.de)

Big Bags may have the following features:

- with in-/outlet,
- with and without inner sealing
- material designed for various grain size
- different dimension to fit materials of varying size and quantities.

QUANTITY ASPECTS

Big Bags are preferably used for waste quantities consisting of small pieces and with volumes lying between sack and skip container (range of weight 300–1,500 kg).

SCALE OF APPLICATION	Big Bags are normally not used as a permanent collection solution but for waste generated in medium amounts on short term at places with space limitations. They are special suited for bulky or granular types of waste.
INTEROPERABILITY	Big Bags can be used for the non-systematic collection or as a complement to any other collection arrangement, e.g. on building sites. Big Bags are often used to deliver industrial raw material. The emptied big bag is then used to collect waste.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
HUMAN RESOURCES NEEDED	Unloading and re-loading on a pick up vehicle can be done by 1 person, usually the truck driver, with the help of hoisting equipment. He also empties the big bag at the disposal facility or facility staff is doing it.
AIDS AND ADDITIVES NEEDED	Hoisting equipment is needed to move filled big bags. Usually a platform truck with an on board crane is used for the pick-up.
SPATIAL NEEDS	The space demands are low. Bigbags should be set up at their final place because moving them in a filled state is difficult and requires additional equipment.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	The capital demands for Big Bags are comparatively low. A Big Bag costs between EUR 4.50 and EUR 13 depending on the quality and number of pieces ordered. Racks for big bags are also available.
OPERATING COSTS	To allow for reuse arrangements for big bags, 30% of the initial investment may have to be spent per each tour (for example for additional lining)

MISCELLANEOUS

MARKET INFORMATION	
REFERENCE FACILITIES	The collection of dry solid waste, above all C&D waste, with big bags is a common practice worldwide. Most waste service providers in Germany do use big bags in their operations or offer services where these type receptacles are being used.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Production and retail of bigbags is a domain of several companies in Germany, most of them are small and medium-sized enterprises. In Germany, such are for example: - Buhck Umweltservices GmbH & Co. KG www.buhck.de - HIRSCH Bremer Reinigung und Recycling GmbH www.hirsch-gmbh.com - akcensis GmbH, Wesel www.ixkes.de/big-bag - ams Umweltschutz GmbH, Berlin www.amsberlin.de

REMARKS AND REFERENCE DOCUMENTS

Reference for applicable norms/standards:
- **DIN 55461-2:1991-07:** Large size packages; flexible IBC; dimensions

REAR-END LOADED REFUSE COLLECTION VEHICLE

APPLICATION OBJECTIVE	- to pick up all kinds of household waste provided in waste containers or other receptacles under a pick-up arrangement

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X[4]	Mixed household waste	X[1]	Bulky waste	X
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material	X	all kinds of solid waste that arise continuously within a larger area and require a frequent pickup			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
Not necessary

Options for the utilisation of the generated output:
The compaction of the waste in the truck body results in a mixture and caking of the waste. This makes a separation afterwards difficult.

Potential health risks:
Loader: Pickup procedures carried out on both sides of a street at once require the loader to cross traffic lanes frequently. If at all, such procedures should only be applied in areas with little traffic.
Driver: Arrangements which require the driver to help as a loader during the emptying of waste containers may increase the risk of personal accidents for the driver due to the fact that he must leave and re-enter the driving cabin many times. Barrier-free driving cabins which can be opened to the kerbside help to reduce this risk.
Vehicle crews shall be required to wear tight footgear and other protective clothing (incl. mouth masks if necessary).

Other aspects:
Collection vehicles can be additionally equipped with on-board computers to keep record on the emptying and other relevant data (e.g. weight of the bin) for purposes of service monitoring, tour planning and billing. Meanwhile the combination with bin identification technology is a common solution (see also fact sheet "Waste bin identification".

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
To allow an efficient waste collection with this type of vehicle, waste collection containers shall be placed at locations easily accessible for the vehicle and the crew of loaders. The setting up of joint container sites for larger numbers of containers at suitable places and no-parking arrangements at the date of pickup can be very supporting in this respect.

Climatic conditions:
No limitations except of the fact that the vehicle itself must be fit for the road conditions in the collection area.

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[4] For door-to-door collections/kerbside collection from households

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

The Rear-end refuse collection vehicle is the most widely spread standard vehicle for the pickup and short distance transportation of various waste types. For that reason a vast number of constructional modifications are in practical use. The receptacles with the waste are emptied either manually or by means of a lifting device into the vehicle body. The usual configuration is a tail lifting device for the emptying of different types of mobile waste containers (See also fact sheet "Mobile waste container"). Integrated into the vehicle body is a compaction mechanism.

The compaction is either done by the linear movement of a packer plate or thru the rotation of a screw-type rotating drum. Upon arrival of the vehicle at the waste treatment facility, the rear-end compartment of the vehicle body is opened and the waste discharged.

BASIC REQUIREMENTS

- in case of a collection in waste containers a comb or diamond lifting device for emptying them into the vehicle's storage body

SPECIFIC ADVANTAGES

- high loading capacity thru on-board compaction of the waste
- can flexibly be used for various types of waste
- can be used for both pickup and short-distance transport at the same time
- comparatively small dimension and low unloaded weight of rear-end loaded vehicles with a screw-type compaction or compaction by rotating drum

SPECIFIC DISADVANTAGES

- relatively high priced vehicle
- minimum of 2 labour force needed
- not suitable for longer waste storage
- use of vehicles with compaction by a screw-type rotating drum limited to residual and organic waste collection to a large degree

APPLICATION DETAILS

TECHNICAL SCHEME

During operation the waste is being thrown manually (sack) into the feed hopper or loaded from the waste container by means of the lifting device on the rear end of the vehicle. The compaction mechanism compresses the waste and forwards it from the feed hopper into the storage body of the vehicle. Once the body is completely filled up, the vehicle goes to the disposal facility where it opens its rear to discharge the waste.
Compaction mechanism and lifting device can be operated manually, semi-automated and fully automated. Economically most relevant are the allowed loading volume and carrying weight as those parameters determining the number of discharge tops.

Figure 13: Standard rear-end loader with separated comb lift system (right) and close-up of a comb lift system (right) (picture source left: Petra Hoeß, FABION Markt + Medien, www.abfallbild.de / picture source, right: MOBA GmbH, www.moba.de)

Figure 14: Double body vehicle for parallel collection of two source-separated fractions (left) and vehicle with rotary drum and low-entry driver cab “Econic” (right) (picture sources left, right: Intecus GmbH)

Figure 15: Emptying of vehicles via press plate (left, right) (picture source left: Intecus GmbH, picture source right: Petra Hoeß, FABION Markt + Medien, www.abfallbild.de)

Further constructional elements of this type of vehicle are:
Two or three axles with one self-turning front or trailing axle for better turning circle, pneumatic or steel springs, platform(s) for outboard rider(s)

QUANTITY ASPECTS	The carrying capacity is limited by the allowed total load of the vehicle and the body type (permitted load).
SCALE OF APPLICATION	Loading volume and loading mass of the different vehicles: in the range of 5–27 m³ and 6–12 Mg.
INTEROPERABILITY	The vehicle can be used for the pickup of waste and short distance transportation under different collection schemes. The construction of the lifter device is compatible to waste bins with comb or diamond-adapted fringe. Other moveable bin types of low weight and sacks can be emptied as well. Also a direct feeding of waste (bulky items) into the feed hopper is possible.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
AIDS AND ADDITIVES NEEDED	none

HUMAN RESOURCES NEEDED	1 truck driver and up to 5 loaders
SPATIAL NEEDS	Normally employed in the pick-up system, the technology does require space for the truck stop at the kerbside only. Moreover parking space at the operating yard (car park) is needed.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	The capital needs (investment) for rear-end loaded refuse collection vehicles (3 axles, 10 Mg carrying capacity) are 140.000–190.000 Euro
OPERATING COSTS	Running costs accrue for - 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)
OTHER RELEVANT ASPECTS	
LABOUR PROTECTION	For the use of this technology tight labour protection regulations need to be observed in Europe. References for this in Germany are for example: - Technical rules for biological working materials – Waste collection, protective measures (TRBA 213), - GUV-Regulations: Safety and health protection during waste management activities, part I: Waste collection and transportation

MISCELLANEOUS

MARKET INFORMATION	
REFERENCE FACILITIES	The rear-end refuse collection vehicle is the most widely used vehicle type for the pickup of various waste types. Despite the growing spectrum of vehicles for waste collection, the number of sales per annum remained at quite a constant level over many years already.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Producer and supplier firms for this technology and its components in Germany are for example: Chassis: - Daimler AG, Stuttgart, www.mercedes-benz.de - MAN Truck & Bus AG, München, www.truck.man.eu Aufbau und Lifter: - HS Fahrzeugbau GmbH, Emstek www.hs-fahrzeugbau.com - ZÖLLER-KIPPER GmbH, Mainz www.zoeller-kipper.de - FAUN Umwelttechnik GmbH & Co. KG, Osterholz-Scharmbeck www.faun.com
REMARKS AND REFERENCE DOCUMENTS	

Further information on this vehicle technology and links to firms providing and using it can be obtained from:
- Verband der Arbeitsgeräte- und Kommunalfahrzeug- Industrie e.V., Berlin, www.vak-ev.de
- Gemeinsame Arbeitsgruppe von VKU und BDE Fahrzeuge und Behälter - Technische Übersicht und Standards www.vku.de/abfallwirtschaft.html

Reference for applicable norms/standards in Germany:
- **DIN EN 1501, Blätter 1, 4 und 5**: Refuse collection vehicles and their associated lifting devices

Umwelt Bundesamt

FRONT LOADED REFUSE COLLECTION VEHICLE

APPLICATION OBJECTIVE	- to pick up in an optimised manner various kinds of household and commercial waste set out in large sized mobile waste containers (see also fact sheet "Mobile waste container") at accessible locations under a pick-up arrangement

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material	X	all kinds of solid waste that arise continuously within a larger area and require a frequent pickup			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material: not necessary

Options for the utilisation of the generated output:
The compaction of the waste in the truck body results in a mixture and caking of the waste. This makes a separation afterwards difficult.

Other aspects:
Collection vehicles can be additionally equipped with on-board computers to keep record on the emptying and other relevant data (e.g. weight of the bin) for purposes of service monitoring, tour planning and billing. Meanwhile the combination with bin identification technology is a common solution (see also fact sheet "Waste bin identification").

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
To allow an efficient waste collection with this type of vehicle, waste collection containers must be set out at points where they are easily accessible for the vehicle and placed in a way that the lifter mechanism can reach them without that any additional physical manipulation or intervention is needed. It is for this reason that this pickup technology is especially suited to areas with a detached building structure (most particularly rural type areas with sufficient space along roads and between houses and at the city outskirt). In the inner city environment with a high traffic density and limited space availability at the kerbside, the effective application of this technology may face rather high limitations.

Climatic conditions:
No limitations except of the fact that the vehicle itself must be fit for the road conditions in the collection area.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	The front loaded refuse collection vehicle plays a growing although not yet so prominent role for the pickup of various waste types. The vehicle is characterised by the front lifting mechanism which empties waste containers overhead (above the drivers cabin) into the storage body. Compared to the rear - end loaded collection vehicle (See also fact sheet "Rear-end loaded collection vehicle") this allows storage bodies of higher capacities and has the advantage that driving and loading can be done by a crew of only one person and thus in a more economical way.

Front loaded refuse collection vehicles are usually employed according to a special logistic concept (principle of logistic nodes) in collection areas with a lower density of pick-up points and a higher proportion of large sized waste containers particularly supplied for wastes generated by commercial sources. That is why front loaded refuse collection vehicles are usually tailored for the emptying of mobile 4-wheel waste containers up to a capacity of 5 m³, although 2-wheel containers can be emptied as well.

BASIC REQUIREMENTS

- for their pickup, waste containers must be accessibly located so to allow the collection vehicle and lifter mechanism to reach them without manual intervention
- waste containers must be compatible to vehicle‘s lifting device

SPECIFIC ADVANTAGES

- needs a crew of one person only
- emptying process can be well controlled from the cabin
- high loading capacity thru on-board compaction of the waste
- can be used for both pickup and short-distance transport at the same time

SPECIFIC DISADVANTAGES

- relatively high-priced vehicle
- not all types of waste emerging in households can be picked up effectively
- operation inefficient in areas with a high building density and problems of narrow streets, traffic and car parking

APPLICATION DETAILS

TECHNICAL SCHEME

The basic parts of this vehicle type are the chassis, the body with a compaction mechanism, the hopper and the front lifting device.

The lifting device is situated behind the driver’s cabin and consists of a two-shanked telescope arm either with forks, a comb- or a pocket-system at its end to fix the bin at the lifter. A front-/side loading type with shanks that can be swivelled from the front to the side of this vehicle exists as a special version. The compaction is normally done by two hydraulic and counter-driven screws. During operation the waste container is being emptied into the hopper by means of the lifting device which moves the container ahead of the driver cabin. Operation of the lifting device can be done in an automatic mode or manually controlled with a joystick outside the cabin.

The compaction mechanism compresses the waste and forwards it from the hopper into the storage body of the vehicle. Once the body is completely filled, the vehicle goes to the disposal facility where it opens its rear to discharge the waste. Some versions of the front loaded refuse collection vehicles are equipped with a chassis for container types used in an exchange system (see also fact sheet "Swap body container")

Figure 16: Front loaded refuse collection vehicle with fixed body construction (left, right) (picture sources left & right: Intecus GmbH)

QUANTITY ASPECTS

The carrying capacity is limited by the allowed total load of the vehicle and the body type (permitted load).

SCALE OF APPLICATION

The loading volume and loading mass of the different vehicles can go up to 34 m³ or 12 Mg.

INTEROPERABILITY	The lifter device is usually compatible to mobile waste containers with a fork-, comb- or pocket-adapted fringe. Other mobile container types and collection receptacles of low weight (see also fact sheet "Non-standardized waste collection receptacles/waste sack") can only be emptied with special equipment.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
AIDS AND ADDITIVES NEEDED	none
HUMAN RESOURCES NEEDED	1 truck driver who also operates/controls the loading process
SPATIAL NEEDS	An adequate space for the collection truck to access the waste container from the front side is advisable considering that this vehicle type is mainly used for emptying large sized mobile waste containers up to a capacity of 5 m³ which can hardly be moved manually by one person alone. Aside from that a parking space at the operating yard (car park) is needed
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	The capital needs (investment) for front loaded refuse collection vehicles (3 axles, 10 Mg carrying capacity) are 140,000–190,000 EUR. Investment costs for an exchangeable body account to ca. 20,000 EUR.
OPERATING COSTS	running costs accrue for - repair and maintenance: ~11 % of the initial investment per annum
OTHER RELEVANT ASPECTS	
LABOUR PROTECTION	For the use of this technology tight labour protection regulations need to be observed in Europe. References for this in Germany are for example: - Technical rules for biological working materials – Waste collection, protective measures (TRBA 213), - GUV-Regulations: Safety and health protection during waste management activities, part I: Waste collection and transportation

MISCELLANEOUS

MARKET INFORMATION	
REFERENCE FACILITIES	The front loaded refuse collection vehicle is a commonly used vehicle type for the pickup of different waste material collected in standardized containers.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Producer and supplier firms for this technology and its components in Germany are i.e.: Chassis: - Daimler AG, Stuttgart, www.mercedes-benz.de - MAN Truck & Bus AG, München, www.truck.man.eu Body and lifting device: - HS Fahrzeugbau GmbH, Emstek www.hs-fahrzeugbau.com - FAUN Umwelttechnik GmbH & Co. KG, Osterholz-Scharmbeck www.faun.com - Schmidt Kommunalfahrzeuge GmbH, Brahmenau www.schmidt-kommunal.de

REMARKS AND REFERENCE DOCUMENTS

Further information on this vehicle technology and links to firms providing and using it can be obtained from:
- Verband der Arbeitsgeräte- und Kommunalfahrzeug- Industrie e.V., Berlin, www.vak-ev.de
- Gemeinsame Arbeitsgruppe von VKU und BDE Fahrzeuge und Behälter - Technische Übersicht und Standards www.vku.de/abfallwirtschaft.html

Reference for applicable norms/standards in Germany:
- **DIN EN 1501, Blätter 1, 4 und 5**: Refuse collection vehicles and their associated lifting devices

Umwelt Bundesamt

SIDE LOADED REFUSE COLLECTION VEHICLE

APPLICATION OBJECTIVE

- to pick up in an optimised manner various kinds of household waste provided in waste containers at the kerbside within a pick-up collection arrangement (see also fact sheet "Mobile waste container")

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	X
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material	X	all kinds of solid waste that arise continuously within a larger area, require a frequent pickup and are collected and forwarded in container of the appropriate standard at locations well accessible to trucks			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
not necessary but collection in standardized waste bins

Options for the utilisation of the generated output:
The compaction of the waste in the truck body results in a mixture and caking of the waste. This makes a separation afterwards difficult.

Potential health risks:
For Pedestrians: Vehicle drivers do not have a direct view on the loading process! This causes a potential risk for pedestrians passing by during the pickup operations to get hurt but this risk is minimized by additional mirrors and cameras attached to the vehicle.
Driver: The driver takes also responsibility for the loading function. A recreation phase that usually occurs during pickup operations with rear end loading vehicle does no longer exist. Inexperienced drivers try to overview the loading process directly. This might lead to physical distensions.

Other aspects:
Collection vehicles can be additionally equipped with on-board computers to keep record on the emptying and other relevant data (e.g. weight of the bin) for purposes of service monitoring, tour planning and billing. Meanwhile the combination with bin identification technology is a common solution (see also fact sheet "Waste bin identification").

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
To allow an efficient waste collection with this type of vehicle, waste collection containers must be set out at points where they are easily accessible for the vehicle (kerbside) and placed in a way that the lifter mechanism can reach them without that any additional physical manipulation or intervention is needed. There may be a need to ensure these conditions by temporarily closing roads for parking and employing teams that places the waste containers in the right way on the kerbside. This pickup technology is especially suited to areas with a detached building structure (most particularly rural type areas with sufficient space along roads and between houses and at the city outskirt) where such favourable conditions are more easily to attain. In the inner city environment with a high traffic density and limited space availability at the kerbside, the effective application of this technology may face rather high limitations.

Climatic conditions:
No limitations except of the fact that the vehicle itself must be fit for the road conditions in the collection area.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

Side loaded refuse collection vehicles are vehicles with a side lifting mechanism for the pickup of waste provided in waste containers at the kerbside within a pick-up arrangement. This type of vehicle is playing yet an important and still growing role for the pickup of various waste types from households and the commercial sector. Compared to the rear-end-loaded collection vehicle, its advantage consists primarily in the one-man-service for driving and loading, thus rendering the service more economical.

Basically, one can distinguish two types of side loaded refuse collection vehicles, the "true" type which is operated entirely from the driver's cabin and the "pseudo"-type or so called "walk alone-"type, where both, forwarding of the waste containers to the vehicle and the release of the lifting mechanism must be done manually. The "true" type of the side loaded refuse collection vehicle is normally tailored to handle mobile 2-wheel waste containers whereas the "pseudo"-type is often adjusted to empty different mobile waste containers up to a volume of 1,100 liters.

SPECIFIC ADVANTAGES

- high loading capacity thru on-board compaction of the waste
- can be used for both pickup and short-distance transport at the same time
- needs a crew of one person only in comparison to rear-end loader

SPECIFIC DISADVANTAGES

- relatively high priced vehicle in comparison to rear-end loader and front loader
- not all types of waste emerging in households can be picked up
- in most cases for 2-wheel mobile waste containers only
- waste containers must be placed accessibly at the kerbside

APPLICATION DETAILS

TECHNICAL SCHEME

Basic parts of the side loaded refuse collection vehicle are the chassis, the body with a compaction mechanism, the hopper and the lifting device.

For the pickup of the waste, the vehicle has to stop beside the waste container. The lifting device, which is attached to the vehicle on the side directed to the waste container, grabs the container and empties it into the feed-hopper. Operation of the lifting device can be manually controlled with a joystick outside the cabin or done in an automatic mode. The lifting device is situated behind the driver's cabin and consists of a telescope arm covering a distance of more than 2 m with a grabbing mechanism or comb/diamond-system at its end to fix the bin at the lifter. Various degrees of automation are available for the lifter.

A compaction mechanism compresses the waste and forwards it from the hopper into the storage body of the vehicle. The compaction is normally done by two hydraulic and counter-driven screws and manually, semi-automatically or automatically controlled.

Once the body is completely filled up, the vehicle goes to the disposal facility where it opens its rear to discharge the waste.

Figure 17: "True" side load refuse collection vehicles (left & right) (picture source left & right: Intecus GmbH)

QUANTITY ASPECTS	The carrying capacity is limited by the allowed total load of the vehicle and the body type (permitted load). The loading volume and loading mass of the different vehicles is in the range of 5–29 m^3 or 6–12 Mg.
SCALE OF APPLICATION	Pickup operations of side loaded collection vehicles can be carried out from one side of the collection vehicle only, in most countries this is on the right. In order to limit the pickup operations to one run per road it is advisable that all waste containers belonging to a road are set out along one kerbside only.
INTEROPERABILITY	The vehicle can be used for the pickup of waste and short distance transportation in different collection schemes. The lifter device is usually compatible to mobile waste containers with comb or diamond-adapted fringe. Other mobile container types and collection receptacles of low weight can only be emptied with special equipment. It is possible to equip the vehicles with GPS and on-board computer technique for operations monitoring and recording. This allows their use in combination with bin identification systems (see fact sheet on "Waste bin identification").
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
AIDS AND ADDITIVES NEEDED	none
HUMAN RESOURCES NEEDED	Normally 1 truck driver, in case of manual forwarding of waste containers one more staff may be necessary.
SPATIAL NEEDS	Normally employed in the pick-up system, the technology does require space for the truck stop at the kerbside only. Moreover parking space at the operating yard (car park) is needed.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	The capital needs (investment) for side loaded refuse collection vehicles are 160,000–220,000 Euro.
OPERATING COSTS	Running costs accrue for - 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)
OTHER RELEVANT ASPECTS	
LABOUR PROTECTION	For the use of this technology tight labour protection regulations need to be observed in Europe. References for this in Germany are for example: - Technical rules for biological working materials – Waste collection, protective measures (TRBA 213), - GUV-Regulations: Safety and health protection during waste management activities, part I: Waste collection and transportation
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES	The side loaded refuse collection vehicle is yet a less common (compared to rear-end loaded vehicles) but already widely used vehicle type for the pickup of various waste types in a number of countries. The number of sales per annum is growing.

RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Producer and supplier firms for this technology and its components in Germany are for example: Chassis: - Daimler AG, Stuttgart, www.mercedes-benz.de - MAN Truck & Bus AG, München, www.truck.man.eu Aufbau und Lifter: - HS Fahrzeugbau GmbH, Emstek www.hs-fahrzeugbau.com - FAUN Umwelttechnik GmbH & Co. KG, Osterholz-Scharmbeck www.faun.com

REMARKS AND REFERENCE DOCUMENTS

Further information on this vehicle technology and links to firms providing and using it can be obtained from:
- Verband der Arbeitsgeräte- und Kommunalfahrzeug- Industrie e.V., Berlin, www.vak-ev.de
- Gemeinsame Arbeitsgruppe von VKU und BDE Fahrzeuge und Behälter - Technische Übersicht und Standards www.vku.de/abfallwirtschaft.html

Reference for applicable norms/standards in Germany:
- **DIN EN 1501, Part 1, 3 und 5**: Refuse collection vehicles and their associated lifting devices

Umwelt Bundesamt

VACUUM (PNEUMATIC) WASTE COLLECTION SYSTEM

APPLICATION OBJECTIVE	- to achieve an automated and highly efficient collection of different waste types from households, public institutions and commercial sources (especially in hygienically and aesthetically sensitive areas)

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste	X	e.g. infectious waste in hospitals			
Branch specific waste					
Other waste material	X	all kinds of small-sized solid waste that arise continuously within a certain area and require a frequent pickup			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
generally not necessary provided that the waste is of a small particle size, a conventional collection/treatment or a shredding is necessary for larger sized waste materials

Other aspects:
The technology is to be applied in combination with other forms of waste collection as alternatives for the disposal of other waste streams (such as for bulky waste items) are needed.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
This system is especially suited to support waste collection in densely built-up areas, in buildings that require a continuous service of waste collection and pickup, such as hospitals, airports, large office buildings and in areas which are highly sensitive against the visual influences and other disturbances (noise) generated by conventional waste collection systems/operations.

Climatic conditions:
no limitations

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

Pneumatic waste collection (also known as vacuum collection) is a means to achieve an efficient, centralised collection of different types of wastes in an area or building marked by a continuous waste generation at many adjacent points at the same time. The system consists of a piping system which connects numerous throw-in or waste discharge ports with a container for intermediate waste storage. A special module produces the negative pressure needed to suck the waste into the storage container. It may also clean the airflow used for the transportation of the waste inside the pipeline. Principal reasons for the employment of such system are the low spatial demand and the comfortable, hygienic and subterranean way in which waste is being taken away from the place where it has been generated. A storage of the waste at the point of its generation until the moment of its pickup is not any longer necessary. Pneumatic waste collection is a prominent solution for areas with a high sensitivity for the disturbances caused by conventional waste service operations. It can help avoiding negative visual and other annoying effects (e.g. bad smell, noise,) and give a relief to congested areas in that surface collection or collection vehicles can be significantly reduced. Although being very successful, the scheme is not extensively used yet and until now can be found in single larger applications only.

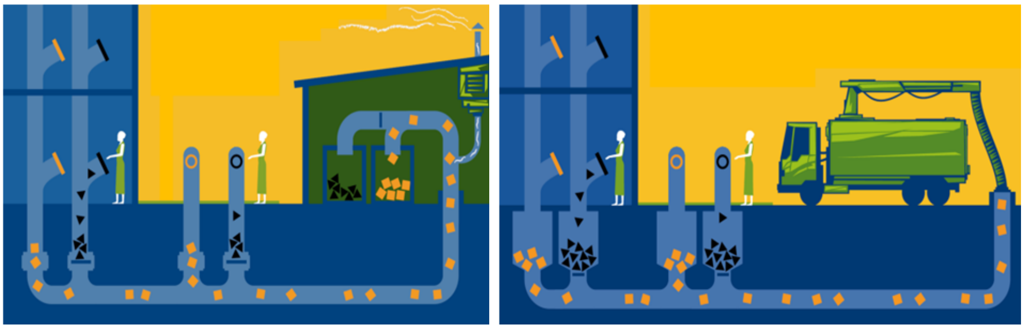
BASIC REQUIREMENTS	- for bulky or large sized waste items alternative collection systems have to be provided, certain materials such as wooden pieces or cardboard boxes may have to be crushed to a smaller particle size manually in order to meet the basic requirements of the system - The system cannot partly be operated but must be fully installed before its use become possible.
SPECIFIC ADVANTAGES	- low space requirements for buildings and (residential) areas - almost “invisible” in the urban environment and accessible for collection vehicles in independency of location of intake posts - aesthetic - highly convenient and hygienic in nature (due to the complete encapsulation) - receptacle management (less efforts for pickup and short distance transportation needed) - can be combined with polluter-pay-charges
SPECIFIC DISADVANTAGES	- takes a high toll for planning and constructional realisation - full installation required before being operational, long installation time

APPLICATION DETAILS

TECHNICAL SCHEME

Basically there is a differentiation between stationary systems in which the waste is pneumatically pushed into an intermediate waste storage container or a tank and mobile systems where collection vehicles suck off the waste from a tank/bunker located at the end of a gravity chute. Discharge ports/throw-in slots for both arrangements can be placed into a building or in the public space.

Figure 18: Stationary pneumatic system with waste container (left) and mobile pneumatic system with suction vehicle (right)



In the mobile system the waste is successively collected by suction of a vacuum collection vehicle from a plurality of tanks installed at the bottoms of gravity chutes of a building, or at the bottoms of post type intakes installed on the ground. Vacuum collection vehicles connect themselves to docking stations and after setting the inside of each storage tank at a negative pressure of approx. -34KPa the refuse may be brought from the tanks to the collection vehicle by letting the refuse swirl through the abrupt influx of air.

Figure 19: Specially designed intake posts for a pneumatic collection (left) and vacuum collection vehicle attached to a docking station to suck off content from a storage tank (right) (picture source left: INTECUS GmbH / Picture source right: Envac Group, www.envacgroup.com)

	It is possible to retain a separation of different waste fractions in the system through the organisation of a fractioned intake. The use of specially marked receptacles for different type materials (e.g. system OPTIBAG) may allow an optical sorting/separation as either an integrated or subsequent component of the pneumatic collection.
QUANTITY ASPECTS	Depending on the overall arrangement storage tanks/bunkers of 1–6 m³ volume are used in mobile systems whereas skip or roll-off container versions (see also fact sheets on "skip container", and "roll-off container") with volumes of 20–36 m³ are used for stationary systems.
SCALE OF APPLICATION	Through the integration of additional storage bunkers, pressure modules and docking stations, the length of the piping system is practically without a limit. Frequently used are piping systems with a diameter of the tubes between 350 mm and 500 mm.
INTEROPERABILITY	Using skip or roll-off container versions (see also fact sheets on "skip container", and "roll-off container") is economically the most efficient solution to get the accumulated waste from large stationary systems eventually forwarded to treatment and/or final disposal. To have additionally a larger number of conventional waste collection systems in place is counterproductive and must be avoided to the extent possible. The combination of the system with a billing scheme based on the pay-as-you-throw principle is highly recommendable and technically feasible. A collection scheme for source separated waste fractions that can be well adopted and used in combination with this technology is the system Optibag. For reference see www.optibag.com
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- generally, electricity is needed to operate the system, - the energy consumption of the system is dependent on the size of the system, the waste amount and waste type
CO_2-RELEVANCE	- The system allows to conserve a significant amount of conventional pickup traffic and waste transports and in this way saves CO/CO_2-emissions.
AIDS AND ADDITIVES NEEDED	- electric current for the operation of the pressure/suction module
HUMAN RESOURCES NEEDED	- Depending on the size of the overall installation but one person can usually take responsibility for several systems (repairs/clean up service not included).
SPATIAL NEEDS	- considerably lower as in comparison to the conventional system with collection container and pickup - Space savings can amount to 0.5–1 m² per accommodation unit in comparison to a conventional collection system.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- Investment costs range between 1,000 and 2,000 Euro per accommodation unit. - Pneumatic collection systems are planned with a running time of ca. 30 years.
OPERATING COSTS	- for repair and maintenance: less than 1 % of the investment per annum

POSSIBLE PROCEEDS	- from savings made in the result of less residual waste that need to be treated and a possible reduction of the number of pickups - where the implementation is directly linked with waste charging in the result of more users paying their charges (estimations in European countries see the proportion of waste containers serviced without an authorisation or under the refusal of the obligatory payments to reach 10 % of the total number of container emptied; these containers can be detected and integrated into the charging system with a bin identification)
POSSIBLE PROCEEDS	- waste fees for collected waste
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES	Pneumatic refuse collection systems are a well proven and reliable technology. Several such systems exist in the world, particularly in the most modern countries of Scandinavia and Asia. In Germany and elsewhere it can be found at spotted occasions, examples are hospitals, airports, at narrow and/or historical city quarters, densely populated residential areas etc. Some selected applications are for example: Inner city centres: Seville (E), Copenhagen (DK), a residential neighbourhood of Helsinki (FIN) Hospitals: Universitätsklinik Heidelberg (D), Änggårdshemmet (S) Airports: Kuala Lumpur International Airport Malaysia, Main building
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Manufacturers/Providers of pneumatic collection systems and/or its principal components in Germany are for example: - Envac Deutschland GmbH, Hamburg www.envacgroup.com Alternative system solutions are offered by: - MariMatic Oy, Vantaa, Finnland www.marimatic.com

(WASTE) BIN IDENTIFICATION SYSTEM

ADAPTED TO PICKUP ARRANGEMENTS FROM HOUSEHOLD AND COMMERCIAL WASTE SOURCES AND INCLUDING THE OF OPTION WEIGHING

APPLICATION OBJECTIVE	- To achieve a recording of the pickup service/container emptying received by a specific waste generator in order to realize an individual billing in accordance with the principle of pay-as-you-throw. - Exclusion of non-registered waste container/non-paying users of the pickup arrangement from further services

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material	X	an installation and application is possible for all standardized mobile waste containers (see fact sheet on "Mobile waste container") with their associated pickup techniques, in principle thus independent from the type of waste collected			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
State of the collected waste has no influence on the applicability of this technology. However standardized waste containers must be used for their collection.

Other aspects:
A proof/certification on that the technical components used for recording/measuring are tampering-proof, secure against external manipulation and/or officially calibrated shall be available (in Germany realized through certification by the Bundesamt für Sicherheit in der Informationstechnik – BSI).

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
An area-wide application covering all structures of dwelling is possible. However, implementation at full scale is most easy in structures where individual waste containers can be provided to each waste generator, i.e. in rural type areas and at city margins with predominantly single family houses and in commercial areas. Logistic or constructional changes in the already applied waste collection scheme are not needed in addition.

Climatic conditions:
no limitations apply

TECHNICAL DETAILS

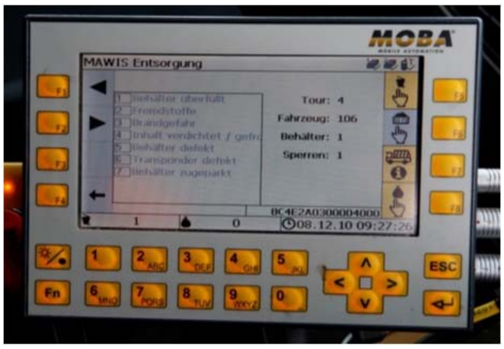
GENERAL OVERVIEW

ABSTRACT

A (waste) bin identification system is a system in which data pertaining to a specific (waste) container are (electronically) retrieved and recorded during the pickup process and afterwards further processed for collection tour monitoring and/or to realize a charging system based on the principle pay-as-you-throw. It functions in that container-related information (such as location, owner, volume) stored on a specific data carrier attached to the container are transferred to an on-board recording unit at the collection vehicle during the process of container emptying. The recorded data can be matched with other process relevant information such as the weight of the collected waste. The following objectives can be achieved with the application:

	- individual billing based on the number of emptying and/or the weight - generation of a proof for the provided / received waste services - receptacle management (averting the pickup of waste amounts from individuals who refuse to pay) - Tour- and Fleet management
BASIC REQUIREMENTS	- standardized waste bins (see fact sheet on "Mobile waste container") - the installation of the necessary technical components on the container, collection vehicles and availability of an adequate processing instrument (e.g. software)
SPECIFIC ADVANTAGES	- Provided pickup services/emptying can be allocated to a specific waste container (and through the recorded data to the owner/address) which allows the generation of an individual bill (individual waste charging). - Ensures that all users of the pickup service will have to pay for the received service and those who set out waste amounts illegally be detected and/or excluded from the service. (avoids free-riding) - pickup services become transparent and can thus be better planned - Convenient system which requires little maintenance or changes in the collection scheme and does not interfere with pickup and transportation logistics.
SPECIFIC DISADVANTAGES	- Rather high investments and initial installation efforts are required. - An appropriate legal framework must be created to ensure functionality and protection of the investment (e.g. clarification of ownership for container and other technical components, the right to keep data records). - need of accompanying measures to protect misuse of other men's waste containers (e.g. locking containers up) and unwanted disposal practices
APPLICATION DETAILS	
TECHNICAL SCHEME	The bin identification system comprises the following principal components: - transponder; alternatively barcode (stickers) can be used - identification unit (data reader) - on board data storage (e.g. on-board computer) - installation for data transfer (e.g. GPRS) - if necessary data carrier (e.g. USB-stick) - data processing unit (e.g. computer and software) In order to achieve their identification, waste containers first need to be equipped with an ID-tag in the form of a transponder or barcode carrying the object-specific information. These are unique and not confidential data. During the process of emptying, these data are transferred via a reading unit to the collection vehicle. Optionally the weight of the waste or the filling height of the container are determined by a dedicated sensor in the vehicle and are transmitted in parallel to the identification data to the vehicle. The vehicle software supplements these data by adding a date and time information and then forms a record of clearance from all these data. After the collection vehicle has finished its pickup tour, the recorded data are transmitted to the office of either the community or the waste management enterprise providing the service by means of different media (data media, wire connection, wireless). In the office these data are stored in a central database. From there the data can be transmitted on a regular basis to authorities or regional computer centres for the billing process. Certain parameters of the transponders used for container identification have been unified to increase reliability and compatibility (in Germany this has been achieved with the creation of the BDE-standard, i.e. transponders work with a transmission frequency of 134.2 kHz, the memory is a "read-only" type, the identification code is of 128 Bit and follows a pre-defined nomenclature). The uniform system led to a stabilization of the market prices and increased the overall functionality of the system.

Figure 20: Transponder with Chip at a mobile waste container (left) and board computer in cockpit of collection vehicle (right) (Picture source left: c-trace GmbH, www.c-trace.de/picture source left: Harald Heinritz /www.abfallbild.de)



The identification unit (data reader) on the collection vehicle comprises an antenna that activates the transponder and receives its data signals, and a processing component which does the decoding of the received signal. The identification process and data transfer from the container to the reader can be realised via an antenna or with the help of a scanner (barcode solution). The storage of the data and control of the entire process during the pickup tour is usually done from an on-board computer unit. The transfer of the data to the final data processing in is accomplished with the help of a SIM-card or a data carrier. The complete process cycle can be illustrated as follows.

Figure 21: Whole process cycle of the (waste) bin identification

1) The waste bins are equipped with a data carrier (ID-Tag). The ID-Tag stores identification data, which are used for the identification of the waste bin. Usually there is a one to one correspondence between a set of identification data and the person who is subject to charge.
2) The identification data are read by the reader during (or before/after) emptying the waste bin. The identification data is then transmitted to the vehicle software. Optionally the weight of the waste or the filling height of the waste bin are determined by dedicated sensors in the vehicle and are transmitted in parallel to the identification data to the vehicle software. The vehicle software supplements these data by adding a date and time information. As a result, a record of clearance is formed based on the data retrieved from the container and measuring process and stored at a SIM-card or another data carrier.
3) The clearance data blocks are transmitted via a security module to office software. A transfer is even possible after a loss of data in the primary memory due to a data backup.
4) The transferred data are linked to a database containing a list of all registered bins and users of the service. Individual records on the service received by a certain user are generated.
5) Individual charges in relation to the amount of services received are calculated and the corresponding bills are produced and sent to the owner/user of the emptied waste container.

QUANTITY ASPECTS	Introducing a waste bin identification system usually results in a much higher source separation of the generated waste, whereby ideally recyclable material is being diverted away from other, non-recyclable waste. This kind of behaviour can be supported in that waste charges are collected for the non-recyclable residual waste and recycling systems become subject of a lower or zero charge. The bin identification system is not the direct cause; however it supports the practical application of a charging system based on pay-as-you-throw. Based on international experience, a reduction of the residual waste by over 20% (and up to 50%) can be expected. Additionally, there will be more persons paying waste charges as a number of so far unregistered waste containers and free-riders will be detected and held responsible for their generated wastes.
SCALE OF APPLICATION	There are no limits as to the area that can be serviced / put under a bin identification system.
INTEROPERABILITY	Waste bin identification can be practically combined with any type of collection vehicle. A dynamic weighing can be integrated to all types of modern standard lifter systems.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- the additional energy demand from the application of such system is negligible
CO_2-RELEVANCE	- The possibility to optimize the provision of waste services with the help of and in result of the waste bin identification process (e.g. reduced amounts of residual waste) may result in a reduction of necessary pickups and thus save CO/CO_2-emissions at a significant scale.
AIDS AND ADDITIVES NEEDED	- no other than the technical components mentioned before
HUMAN RESOURCES NEEDED	- no additional personnel needed for pickup operations, slightly increased demand for data processing and administration and for system maintenance
SPATIAL NEEDS	- no additional space required
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	Indicative cost figures for purchase and installation of the system - transponder : 1,00 EUR/unit - data reader and on-board computer unit: 6,000–8,000 EUR per vehicle - device for dynamic weighing: 16,000–20,000 EUR per vehicle - handheld reader/scanner: 1,000 EUR/unit - central data processing unit and software: 8,000 EUR/unit - installation: 3 EUR/container up to 240 litre, 10 EUR/container of 1,100 litre - overall project management: (depending on scale of implementation from 10,000 EUR up)
OPERATING COSTS	- for operations, repair and maintenance: approx. 7 % of the investment - Data transfer via GPRS: 12–15 EUR per vehicle and month
POSSIBLE PROCEEDS	- from savings made in the result of less residual waste that need to be treated and a possible reduction of the number of pickups - where the implementation is directly linked with waste charging in the result of more users paying their charges (estimations in European countries see the proportion of waste containers serviced without an authorisation or under the refusal of the obligatory payments to reach 10 % of the total number of container emptied; these containers can be detected and integrated into the charging system with a bin identification) - additional savings become possible if the system data are used for tour optimization

MASS SPECIFIC OVERALL COSTS	- additional costs of 5–7 EUR per Mg of collected waste for electronic systems
OTHER RELEVANT ASPECTS	
PRIVACY PROTECTION	In order to ensure the confidentiality of any data on the ID-tag and prevent data manipulation or tampering, functional and assurance requirements have to be specified and secured by a competent body in advance to the adoption of such technical system.
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES	Waste bin identification is a well-tested technology with a proven effectiveness over many years now. To date, more than 20 million waste containers in Germany do carry a transponder for bin identification already. A large number of local authorities trust such system for the generation of their waste bills and to monitor and optimize the collection continuously.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Manufacturers/Providers of bin identification technology and/or principal components in Germany are for example: - MOBA Mobile Automation GmbH, Dresden www.moba.de - c-trace GmbH, Bielefeld www.c-trace.de - Envicomp Systemlogistik GmbH & Co. KG, Bielefeld www.sulo.de - WasteWatcher.NET GmbH, Duisburg www.wastewatcher.info - Sywatec Logistic GmbH, Dieburg www.sywatec.de
REMARKS AND REFERENCE DOCUMENTS	

Standardised norms:
- DIN EN 14803:2006-05: Identification and/or determination of the quantity of waste

Competent organisations and sources for further information on the subject are:
- BDE-VKU Arbeitskreis „Mobile IT-Systeme" www.bde.world/themen/logistik/mobile-it-systeme
- Bundesamt für Sicherheit in der Informationstechnik www.bsi.bund.de
- Physikalisch-Technische Bundesanstalt (PTB) www.ptb.de

SEMITRAILER TRUCK WITH WALKING FLOOR SYSTEM

APPLICATION OBJECTIVE	- long distance transportation of waste

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	X
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood	X	C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	X
Hazardous waste					
Branch specific waste					
Other waste material					

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
generally not necessary but pre-sorting could be useful to optimize the load and transportation expenses

Options for the utilisation of the generated output:
no limitations or dependencies from the employed system

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

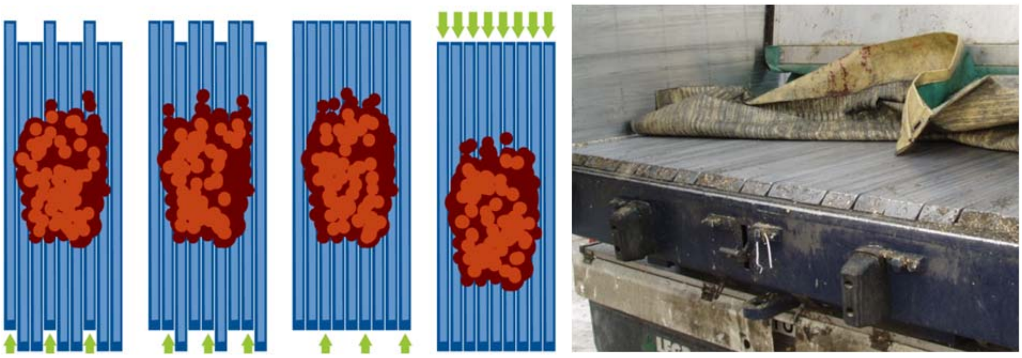
Infrastructural conditions:
There must be a sufficient infrastructure (e.g. a stable and solid ground) with enough space for driving manoeuvres and to ensure that loading/un-loading procedures can be safely carried out. There are no additional support tools or installations required, however

Climatic conditions:
No limitations but trailer truck must be fit for the road conditions in the area.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	This transport system can be used for the long distance transportation of suitable waste materials between the collection facilities or transfer stations in the collection areas and the recycling facilities or disposal sites. The uploading of the waste material on semitrailer trucks with walking floor is usually done at transfer stations (See also fact sheet "Transfer station"). Because of the walking floor system the discharge of the waste from the truck can be done without further support. In contrast to other transport systems which also allow for the discharge of their load without additional means such as the truck-trailer with swap body container (See also fact sheet "swap body container"), a semitrailer truck with walking floor system can carry higher loads in terms of mass and volume.
BASIC REQUIREMENTS	The waste material must be suitable for the walking floor system, i.e. non-liquid, no powdery or sandy waste material), also particularly heavy or massive parts should be removed from the waste before transportation as they can cause damages to the walking floor and its mechanical system.
SPECIFIC ADVANTAGES	- low mass-specific transportation costs due to a high loading capacity, - easy and quick discharge of the load without additional support systems

SPECIFIC DISADVANTAGES	- Vulnerability to damages caused from specially heavy or massive waste components - shorter usage phase in comparison to other transport systems in case of very intensive use with high mechanical stress
APPLICATION DETAILS	
TECHNICAL SCHEME	The walking floor system is a horizontal loading-/unloading system for trailers. With this system it is possible to transport most types of cargo, both in bulk and palletised bags, etc. The walking floor is based on the principle of friction between the material and the charge. The floor (standard 2.5 m wide) is usually divided into 21 aluminium floor profiles. The floor profiles are divided in 3 groups, every group consists of 7 floor profiles. When all groups are moving at the same time the load will be transported. After this every time one group will be pulled backwards, the load does not move until this happened at all of the 3 groups. The floor then has reached his point of departure again and the cycle can start all over again. Figure 22: Function of a walking floor system (left) and Look at the floor profiles of the walking floor system inside the semitrailer (right) (Picture source right: Intecus GmbH)  The system producers usually offer specially adjusted solutions of the walking floor systems and semitrailer for specific waste types, e.g. with reinforced floor profiles. The basic construction of the semitrailer with walking floor can be compared with that of other semitrailer systems, however. Ordinary semitrailer truck tractors can be used.
QUANTITY ASPECTS	- dead weight of the semitrailer: approx. 8 t and the semitrailer truck tractor approx. 7 t respectively - loading weight: approx. 25 t (at a maximum overall weight of the semitrailer truck of 40 t) - effective volume: approx. 90 m³ - discharge time: between 10–30 min. at least depending on the material
SCALE OF APPLICATION	- For different types of transportable goods incl. waste and on all roads allowed for the above specifications and vehicles with a dimension of L x B x H = 13.5m x 2.5m x 4m (semitrailer without truck tractor).
INTEROPERABILITY	- This technology can be used in conjunction with most of the standard up-/unloading processes and reloading procedures and applied for different kinds of transports.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- As an indicative value 40 litres per 100 km may be calculated for the fuel consumption of standard versions of this technology.
CO_2-RELEVANCE	- The CO_2-balance of road transports is generally not as good as those of a direct transportation by railway or ship.
AIDS AND ADDITIVES NEEDED	- none

HUMAN RESOURCES NEEDED	- 1 truck driver
SPATIAL NEEDS	- an adequate parking space is required
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- Semitrailer with walking floor: about 50,000–70,000 EUR - semitrailer truck tractor in the price span 70,000–120,000 EUR
OPERATING COSTS	Running costs: - fuel (approx. 40 litre per 100 km) - insurances - repair and maintenance: - approx. 10% of the investment costs per annum, tires and lubricants - personnel costs: - 1 truck driver
MASS SPECIFIC OVERALL COSTS	- For a transportation distance of 250 km with full load the overall costs may be in the range of 15 EUR/Mg.
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES	The system is in worldwide use for different types of transportable goods including waste materials.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Manufacturers/Providers of this technology in Germany are for example: - Schmitz Cargobull AG, Horstmar www.cargobull.com - F.X. MEILLER Fahrzeug- u. Maschinenfabrik-GmbH & Co KG, München www.meiller.com - Martin Reisch GmbH Fahrzeugbau, Ehekirchen-Hollenbach www.reisch-fahrzeugbau.de
REMARKS AND REFERENCE DOCUMENTS	

Reference for applicable norms/standards: in Germany:
- **DIN-EN 12195-1:** Load restraint assemblies on road vehicles – Safety

Competent organisations and sources for further information on the subject are:
- Verband der Arbeitsgeräte- und Kommunalfahrzeug- Industrie e.V., Berlin, www.vak-ev.de

SWAP BODY (CONTAINER) SYSTEM

APPLICATION OBJECTIVE	- Mobile (exchangeable) container system for the long-distance transportation of waste

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	X
Lamps	X	Textiles	X	Electrical and electronic waste	X
Scrap metal	X	Waste wood	X	C&D waste	X
Waste oil	X[5]	Old paint & lacquer	X[1]	Waste tyres	X
Hazardous waste	X[1]	Liquid/semi-liquid waste and hazardous waste with special containers			
Branch specific waste	X				
Other waste material	X				

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
not necessary

Options for the utilisation of the generated output:
no limitations or dependencies from the employed system

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
There must be a sufficient infrastructure (e.g. a stable, solid ground preferably with a paved surface) with enough space for driving manoeuvres and to ensure that loading/un-loading procedures can be safely carried out. There are no additional support tools or installations required, however.

Climatic conditions:
no limitations

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	Swap bodies are used for the long-distance transportation of various goods. Opposite to the transportation in bodies which are fixed on the vehicle, swap bodies can be easily exchanged between different transporters so that there is no need to reload the goods from one vehicle's container body to that of another vehicle. Swap bodies due to this fact are especially suitable for the combined transportation on truck, railway and ship. Also possible is the longer storage of goods in such type of container body. Swap bodies get more and more used for the transporting of waste because of the encapsulated way in which the waste can be brought from one place to another even in broken transportation chains.
BASIC REQUIREMENTS	- transporters with the adequate superstructure to carry swap bodies - transfer stations with the equipment to fill and reload swap bodies or the relevant installations to handle them at the place of origin and/or destination

[5] with special containers

SPECIFIC ADVANTAGES	- reasonable option for the long-distance transportation of different types of waste As compared to the transportation with transporters with a fixed bodywork: - less emissions along the transport chain, especially during reloading processes - faster reloading, in some arrangements without any support installations - allowing an encapsulated transport and longer temporary storage of waste - higher loading capacity per transportation unit employed
SPECIFIC DISADVANTAGES	As compared to the transportation with transporters with a fixed bodywork: - possibly higher capital investment - possibly limitations of load due to particularly heavy superstructures - problems of compatibility with different swap body versions can occur, especially at the carrier systems

APPLICATION DETAILS

TECHNICAL SCHEME

Fewer emissions along the transport chain and faster reloading between different carriers are the main arguments why swap bodies are becoming more frequently in use for waste transportation. Between some transporters the reloading can even be done without additional technical installations such as transfer stations. To avail of these kinds of benefits already at the moment that the collected waste is transferred to long-distance transportation, more and more collection vehicles are nowadays getting equipped with swap bodies.

For materials from municipal solid waste the following standardized swap body systems are most commonly in use:

- Container system – ACTS which is compatible to the Roll-off container systems described in an extra factsheet (See fact sheet on "roll-off container")
- Interchangeable bridge (BDF Swap body) system

Special versions for very specific uses and applications (e.g. for sewage sludge) are also produced (see for example fact sheet on "skip container system").

Figure 23: Scheme for the transportation process with swap body

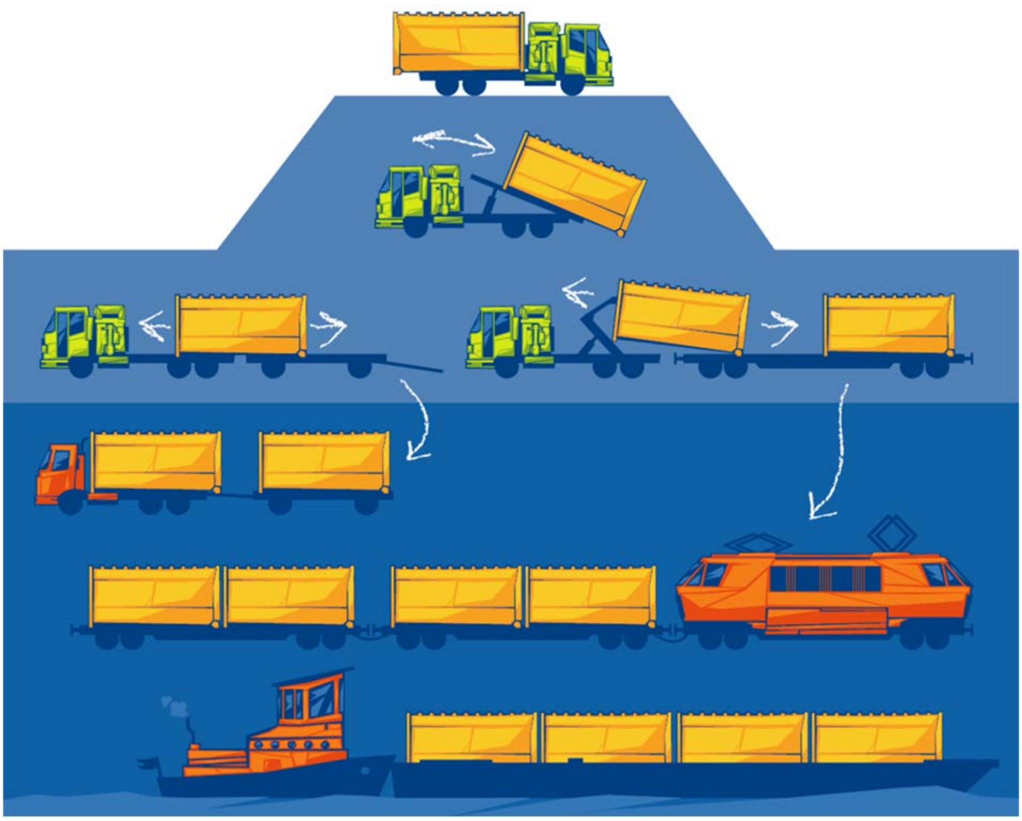


	Figure 24: Swap body container for street transportation (top left & top right(Picture sources top left & top right: Petra Hoeß, FABION Markt + Medien / www.abfallbild.de) / Ship transfer station for swap body containers (bottom left) and swap bodies of the ACTS-container system (bottom right) (Picture source bottom left: INTECUS GmbH / picture source bottom right: Author: Priwo, License „Creative Commons Attribution/Share Alike“ 
QUANTITY ASPECTS	- The loading capacity of a swap body depends on the body dimension and compressibility of the waste loaded and is further limited by the allowed total load of the vehicle and the container (permitted container load). - Swap bodies for collection trucks can for example carry loads between 6–12 t of residual waste. - The transport logistics can be adapted to the waste quantity by adjusting the capacity of the transfer station and using a different number and size of containers and trucks.
SCALE OF APPLICATION	- Swap bodies of the ACTS and interchangeable bridge type made for truck and railway transportation are usually 2.4 m x 2.5 m in size (B x H). There is a difference in length in the range from 4.5 to 12.2 m, however. The volume therefore varies between 20 to 75 m³. - For collection vehicles swap body container with a length between 4.5–max. 7 m are used. For long-distance transportation two to three of these containers are being combined then. Container with a length over 7 m are used in long-distance transportation only, for example one on a semitrailer truck.
INTEROPERABILITY	- It is useful while using swap body containers for long-distance transportation to also have the collection vehicles equipped with them. Alternatively, waste transfer stations (see fact sheet on “waste transfer station”) are needed to reload the waste which has been collected with trucks with fixed bodywork. - Swap bodies of the ACTS-container type are normally compatible to other roll-off container systems (see fact sheet on “roll-off container“) which means that the same vehicles can be used.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE CO_2 – RELEVANCE	- Depending on the logistic system employed (truck, railway, ship); however, due to the reduced transfer needs a generally better balance can be expected as compared to a conventional process of reloading and transportation of the same scale

AIDS AND ADDITIVES NEEDED	- depending on the logistic system employed (truck, railway, ship)
HUMAN RESOURCES NEEDED	
SPATIAL NEEDS	
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	The capital needs (investment) for a swap body system are as follows: - Swap body container: ~ 10,000 EUR - Truck trailer combination for long-distance transportation carrying 2–3 swap bodies: ~140,000 EUR
OPERATING COSTS	- depending on the logistic system employed (truck, railway, ship)
MASS SPECIFIC OVERALL COSTS	
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES	The swap body system is a proven technology with a worldwide application for the transportation of various goods by truck and railroad. It becomes more and more popular for waste management operations as well. Waste service organisations in Germany using swap bodies for the transportation of waste by railroad are for example: - Gesellschaft Abfallwirtschaft Breisgau GmbH, Freiburg www.abfallwirtschaft-breisgau.de - Abfallwirtschaftsbetrieb Ilm-Kreis www.aik.ilm-kreis.de - Zweckverband Abfallverwertung Südostbayern, Burgkirchen www.zas-burgkirchen.de
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Manufacturers/providers of this technology in Germany are for example: - Max Aicher Bischofswerda GmbH & Co. KG, Bischofswerda www.the-waste-pro.com - AWILOG-Transport GmbH, Oberriexingen, www.awilog.de Producers of collection vehicles (see for example fact sheet on "Rear-end loaded collection vehicle") and container systems often also offer swap body systems and the corresponding vehicles
REMARKS AND REFERENCE DOCUMENTS	

Reference for applicable norms/standards: in Germany:
- **DIN-EN 12195-1:** Load restraint assemblies on road vehicles - Safety

Competent organisations and sources for further information on the subject are:
- Verband der Arbeitsgeräte- und Kommunalfahrzeug- Industrie e.V., Berlin, www.vak-ev.de

WASTE TRANSFER STATION

APPLICATION OBJECTIVE	- to aggregate single amounts of waste delivered from collection vehicles to larger quantities and reload them for a long distance transport on other means of transportation

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging	X	Biowaste	X
Paper / paperboard	X	Mixed household waste	X	Bulky waste	X
Lamps		Textiles		Electrical and electronic waste	
Scrap metal	X	Waste wood	X	C&D waste	X
Waste oil		Old paint & lacquer		Waste tyres	X
Hazardous waste					
Branch specific waste	X	especially solid wastes			
Other waste material	X	especially solid wastes			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
As a general rule no pre-treatment of the input is necessary. It can prove useful to reduce the size of some waste material, e.g. bulky waste, to attain an efficient usage of the available transportation volume, however. Municipal waste often gets reduced in size by the compaction unit in rear end refuse collection vehicles already.

Options for the utilisation of the generated output:
Crushing the input may complicate a high quality separation and recycling of valuable materials later on.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
The location of a transfer station must be generally well accessible for different types of vehicles and means of transportation and should preferably be situated near (or in a central position) to the principal points of waste generation. There must be a sufficient infrastructure (e.g. electricity) with enough space for driving manoeuvres and to ensure that loading/unloading procedures can be safely carried out. There shall be a limited vulnerability of the location to be affected from extreme weather conditions (blocked roads, steep roads, flooding etc.)

Climatic conditions:
For reasons of reduced emissions and to protect the waste from weather effects waste transfer stations are normally set up in halls or under shelters, especially where a press is installed and open reloading of the waste would otherwise have to take place.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

Waste transfer stations are technical facilities set up 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 treatment or disposal facilities. By combining 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 makes particular sense when the place of treatment, the disposal site or recycling facilities is in such distance from the collection area that the costs for the transportation of the waste with the collection vehicles exceed that for the reloading and the transportation with long distance vehicles.
Some reloading arrangements can be combined with a compression or baling of the waste to further optimise the transport. That way the total number of vehicular trips traveling to and from the disposal site can be further reduced.

BASIC REQUIREMENTS

- A waste transfer station as an environmentally relevant activity because of its potential to cause environmental burdens and nuisance will require an environmental authority licence.
- Waste transfer stations must have a connection to the relevant transport routes and should have a sufficient infrastructure and be located in a central position to the collection areas.

SPECIFIC ADVANTAGES

- Collection vehicles can be used more effectively due to the minimisation of transport distances for the collected waste.
- Overall transportation of the waste from the collection point to the place of utilisation or final disposal becomes more reasonable due to increased transportation efficiency (higher loads) moreover the waste transfer can help reduce the impacts of trucks traveling to and from the disposal site.

SPECIFIC DISADVANTAGES

- Erection and operation of a waste transfer station consumes additional resources and costs.
- Waste transfer stations can cause an increase in traffic in the area where they are located. If not properly sited, designed and operated they can cause burdens and nuisance for their neighbourhood.

APPLICATION DETAILS

TECHNICAL SCHEME

Waste transfer stations can be of different technical arrangement. Some essential criteria which determine the arrangement used are:

1) type of vehicles delivering the waste and type of vehicles picking them up
   - vehicles with swap body container or fixed superstructure
   - other means of transportation such as for rail transport or ships
2) reloading with and without compression of the waste material
   - A compression of the waste can be done in a stationary press before the waste is reloaded to the means used for long distance transportation or within the same.

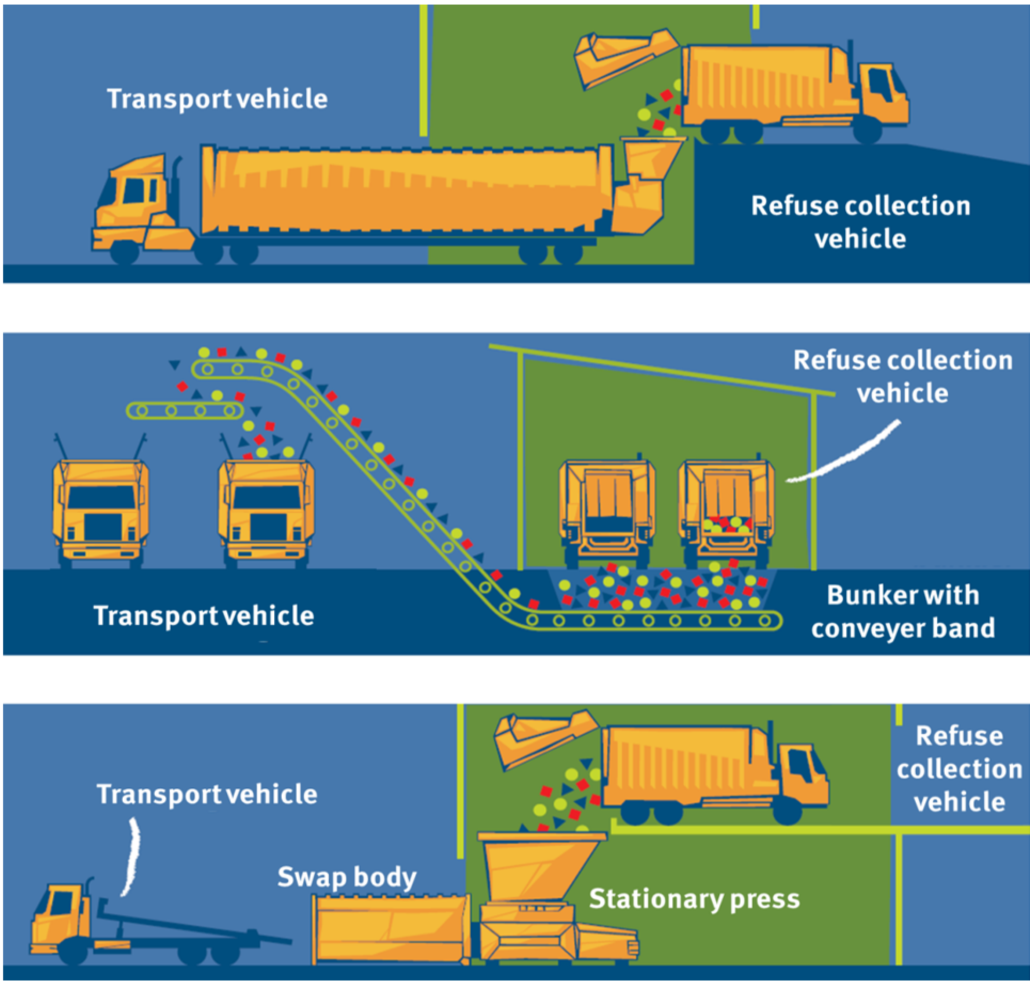
The simplest arrangement for a waste transfer station is a plain area where swap body containers can be transferred from waste collection trucks to long-distance vehicles. There are different swap body systems existing so that the reloading between the different vehicles can either be done without additional technical support or with the help of cranes, ramps, etc. only (see also fact sheet on "swap body container"). Vehicles with a fixed superstructure must be first unloaded at the transfer station. This applies also for swap body containers if they are not directly reloaded from the delivering vehicle to the long-distance transporter. Unloading of the waste can be done on a plain ground from where wheel loaders, conveyor belts or excavators take them up and reload the material into the long-distance transporter. Another way of unloading is via ramps from where the collection trucks discharge the waste directly onto the bed of the long-distance transporter, into open containers or the feeding chute of a press. Figure 1 presents some schematically examples of reloading processes in waste transfer stations.

Reloading into railroad transporters or ships works principally in the same way like truck-to-truck transfers, except that the transfer station needs to have a connection to the railroad system or waterways. This also applies to the place of final destination. The waste amounts for railroad or ship transports must be relatively large to ensure an economical implementation. Railroad or ship transportation has to deal with a number of logistic and economic limitations and its application in the waste sector is hence rather seldom. To overcome part of these problems special wagons for swap body containers are available for railroad transports. Here, collection vehicles can transfer their swap body directly onto the wagon without further technical means.

Whether or not it makes sense to have the waste material compressed during the reloading depends largely from the costs for the compression and the savings resulting from the higher loads that can be send on long distance transport at once.
It proved to be useful to have the following additional installations integrated into a waste transfer station:

- Weighing bridge for the registration of the incoming waste amounts
- A plain, sealed area or bunker for the temporary storage of waste
- Reception point for small waste amounts delivered by individuals

Figure25: Examples of reloading processes in waste transfer stations



QUANTITY ASPECTS	As a matter of efficiency waste transfer stations should be planned with a basic work load which considers the technical and personnel expenses for its operation. Above this, waste transfer stations can be adjusted in size to the waste amounts that need to be handled.
SCALE OF APPLICATION	- from as low as 5,000 Mg/a up to 500,000 Mg/a and more - typical examples are described in the section on the human resources needed - waste transfer stations can be more easily adjusted to the actual needs of an area
INTEROPERABILITY	Can be integrated at any point of the waste transportation chain and flexibly adjusted to the available infrastructure and technical systems in use for the collection/pickup and transportation of the waste
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
AIDS AND ADDITIVES NEEDED	- Usually some mobile equipment such as cranes, excavator or wheel loader is necessary for the reloading procedures. Optional a press can be installed.
HUMAN RESOURCES AND SPATIAL NEEDS	The following considerations on resource consumption and costs are made on the example of three different arrangements for a waste transfer station with an annual throughput of about 30,000 Mg and trucks for long-distance transportation. These arrangements are as follows:

	1) reloading of swap body container from the collection truck onto long-distance trucks without additional technical support - needed is a suitable surface only - the drivers of the different trucks exchange the containers by themselves 2) reloading from a collection vehicle with a fixed superstructure into a long-distance vehicle without the compression of the waste - the reloading is done in that the collection truck discharges the collected waste material directly into the long-distance vehicle via a ramp - the waste transfer station is placed within a hall - a technical staff of 2 persons is needed to supervise the reloading process 3) reloading from a collection vehicle with a fixed superstructure into a long-distance vehicle with closed swap body container including the compression of the waste - reloading from the collection vehicle into the press is done by means of a wheel loader or excavator - the waste is directly pressed into the swap body container by the press installation - a technical staff of 4 persons is needed to supervise the process
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS/ 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): - up to 10,000 EUR/a - 250,000–350,000 EUR/a plus the personnel costs (2 persons) and infrastructural costs - 300,000–450,000 EUR/a plus the personnel costs (4 persons) and infrastructural costs Cost differences between collection and transport vehicles are not considered (e.g. swap body, fixed structure). Total investment costs can add up to 1 to 5 Million Euro.
POSSIBLE PROCEEDS	- from savings made in the result of less residual waste that need to be treated and a possible reduction of the number of pickups - where the implementation is directly linked with waste charging in the result of more users paying their charges (estimations in European countries see the proportion of waste containers serviced without an authorisation or under the refusal of the obligatory payments to reach 10 % of the total number of container emptied; these containers can be detected and integrated into the charging system with a bin identification)
MASS SPECIFIC OVERALL COSTS	- 0.1–15 EUR/Mg
OTHER RELEVANT ASPECTS	
LABOUR PROTECTION	For the use of this technology tight labour protection regulations need to be observed in Europe. References for this in Germany are for example: - GUV-Regulations 238-1: Safety and health protection during waste management activities, part I: Waste collection and transportation
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of firms does not constitute a complete compilation of companies)*	Waste transfer stations of different arrangement and technical design are set up everywhere in the world. Some examples from Germany are: Zweckverband Abfallwirtschaft Oberes Elbtal www.zaoe.de Zweckverband Müllverwertung Schwandorf http://z-m-s.de/muellanlieferung Waste transfer station components & design (solutions of Werner & Weber Germany GmbH) www.werner-weber.com/upload/file/TransferStations-EN-10_2014_v02.pdf
RECOGNIZED PRODUCER AND PROVIDER FIRMS	No specialized manufacturers are needed for waste transfer stations as these can be erected from ordinary construction firms and with equipment provided by a large spectrum of producer firms for transhipment technologies

Processing, treatment and utilization of municipal solid waste

Introduction

Waste consists of many different materials whose disposal on landfills would mean a loss of valuable resources (particularly land and material resources) and for the most part entail a maximum of environmental burden. That's why European legislation makes clear provisions towards the implementation of a hierarchy for waste management, putting the reuse of products and recovered parts before recycling and material utilization. Only where practical limits hinder to follow this order of management options other forms of utilizing the waste, including energy recovery, shall be applied with landfilling always being the last option of disposal. Behind this concept stands also the idea that handling waste differently according to its composition has also important social and economic functions. Splitting and managing different waste streams generates employment for many people, creates a strong economic sector on its own and last but not least is essential to ensure environmental safety and human health. All around the world the existence of this relationship still gets reflected in tragic incidents. Wherever uncontrolled waste disposal takes place in populated areas or along waterways, where people are forced to spend a living on garbage dumps or where sanitary waste disposal, water and sewage treatment is non-existent for whatsoever reasons, life-threatening diseases and epidemics do often spread virtually unchecked.

A sustainable and successful waste strategy uses an integrated approach to recover the highest environmental and economic value from the various waste fractions. All ***integrated waste management systems*** comprise a specific mix of waste management options. The available spectrum and adoption of these options depend on the individual waste management targets as well as on specific local factors. Targets and preferences are either fixed through standards provided through legislative frameworks (such as in the European Union) or by the national law but they can also be determined by the strategic planners and decision-makers on the local ground.

Various processes form the basis to manage the collected waste in an integrated manner. They comprise different processing, treatment and recycling techniques (see factsheets on 'Waste processing/Material recovery' and 'Waste pre-treatment/stabilization' - techniques), the thermal treatment of waste with energy recovery as a combined waste pre-treatment and utilization (see fact sheets on 'Incineration/Industrial co-combustion'), and the temporary storage or final deposition by way of landfilling (see fact sheets on 'waste disposal' - techniques).

Under ideal conditions, the different process options would complement each other in an optimal manner and allow the establishment of an integrated waste management system as illustrated in Figure 1.

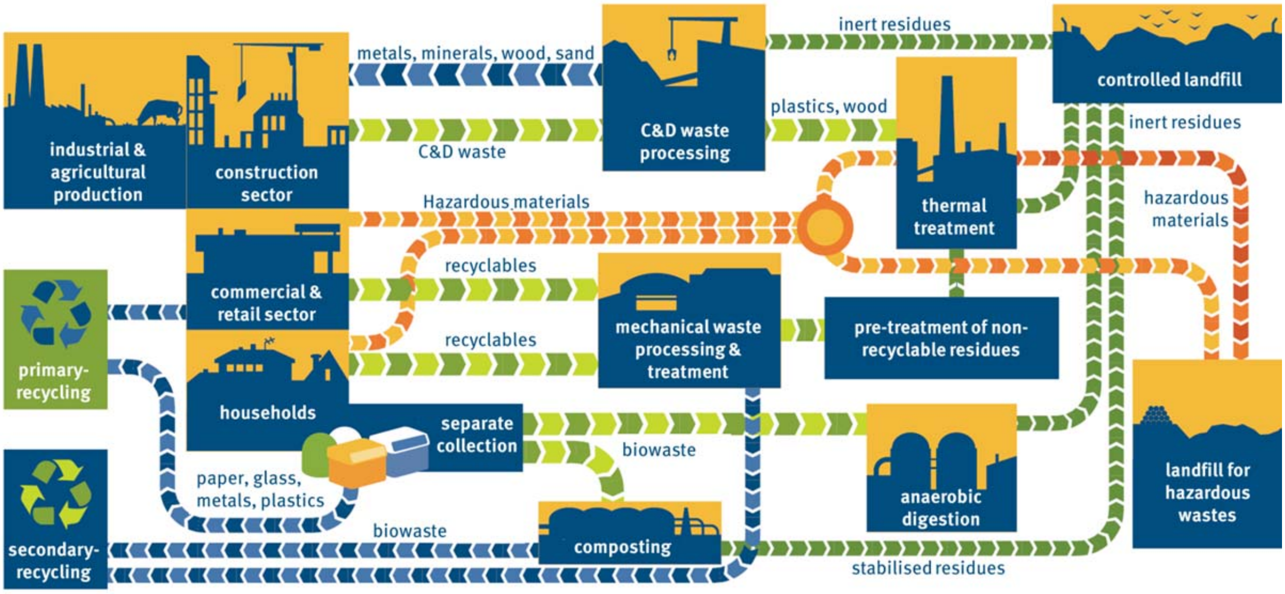
Material recovery

Recycling and the utilization of waste material are key elements towards waste minimization as an essential goal of waste management. Within this, direct material recycling takes a high preference.

Much of what is contained in the waste has maintained its material value throughout the lifespan of a product and/or disposes of properties which permit the direct utilization as secondary material in the production of new goods or as a substitute for other scarce materials. In order for this to be achieved, these materials have to be separated from the rest of the waste and recovered individually. Direct material utilization and recycling demand for a certain purity of the material. Both, separation and recovery of different materials to obtain a pure feedstock for various applications can be achieved by waste processing and sorting.

Sorting can be done right on the place where the waste is generated (thus at source) and further hereto also by way of industrial processes. The benefit from sorting is not just one for the industry who gets a ready to use material but is received already at municipal level where citizen can reduce their waste charges thru source separation and communities will save landfill capacities and generate revenues from selling material fractions with higher market value.

Figure 1: A paradigm for the integrated management of wastes under optimal conditions (modified after Koch,T., Seeberger. J.: Ökologische Müllverwertung. 1984)



Source separated recyclables from households and the commercial sector that need to be processed for the purpose of material recycling are in particular:

- Waste paper
- Waste glass and
- Packaging of different type.

The processing usually involves multiple steps and combinations of different techniques. The principal objective of any processing scheme is the generation of defined material fractions from the collected waste which can be directly forwarded to recycling. Removing impurities and disturbing materials is the main step. Sorting and various separation techniques are used for that. The intensity of processing and the quality of the output (e.g. share of the different paper grades) is determined by the availability of a market (demand), the market price and the possible profit from selling the different materials.

It is largely impossible to identify and describe all possible combinations and methods used for the processing of collected waste. It is for this reason that three principal plant configurations representing the most common technological solutions for each of the above specified waste materials have been chosen and will be presented in the corresponding fact sheets.

- The "*basic configuration*" is marked by a rather low degree of automation and intensity of equipment but comparatively high demand in labor force and possibilities for job creation.
- The "*advanced or extended configuration*" has a higher degree of automation and intensity of equipment than the basic configuration and a reduced labor demand.
- "*High-tech configurations*" comprise in particular processes and equipment whose application serves the aim to achieve a largely automated processing of the waste, often tailored and optimized on customer requirements and the needs in specific market environments. Frequently these solutions are intensive in terms of required personnel qualification and investment which is why an easy transfer and high efficiency cannot therefore guaranteed in any region.

Waste paper

In order to obtain a recyclable quality, waste paper from households has to be source-separated and collected separately from other waste materials, especially the organic, fatty and wet ones. The simplest concept to collect source separated waste paper is that of a mix of graphical and non-graphical qualities (e.g. news print and packaging paper). The separate collection of graphical and non-graphical paper is not yet that widespread in Europe although it is the best way to optimize the proceeds from waste paper sale and to facilitate recycling in the most extensive manner.

Most appropriate for the collection of waste paper from households are bring schemes with drop-off stations/bring banks (see fact sheet on "drop-off station") set up at centralized locations or public amenity sites. Special modifications at the feeding slots are meant to reduce the amount of unwanted components (impurities) disposed of via these containers. Likewise possible is the pickup scheme by means of different waste containers (see fact sheet on "mobile waste container"), or the collection of waste paper bundles from the curbside. Bundle collection and specially marked drop-off container sites/bring banks are particularly suited for the separate collection of graphical and non-graphical papers.

Together with the paper waste collected from commercial sources, the paper is processed in dedicated sorting facilities to generate fractions of certain quality (paper grades). The four most important standard grades of paper for recycling in Europe are:

- mixed paper and board (1.02.00)
- corrugated paper and board packaging (1.04.00)
- sorted graphic paper for deinking (1.11)
- newsprint (2.01.00)

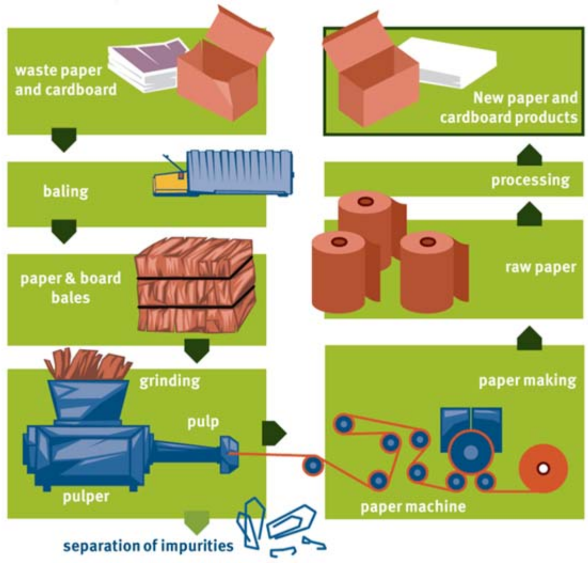
These and other marketable paper grades are described in the European list of standard grades of paper and board for recycling EN 643:2014.

The fraction classified as "mixed paper and board" is a mixture of various qualities of paper and board, containing a maximum of 40 % newspaper and magazines. Thru this standard it is possible to adjust the sorting operations and yields to the actual market situation.

Average market prices for the different paper grades can be found in the factsheet on waste paper sorting (see fact sheet "waste paper sorting"). Considerable influence on the output stream from paper sorting have also the local customer structure and distance to the nearest recycling facility (e.g. either graphical paper mill or producer of corrugated and cardboard applications).

In Europe, the average incurring costs to collect and supply recovered paper to the recycling industry (paper mills) are in the range from 60 to 150 EUR per Mg. (Source: EcoPaperLoop, 2014).

Figure 2: Paper recycling process



Waste glass

To facilitate a high quality and economically attractive recycling, glass waste from households should preferably be collected separated by color. The commonly applied division of colors is green, brown and transparent (white), whereby a separate collection container must be provided for each color. Where demands for secondary use are lower, glass of brown and green color can be collected together. Collection from households should exclude all types of glass other than glass from packaging (e.g. float glass). Such specific types of glass would better be subject of special collection schemes (e.g. take back schemes, bulky waste collection).

Most suitable for the collection of glass from households are bring schemes with drop-off stations/bring banks (see fact sheet on "drop-off station") set up at centralized locations or public amenity sites, or larger-sized (1.1 m³) waste container (see fact sheet on "mobile waste container"). Special modifications at the feeding slots are meant to reduce the amount of unwanted components (impurities) disposed of via these containers.

Recommendable as a standard is the processing of the glass separated by color. Transparent glass can be used for a wide range of applications and is hence the fraction with the best prospects and highest price on the market. Glass of green and brown waste can be forwarded also in a mixture (thus without intense sorting) to the glass industry where it is going to be used for the most part in darker colored glass production only. Waste glass sorting is therefore a standard procedure in modern economies. With prior color separation a fully automated processing is mostly possible and representing the state of the art in this sector.

Figure 3: Glass recycling process

These automated processes differ mainly in the number of lines installed for the removal of inert, non-glass components such as stones and ceramics and to improve the purity of colors. In one-line processes, inert, non-glass components are eliminated at only one mesh size, multi-line processes do the same at different mesh size, for example < 15 mm, 15–30 mm, 30–60 mm and > 60 mm (see fact sheet "Processing & sorting of waste glass")

The glass industry benefits from the recycling of waste glass mainly in two ways; thru the substitution of raw material and a lower specific energy demand during the melting due to the use of glass cullet. A high purity of the used waste glass in terms of color and content of disturbing matter/impurities is a pre-requisite for this. A separation of the different types of glass (packaging glass vs. float glass) must also take place. Take back schemes for packaging waste such as the green-dot can help in the recovery of the sufficient amounts of waste glass and provide a means for financing the corresponding activities.

In Germany, the average incurring costs to provide waste glass to the recycling industries stay rather constantly between 50–100 EUR per Mg (according to the price search in 2008).

Packaging waste

For (light weight) packaging wastes from households a mixed collection is possible and useful. In a pickup arrangement sacks (see fact sheet on "waste sacks") or mobile waste container (see fact sheet on "mobile waste container") give suitable receptacles for a source-separated collection. Drop-off stations/bring banks (see fact sheet on "drop-off station") work well in bring systems. Sometimes a separate collection for directly marketable fractions such as metal packaging or PET can make sense, as a complementary approach or stand-alone concept. Depending on the market situation and the availability of sorting installations of the appropriate kind, the (mixed) packaging can be sorted into the following fractions:

- tin plate
- aluminum
- beverage cartons (tetra packs)
- composites of different paper/board material
- colored plastic foils
- white plastic foils
- hallow plastic bodies
- plastic pails and similar products
- mixed plastics
- scrap metals
- other materials including sorting residues

The applied sorting technologies vary greatly. On the one hand site there are simple configurations with a high share of manual labor. More recent installations are marked by a higher rate of automation, meanwhile many plants in Germany use near-infrared (NIR) technology in their sorting operations. With NIR technology it is possible to separate automatically different plastics according to the type of polymer used. Modern plants permit the separation into the following polymers PE, PP, PET and PS. Also possible is the separation of glass according to color. NIR modules can detect per infrared light the location of the different items on sorting conveyors and the materials they are made from. These modules then send their data to processor units from where the respective nozzles get a signal to blow out a specific item from the waste stream (see fact sheet "Processing & sorting of packaging waste")

The costs for packaging recovery and recycling are mostly covered by take back schemes, such as the green-dot, which can be established on the basis of producer responsibility regulations. These schemes are useful especially in environments where sorting capacities are scarce and their development from state budget difficult or slow.

Even where a separate collection of packaging doesn't work sorting from commingled household waste is possible with current recovery technology. However, this concept mean a considerable loss in quality, results in lower marketability of the materials and limited suitability for certain recycling applications.

Plastics

To recycle plastics recovered from the different waste streams in plastics production is principally possible, provided they are thoroughly sorted by polymer types and washed clean. Partly this represents a great challenge both technically and in terms of organizational and financial burdens. To use plastic wastes energetically or add them to the feedstock of cement kilns and blast furnaces where they work as an additional fuel, catalyst and/or reduction agent is therefore often a preferred and more economical utilization route.

To reintroduce recycled plastics into production requires the cleaning and melting of the plastic material, and the production of granule or direct re-molding to obtain a new plastic product.

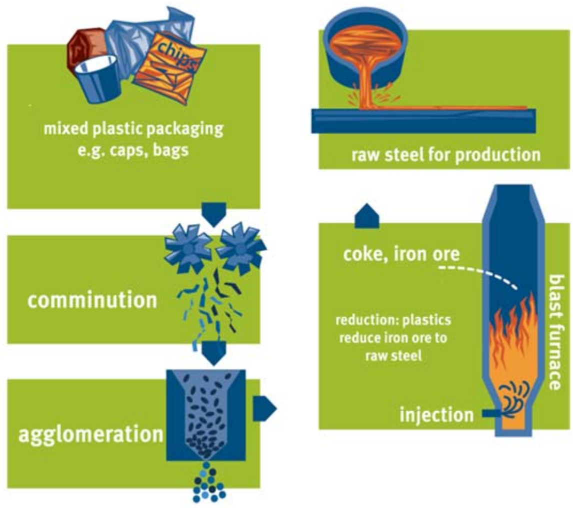
Users of the granule are among others foil manufacturers, producers of tubes and pipes or die casting factories. The URRC-process is one possibility to recycle collected PET back, for instance, into new plastic bottles.

In Germany, the average incurring costs to provide plastic material from packaging waste streams to the recycling industries are in the scale of 300 EUR per Mg (Source: Itad/consultic, 2015).

Figure4: Recycling process of plastic packaging sorted by grades

Mixed plastic waste due to the high calorific content can be processed into a fuel substitute. Specialized waste-to-energy plants use these fuels for energy production (see details on mono-incineration plants in the fact sheet "Fluidized bed combustion") but demand exists as well in cement plants or power stations (see fact sheet on "Industrial co-combustion") and sometimes also in the steel industry.

Figure 5: Process option for the utilization of mixed plastic packaging



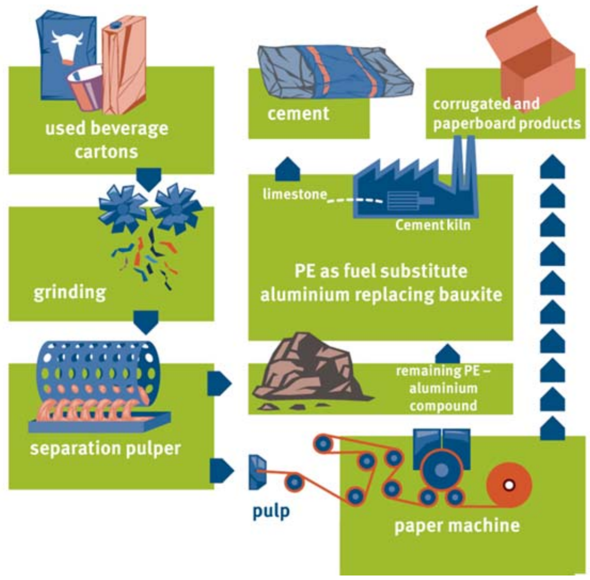
Beverage carton (Tetra Pak)

Also for multi-component beverage cartons such as tetrapaks separate recycling is a preferable option. For this the cartons have to be chopped, and dissolved in a pulper. Thru their swelling in the pulper, wood fibers separate from the foil of polyethylene and aluminum. The fiber slurry is discharged and forwarded directly to paper and board production.

The secondary fibers are a valuable raw material for different high-grade paper applications. The material is used to produce cardboard boxes, corrugated board and sleeves to reel up fabric and carpets. Also sanitary and household papers, paper bags and kraft paper can be produced from it.

Recovered polyethylene and aluminum are used as crude material in the plastics and aluminum production, respectively. The aluminum can also be used in substitution of bauxite in the cement production where it is add to the feedstock to support the calcination process.

Figure 6: Recycling process of multi-component beverage carton



Biodegradable waste

Likewise kind of a recycling process is composting. ***Composting*** specifically aims at utilizing the source separated biodegradable waste by converting the organic components into a humus product. Composting processes can also be employed in the biological stage of mechanical-biological treatment of mixed, organic-rich household waste so as to biologically stabilize this material mix. In this case it is a vehicle for pre-treatment and not anymore a recycling process, however. Composting can be done in rather simple arrangements such as open windrows or in more sophisticated ways using encapsulated systems (see also fact sheet "Composting"). In order to be able to generate a compost product which meets the required quality and environmental safety for agricultural use, a separate collection of the biodegradable waste, known as biowaste collection, is indispensable. Why such dedicated effort becomes necessary can be derived from the Table 1 and Table 2.

Accordingly it is only with material from biowaste collection that waste-derived compost products compliant to the general rules of quality and safety can be produced. Composting mixed waste with a high organic content is technically an option but none to generate an output that can be used as a recycling product without further precaution.

Table 1: Mean concentrations of heavy metals as established for different composting schemes

Heavy metals	Compost from source separated biowaste Representative sample values in mg/kg for Europe and North America	Compost standard as proposed for developing countries	Compost from non-source separated MSW Sample values in mg/kg established in The Netherlands
Arsenic	0	**10**	0
Cadmium	1.2	**3**	7.3
Chromium	27	**50**	164.0
Copper	15	**80**	608.0
Lead	86	**150**	835.0
Mercury	0.9	**1**	2.9
Nickel	17.0	**50**	173.0
Zinc	287.0	**300**	1567.0

Table 2: Global standards for waste-derived compost products [in mg/kg dry substance] (timeliness of data as per cited sources)

Country	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
USA (S)	41	39	1200	1500	300	17	420	2800
Canada (MO)	13	2.6	210	128	150	0.83	62	500
Netherlands (MO)	15	1	50	90	100	0.3	20	290
Italy	10	1.5	100	300	140	1.5	50	500
Austria (MO)	--	4	150	400	500	4	100	1000
Belgium (SSMO)	--	1	70	90	120	0.7	20	280
Denmark	25	1.2	--	--	120	1.2	50	--
France (MO)	--	8	--	--	800	8	200	--
Germany*	**--**	**1.5**	**100**	**100**	**150**	**1**	**50**	**400**
Switzerland	--	3	150	150	150	3	50	500
Spain	--	40	750	1750	1200	25	400	4000

(S) refers to sewage sludge, (MO) refers to mixed organics, (SSMO) refers to source-separated mixed organics
Source Figure tab 7/8: World Bank, 1997 / Brinton, 2000/ * Guideline of the Federal Association for Compost Quality in Germany (2012)

Quality and environmental safety of waste-derived compost products can be secured through the introduction of quality standards and installation of a monitoring and certification system. Such has become a common practice in many European countries but also elsewhere in the world.

A prominent example and system which has gained a leading role for many other initiatives is the quality control and certification system RAL in Germany. A brief overview how the system is applied on waste composting is contained in the below info box.

Information box

To secure quality and environmental safety of the compost product, a quality standard, a quality label and the RAL quality monitoring system for the composting of source separated organic waste from households and gardens was established in 1991 in Germany. The Federal Association for the Assurance of Compost Quality in Germany (BGK) is the carrier of the RAL compost quality label. It is recognized by the RAL, the German Institute for Quality Assurance and Certification as being the organization to handle monitoring and controlling of the quality of compost in Germany. In 2000 an additional quality assurance system for digestion residuals was introduced.

Quality assurance system for compost RAL- GZ 251
The standard RAL-GZ 251 contains regulations of the BGK concerning quality criteria and the quality assurance of compost. This is a private, voluntary agreement for a quality assurance system of the composting industry. Several of the RAL-GZ 251 aspects can be found in the corresponding German laws (e.g. Biowaste Ordinance (BioAbfV)) and regulations.

Quality assurance system for digestion products RAL- GZ 256/1
Since August 2000 the standard RAL-GZ 256/1 contains regulations of the BGK concerning quality criteria and the quality assurance of solid and liquid digestion residuals. This is a private, voluntary agreement of the anaerobic digestion industry.

A multitude of obligations concerning regular product analysis and validation which are to be executed by the compost plants have meanwhile been introduced. The long-standing activities of the BGK for the standardization, monitoring and declaration of high quality humus products led to an acknowledgement of these measurements by the law maker as "self-obligation of the industry". In addition, the law making body implicates that the biowaste which is under continuous monitoring by and independent organization is not a product but "likely a product". So members of the Association for Quality Assurance which render themselves subject to a voluntary quality monitoring are widely exempted from a control (max. 12 instead of max. 24 analysis/year) and from proof obligation by regional authorities as laid down by the German biowaste ordinance.

Waste treatment and pre-treatment before final disposal

Treatment operations are basically aimed at diverting the different recyclable materials still contained in the residual waste after source separation from the waste stream for final disposal and to process them in a way that permits subsequent recycling and utilization of the material, material properties and/or energetic content. Further goals of the treatment are the discharge, demobilization or even destruction of potentially harmful substances from the residual waste stream, the reduction of the volume of the waste stream expecting final disposal and stabilization of the waste before it is deposited at landfills. For the latter operations one speaks of a pre-treatment before final disposal.

Pre-treating waste for a safe final disposal can as well go hand in hand with a material recovery and utilization of the energy content from the waste. Treatment is part of an integrated waste management but can also make up an independent process combined with other waste management operations.

Treatment processes based on anaerobic digestion and fermentation lend themselves as a supplementary technology to composting in the area of biological treatment measures. They combine with the advantage of generating biogas for energy production while having lower requirements towards the purity of the input and in terms of space needed. Anaerobic digestion (see fact sheet "Anaerobic digestion") may be employed as an independent process mainly for source-separated biodegradable waste but it can be part of the mechanical biological treatment of mixed residual waste as well.

Mechanical biological waste treatment (see the fact sheet "Mechanical-biological treatment") has strongly emerged as a technology that helps in reducing the disposable waste volume and in particular the share of reactive organic matter contained in residual municipal solid waste. Hence it represents one possible option to meet stringent requirements for the landfill disposal and its application has therefore vastly spread in countries with landfill bans or fierce restrictions on biodegradable waste management. In Germany the years after 2005 marked a milestone in the development and adoption of mechanical biological waste treatment in the wake of the ban on landfilling untreated wastes. The technology combines in various steps the recovery of different materials for the further utilization in recycling and waste-to-energy processes, the recovery of energy from the biodegradable material and its stabilization before landfilling.

Mechanical biological treatment actually is an umbrella term for all concepts of treating waste using the combination of mechanical and biological processes in one or the other way (i.e. also in a reverse order, like biological mechanical treatment). The main distinction between the different concepts is made on the basis of the order of the process steps and the purpose of the biological treatment.

The arrangement of the process steps is based on either the concept of “splitting” or “stabilization”.

In the first option the waste is first split mechanically into recyclables including (optionally) a fraction of high calorific value and an organic rich fraction that will be subsequently treated biologically. The core biological process used can be composting or anaerobic digestion or elements of both technologies as in some of the newer processes. When anaerobic digestion is incorporated into the biological stage, the process is usually configured to optimise biogas production. When composting is the core technology for mixed waste streams, no biogas is produced and the technology used to produce a stabilized material.

In a “stabilization” concept the entire waste is subjected to biological treatment to dry and sterilize (but not digest) the waste before it is mechanically sorted to remove non-combustible materials from the waste stream. The remaining material can be combusted and so is referred to as Waste or Refuse Derived Fuel (RDF), which could be utilized on-site in a dedicated waste-to-energy facility or sent off-site to be utilized as an additional fuel.

For specific wastes (especially sewage sludge but also mixed household waste) a stabilization and conversion into a waste-derived fuel can also be facilitated by way of a physical drying process. Solar drying (see fact sheet on “Solar drying”) has become a prominent option for that, especially in the field of sewage sludge treatment. Sewage sludge is also the waste stream on which a focus is currently laid for the recovery of phosphorous (see fact sheet ”Phosphorous recovery“).

Mechanical biological waste treatment is not a disposal method as the residue will still require disposal through landfill or incineration. However, the end disposal route, be it incineration or landfilling, will need to be determined before investments into mechanical biological treatment processes and corresponding facilities are undertaken.

Incineration or ‘Waste to Energy’ concepts have been widely acknowledged as making a significant contribution to a modern integrated waste management strategy. Thermal waste treatment in incinerators with energy recovery and heat extraction still is the most effective and reliable option for the management of non-recyclable wastes.

Conventional techniques such as the incineration on grates (see fact sheet on “Grate combustion”) and in fluidized beds (see fact sheet on “Fluidized bed combustion”) are in a permanent process of optimization and efficiency improvements. In the necessary combination with emission reduction and cleaning technologies and aftercare measures for the residues stream both technologies lend themselves as rather trouble proof and reliable processes to a large number of waste materials, including such with concentrations of hazardous components. To use refuse derived fuels as fuel substitutes for industrial power generation is a concept adopted mainly for specially pre-treated (segregated) and conditioned high calorific waste components. Today, the use of these type fuel products mainly takes place in cement kilns, calcinators, boilers of the paper industry or in industrial power stations co-incinerating or specialized on this fuel (see fact sheet “Industrial co-combustion”).

All thermal treatment processes have to give respect to an increasingly stringent and expanding array of regulatory measures to control the potentially toxic emissions (gas, liquids and solids) associated with the incineration. These regulatory controls have also a significant impact on the capital and operating costs of thermal technologies. What are the emissions produced dependent largely from the different chemical makeup of the waste input and the type and nature of the applied thermal process. Often highlighted in this context are differences between conventional incineration and processes based on the pyrolysis of a waste. As of now, pyrolysis has not made it to a widely recognized standard technology for the thermal treatment and/or utilization of waste in Germany but also from a large-scale and wider country perspective. Problems resulting from inhomogeneities in waste streams and the economics of the process make up part of the reasons. It is therefore not excluded that under specific favorable circumstances and frameworks and adopted to some specific waste material streams the individual examination of the feasibility of such technology can be worth the effort, and that, reliability and cost-efficiency proven on larger scale applications in a longer term, the use of this technologies might also be practical and advantageous.

Utmost attention in all thermal waste treatment processes and a central position in their development and operation in any case need to be devoted to ***emission control and abatement***. Flue gas cleaning technology (see fact sheet "Exhaust and flue gas cleaning") therefore is an integral element of waste treatment and the technical details one should have at hand about suitable technologies.

Note: Detailed descriptions of the technology and equipment referenced in the text are provided with the following fact sheets

Table 3: Overview on separately provided fact sheets related to MSW processing, treatment and utilization

Fact sheets MSW processing, treatment and utilization
Waste processing/Material recovery
Sorting and processing of waste paper
Sorting and processing of waste glass
Sorting and processing of (other) mixed packaging
Sorting and processing of bulky waste
Composting
Anaerobic digestion
Phosphorus recovery
Waste pre-treatment/stabilization
Mechanical-biological waste treatment
Solar waste drying
Incineration/Industrial co-combustion
Grate combustion
Fluidized bed combustion
Exhaust/flue gas cleaning

PROCESSING & SORTING OF WASTE PAPER/PAPER FOR RECYCLING

APPLICATION OBJECTIVE	- Generation of paper fractions conforming to the European List of Standard Grades of Paper and Board for Recycling (EN643) for use in the production of graphical and non-graphical paper products taking different technical effort and degree of automation into account

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper / paperboard	X	Mixed household waste		Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material					

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
The collection of waste paper with other waste materials and in particular with such that are wet, fatty or otherwise contaminated shall be avoided. The most suitable way to guarantee an efficient recycling and recycling products of high quality is the separation of the material at source and its selective collection. Waste paper which has not been separately collected and is recovered from commingled waste streams or at waste disposal sites, usually shows to have a quality which is rarely good enough for producing low-grade paper applications such as low quality cardboard. Beside separate collection at source no further pre-treatment is necessary before quality sorting.

Options for the utilisation of the generated output:
The different paper fractions obtained with sorting can be directly used in the production of new paper applications or for other forms of recycling. Other recycling options include the use of recovered paper for example as insulating material, for mould fibre applications, in fibre board or as an additive in asphalt.

Options for the disposal of process output and/or residues:
Impurities and disturbing materials removed during the sorting operations must be disposed of. The most prominent options exist with incineration or the processing of refuse derived fuel.

Protective needs:
Of particular importance is the protection from ignition and fire, and operational safety resp. accident prevention at installations with driven equipment (forklift), moving parts (conveyor belts) and loads (paper bales). The processing area and paper material must be protected from weather impacts, especially rainfall, moisture and wind.

Potential health risks:
Source separation and sorting waste paper prior to its use in paper production also has the objective to make sure types of paper containing volatile chemicals such as DIPN (for example included in non-carbon required copy paper) are removed from material streams forwarded to the production of applications with food contact. The process thus can also lower human health risks.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
Installations must be well accessible and possess of good connections to main transport lines resp. routes.

Climatic conditions:
The collected paper and sorting facilities should be protected from weather effects which means that especially operating areas and storage yards shall be sheltered from excessive rainfalls and wind.

Employment potentials:
Sorting waste paper, even quality control steps subsequent to automated processes can be manually performed as well. This opens up good employment opportunities whereby it is also possible to employ personnel with lower levels of education and technical qualifications.

Others:

Essential for economically viable operations are larger areas of supply and a sufficiently high purity of the input (from separation at source) and especially as the sorted output is concerned. From the growth in electronic communication follow decreasing rates in graphic paper consumption. The decline in the newsprint and office paper until 2020 is estimated to get as low as 50% of the demand this section has seen in 2008. Paper use in cardboard application and for packaging is assessed to rise or remain stable. Sorting operations should be flexibly designed in order to get adjusted and quickly cope with changes on the market.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	The process generally comprises a mechanical processing for the removal of fine matter and disturbing materials (e.g. mineral substances, small metal parts) and sorting operations with a varying degree of automation (e.g. near infrared-NIR, visual spectrometry-VIS, manual sorting) with the aim to obtain different paper grades from separately collected waste paper.
BASIC REQUIREMENTS	- The input must be collected separately from other waste and material streams - Material has no greater pollutions and is relatively dry. The novel European List of Standard Grades of Paper and Board for Recycling (adopting the EN643 as of 2013) prescribes an allowable maximum of non-paper content and unwanted matter for each paper grade. In general the limit is set for such material at not more than 3% by weight in aggregate.

EXPECTED RESULTS	- Grades of Paper and Board for Recycling with a defined quality; when conforming to EN643 these are, for example:
	  - *1.11 Sorted graphic paper for deinking:* Sorted graphic paper, consisting of a minimum of 80 % newspapers and magazines. It has to contain at least 30 % newspapers and 40 % magazines. Print products which are not suitable for deinking are limited to 1.5 %.
	  - *1.02 Mixed papers and boards (sorted):* A mixture of various qualities of paper and board, containing a maximum of 40 % of newspapers and magazines.
	  - *1.04 Supermarket corrugated paper and board:* Used paper and board packaging, containing a minimum of 70 % of corrugated board, the rest being solid board and wrapping papers.
	- Sorted output with non-paper components and unwanted material in the paper fractions below maximum tolerance levels (e.g. according to EN643 maximum of 1.5% non-paper for the majority of grades)

SPECIFIC ADVANTAGES	Are differently assessed depending on the employed process scheme and plant configuration *Basic configuration* - simple techniques, thus relatively moderate capital costs and low maintenance expenses - very reliable, i.e. little failure prone (95% effectively available) - high flexibility *Advanced configuration* - automated processes (i.e. use of NIR detection techniques), thus little labor intensive - higher purity of the output due to mechanized and sensor-supported pre-sorting - significantly higher throughput than with basic configuration possible
SPECIFIC DISADVANTAGES	Are differently assessed depending on the employed process scheme and plant configuration *Basic configuration* - highly personnel intensive (high labour demand) - comparatively low throughput *Advanced configuration* - relatively capital intensive due to the more sophisticated and sensitive equipment used - personnel with quite a high qualification needed - energy demand comparatively higher

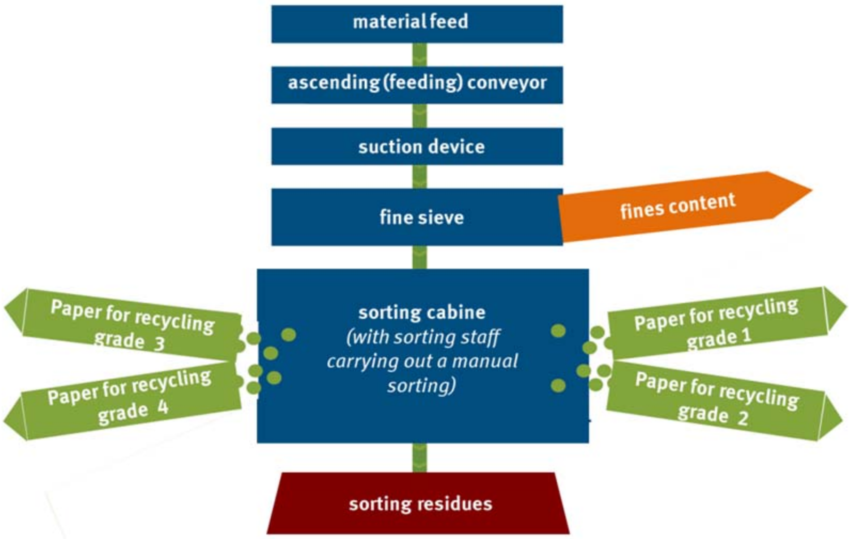
APPLICATION DETAILS

TECHNICAL SCHEME

A continuous feeding of the input and its segregation and even distribution on the conveyor is essential to make optimal use of the sorting capacity and ensure high efficiency of the process.

In the *basic configuration,* the technical arrangement consists of a processing by way of mechanical-physical process steps (e.g. screening, magnet separation, gravitational, suction or blow techniques) for the removal of fine materials (e.g. mineral substances, small metal parts) and a subsequent manual sorting into different paper grades. The following scheme applies:

Figure 1: Example of a technical arrangement for sorting paper for recycling using a basic process configuration



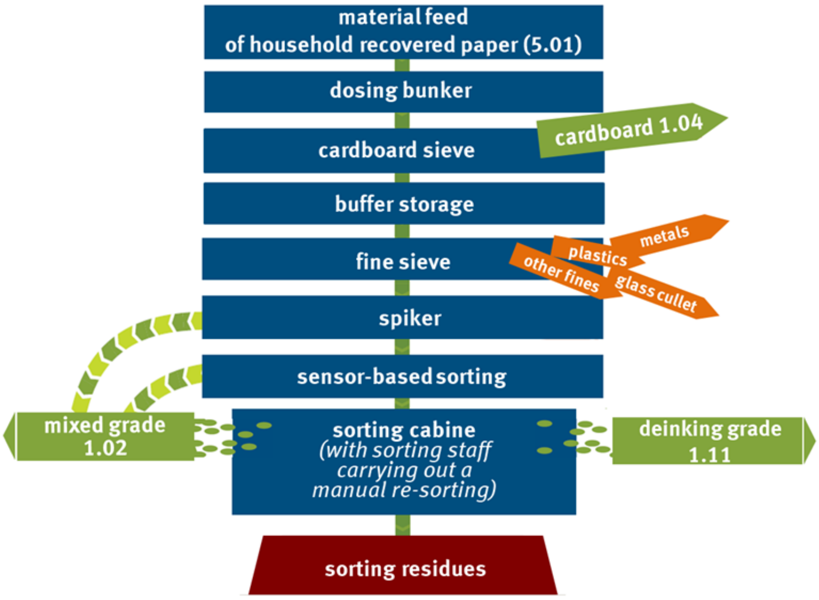
In an *advanced configuration,* the process is partly automated and sensor-based. Objective of the process is mainly the generation of high quality paper fractions (de-inking grades, grade 1.11) usable for the production of print products (newsprint and magazines). At the beginning, mechanical-physical process steps similar to those employed in the basic configuration are applied for the removal of fine and disturbing matter (e.g. mineral substances). Hereafter, mainly a quality separation of the paper is taking place by means of various techniques and methods, involving among others spikes and ballistic separator devices, various types sensors and also manual sorting. The separation usually leads to fractions of card-/paperboard, newsprint, mixed paper grades and a sorting rest.

Generally a tendency to increase the purity of the sorted fractions is observed and thus to go for highly automated, opto-electronically supported and partly multi-level sorting procedures that end with a manually performed quality control and refinement. Without that last step of after-sorting still significant amounts of de-inkable paper (20–40%) wouldn't be recoverable and lost. Integrating manual sorting steps can reduce this loss by about 50% and results in much better quality and sales revenues in the overall.[1] How sorting gets organized and which technical arrangement is used in an advanced configuration can be seen in a process scheme displayed in Figure 2. It should be remarked that sequence of the process steps and positioning of the individual component therein can be varied and do not follow uniform patterns.

To be able to react on and cope with the ongoing changes in the kind of paper products and waste paper composition (currently a decrease in office paper and constantly rising amounts of packaging applications and cardboard) thru a highly flexible design and rearrangement of sorting processes is a big challenge but the only option that can secure the operations economic viability.

[1] Hanke, A., Tempel, L. (2014): Anlagenbau im Aufbereitungsbereich – am Beispiel der Altpapiersortierung. In: Thomé-Kozmiensky, K.J.; Goldmann, D. (Hrsg.): Recycling und Rohstoffe, Band 7, Nietwerder: TK Verlag Karl Thomé-Kozmiensky, 2014, S. 332-248

Figure 2: Example of a sorting arrangement for paper for recycling using an advanced process configuration



QUANTITY ASPECTS

- differ depending on the employed process scheme and plant configuration

Basic configuration

- The average throughput rate is approx. 5 Mg/h
- Sorting intensity and depth can be easily adjusted depending on markets and sales strategies

Advanced configuration[1]

- Throughput rates can go as high as approx. 8–12 Mg/h per separate process line
- Per Mg of plant throughput a proportion of not more than 1.5% disturbing matter should (= plastic foils, styrofoam, fabric, electronic components) be acceptable
- up to 70% of a mixed paper input should be sortable into de-inking grades (grade 1.11)
- 30-40% of the suitable paper input can be sorted in mixed grades (1.02) and packaging (1.04)

SCALE OF APPLICATION

Plants of the advanced configuration are set up in countries/areas with an intensified separate collection and supply of paper for recycling, usually these are facilities of large size

INTEROPERABILITY

The process can be combined with the actual recycling operations in the paper mill itself and integrated there as a preceding step based on additional installations, external facilities are not necessarily required.

OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION

ENERGY BALANCE

The energy demand for waste paper sorting operations lies in a range from 20–50 kWh/Mg[2]. Sorting paper for recycling purposes is necessary in order to be able to close material loops efficiently and to obtain an overall environmental benefit through recycling. How this works and where a net benefit from high-quality recycling derives from is shown in the table below:

Table 1: Comparison of energy and raw material needs for paper made from primary (wood) or waste paper fibres[3]

	Per kilogram recycling paper	Per kilogram virgin paper
Water	15 Litres	50 Litres
Energy	2 kWh	5 KWh
Fibre source	1.2 kg waste paper input	1 kg of fibreous matter obtained from cellulose supplied/extracted from 2.2 kg wood
COD	3 g	15 g

[2] State of 11/2010. EnergieAgentur.NRW: Effiziente Energienutzung in der Papierindustrie

CO2-BALANCE	Paper recycling reduces the need to use primary (wood) fibres for paper production and results in an overall lower consumption of energy for this process. In average an equivalent of 700 kg CO_2 is saved when one ton of waste paper is recycled and used to substitute primary raw materials in paper production[4]. A reference plant of the advanced configuration operating with an annual throughput of 120,000 Mg in Berlin claims to save approx. 75.000 Mg CO_2 in total due to the sorted waste paper it returns to production.
AIDS/ADDITIVES NEEDED	- No other than those technical aggregates mentioned before
HUMAN RESOURCES	*Basic configuration* - usually up to eight labourers, one of which is the foreman. Manual sorting is performed by six of them and one staff operates flexibly as engine driver and machinist *Advanced configuration* - to run the process in shifts a higher staff number is required (in the range of 15–20 labourers in total), the staff ratio in relation to the achievable throughput is often more favourable compared to the basic configuration, however
SPATIAL NEEDS	A hall space of approx. 4,000–5,000 m² is needed for an average size facility
AFTERCARE DEMANDS	The expectable amount of impurities in the source separated input stream in the average is in the range of 3 % by weight, most of that must be disposed of as residual waste
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	*Basic configuration* - the net capital need without building and other auxiliary structures can be estimated in the range of EUR 30,000–80,000 Euro for an average processing line *Advanced configuration* - depending on the use of, for example, opto-electronic and other sensor based separation units a net investment up to EUR 10 million is required for an average processing line
OPERATING COSTS	*Basic configuration* - normally in a range of 15–20 EUR/Mg, of which repair and maintenance costs amount to about 2,000–5,000 EUR per annum (6-8 % of the initial investment) *Advanced configuration* - normally in the range of 11–15 EUR/Mg, the variability of these costs is however significantly higher depending on the equipment employed and the intensity of after-sorting
POSSIBLE PROCEEDS	Following prices could be obtained on the central European markets in the first half of 2015: - Mixed paper (1.02): 70–91 EUR/Mg (compared to 128 EUR/Mg in July 2011) - Carton and cardboard (1.04): 72–90 EUR/Mg (compared to 129 EUR/Mg in July 2011) - De-inking grades (1.11): 77–84 EUR/Mg (compared to 120 EUR/Mg in July 2011)[5]

[3] Based on diverse literature sources, inter alia German Environment Agency (2000); IFEU Institut (2008), JRC (2012), FÖP (2012)

[4] German Environment Agency: Umweltbundesamt Texte 46/2015: The Climate Change Mitigation Potential of the Waste Sector

[5] German Statistical Office: Index of selling prices in wholesale trade of paper for recycling and scrap metals, August 2015, Wiesbaden

MASS SPECIFIC OVERALL COSTS	*Basic configuration* - Essentially determined by the operating costs *Advanced configuration* - Vary considerably due to the different and often very tailor-made technical solutions found, the range can be estimated with 30–90 EUR/Mg exclusive the proceeds made from sales

MISCELLANEOUS

MARKET INFORMATION

REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	Sorting installations of the two different types of configurations can be found in large number across Europe and in many developed countries elsewhere around the globe. Plants of the advanced configuration in Germany are for example: - Altpapier Sortierung Dachau GmbH www.asd-entsorgung.de - Wertstoffunion Berlin www.wertstoffunion.de Further plants of this type are listed in a database of the Federal State of Brandenburg Complete system solutions are offered inter alia by: - Sutco Recycling Technik GmbH www.sutco.de - Entsorgungstechnik Bavaria GmbH www.entsorgungstechnik-bavaria.de
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Almost all large waste management providers in Germany undertake the processing of paper for recycling in facilities set up in various configurations. Some relevant company references are: - Sulo www.sulo.com - SUEZ Deutschland www.suez-deutschland.de - Remondis www.remondis.de - Alba-Gruppe www.alba.info The aggregates and equipment used for the process belong to the pool of technical equipment which is generally available and in use for mechanical operations in the waste management sector. In particular these are: *Feedhopper/conveyor:* - Rudnick + Enners Maschinen- u. Anlagenbau GmbH, Alpenrod www.rudnick-enners.de - Ludden & Mennekes, Meppen www.ludden.de - Spezialmaschinen & Recyclingtechnik, Chemnitz www.sr-recyclingtechnik.com *Classifier/screens:* - Mogensen GmbH & Co. KG, Wedel www.mogensen.de - EuRec Technology GmbH, Merkers www.eurec-technology.com - Spaleck – Förder- und Separiertechnik www.spaleck.de *Suction equipments:* - NESTRO Lufttechnik GmbH, Schkölen/Thüringen www.nestro.com *Metal separators (Fe and non-Fe):* - Steinert Elektromagnetbau GmbH, Köln www.steinertglobal.com - IMRO Maschinenbau GmbH, Uffenheim www.imro-maschinenbau.de - Wagner Magnete GmbH & Co. KG, Heimertingen www.wagner-magnete.de *Press/balers:* - HSM GmbH + Co. KG, Salem www.hsm.eu *Sensor-supported sorting:* - Tomra Systems GmbH www.tomra.de - Sesotec GmbH www.sesotec.com

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

The paper industry in Europe represented by the CEPI (www.cepi.org), initiated a voluntary agreement by which was declared that paper recycling will be further enhanced among others through investments in technological developments, research and by way of a further promotion and increased effort towards separate paper recovery and the utilization of paper for recycling in production. Many other organizations in Europe (e.g. European Recovered Paper Council) and at national level (e.g. German Pulp and Paper Association) join in these kinds of efforts. Voluntary commitments and/or declarations of the industry have the purpose to ensure that recycling is continuously being enhanced and introduced to production without that massive interventions and legislative pressure must be developed or mandatory requirements set by the state in order to establish a functioning paper recycling system.

Umwelt Bundesamt

PROCESSING & SORTING OF WASTE GLASS

APPLICATION OBJECTIVE	- Preparation of (separately) collected container glass for use as raw material in production, especially in the glass industry

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X	Light-weight packaging		Biowaste	
Paper / paperboard		Mixed household waste		Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material					

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:

The collection of waste glass shall be done separately from other waste materials (selective collection). Also a commingled collection of container glass with other glassware such as float glass, speciality glass or glass tableware must be avoided due to the different material compositions and the negative influence this has on the production process and quality of the recycling products. Where the collection is not separate from other materials, a segregation of the glass fraction must be performed first.

To increase efficiency, possibilities and quality of recycling it is also very useful to collect waste glass already separated by colour. The collection of waste glass by colour in Germany results in glass fractions separated at source in the proportion of 50% transparent / 40% green / 10% brown.

Options for the utilisation of the generated output:

The glass fractions obtained in the sorting can be introduced directly in the production of new glassware or used for other applications, such as insulating products (glass wool, foam glass products). Metals sorted out from the collected glass can be directly recycled as well.

Options for the disposal of process output and/or residues:

Other residues from sorting such as inert non-glass materials to the most part can be landfilled without further treatment.

Protective needs:

Measures for protecting the staff and surroundings against noise shall be implemented during sorting operations.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:

Installations must be well accessible and possess of good connections to main transport lines resp. routes.

Others:

Larger supply areas will be needed for economically viable operations

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	The process of preparing the collected container glass for recycling generally comprises a mechanical processing with varying arrangements for pre-sorting of the glass, the removal of disturbing matter and separation of other materials (e.g. metal parts) and a subsequent automated sorting with the aim to obtain glass of a certain purity by colour.

BASIC REQUIREMENTS	- The input material must be glass selectively collected from other commercial and mixed household waste and preferably separated by colour. Main portion should be made up from container glass, in any case should be avoided a mix of different glass types (container/float/shatterproof/heat-resistant glass) and the presence of ceramic components - for efficient sorting and to feed the melting furnace, maximum particle size should be approx. 20 mm (crushing might hence be necessary), high material purity must be ensured in addition

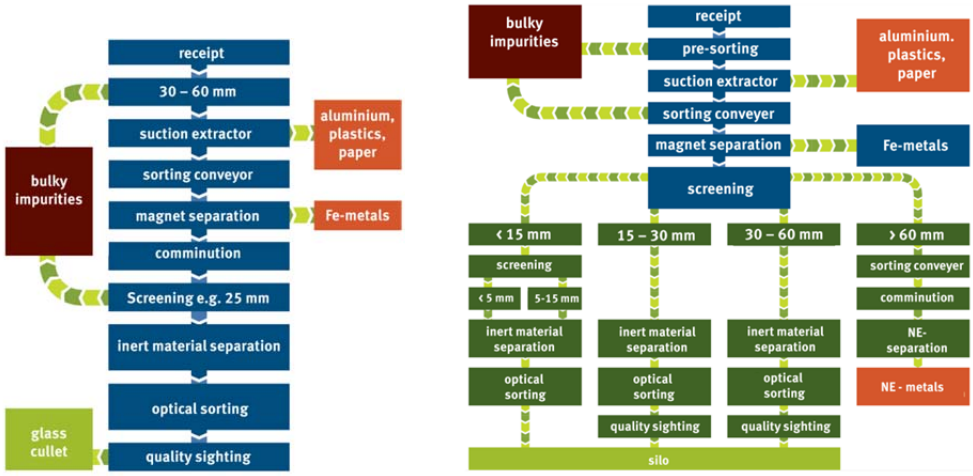
EXPECTED RESULTS	- Glass cullet of defined quality conforming to industrial specifications
	- Sorted material usually is expected to have the following maximum content of impurities[6]:
	  - ceramics, stones, other inert non-glass components <20 g/Mg (10 g/Mg is in discussion)
	  - non-ferrous metals <3 g /Mg
	  - Fe-metals <2 g/Mg
	  - glass ceramics <5 g/Mg (for particles above 10mm), <10 g/Mg (for particles smaller 10mm)
	  - loose organic substances <300 g/Mg
	- mistakes in colour after sorting not exceeding prescribed limits:

Table 2: Maximum of acceptable mistakes in colour after sorting[6]

Glass Fraction	Acceptable mistakes
Transparent	particles of brown glass: ≤ 0.3% particles of green glass: ≤ 0.2% particles of other colour: ≤ 0.2%
Green	brown particles max. 10 %, minimum share of 75% green cullet
Brown	green particles max. 10 % minimum share of 80% brown cullet

SPECIFIC ADVANTAGES	- largely automated process - high throughput - output of stable quality
SPECIFIC DISADVANTAGES	- rather expensive - large supply area is needed
APPLICATION DETAILS	
TECHNICAL SCHEME	For the processing and sorting of waste glass a set of standard techniques is adopted and more or less sophisticated combinations and cycles of repeated applications of these techniques are used. Manual separation has almost no role in processes of industrial scale. Glass delivered to these kind plants is kept under a sheltered area separate by colours (if so collected at source). From here it goes into a feed bunker after which a coarse screening and manually performed pre-sorting for the removal of disturbing materials from the glass follow. Further undertaken are the elimination of light materials such as paper and plastics, a magnetic separation of ferrous components and additional steps of screening with different mesh size (e.g. 15 mm, 30 mm, 60 mm). Additional steps comprise: - improvement of material purity in the screen fractions 5–15 mm, 15–30 mm and 30–60 mm, for example by way of optical sorting devices, - a comminution of the material, - repeated separation and discharge of non-glass particles and non-ferrous metal, - colour sorting with optical techniques such as near infrared technology.

[6] BV Glas, BDE, bvse: Guideline „Quality requirements on glass cullet for use in the container glass production" (in original " Leitlinie „Qualitätsanforderungen an Glasscherben zum Einsatz in der Behälterindustrie") Standardblatt T 120, 14. August 2014

	The following two process schemes are common: Figure 3: State-of-the-art technical arrangements for sorting of waste glass 
QUANTITY ASPECTS	The throughput in an single line arrangement is about 20 Mg/h, in a multi-line arrangement a throughput of 50 Mg/h is possible
INTEROPERABILITY	The process can be combined with the actual recycling operations in the glass factory and integrated there as a preceding step based on additional installations; external facilities are not necessarily required. Glass sorting can also be integrated to the processing and sorting of dry packaging waste, although this does not normally happen then to the same extent and intensity like in the specialized facilities.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- The annual energy demand for plants using technical arrangements as outlined above may reach 10,000 MW. - Generally associated with the use of 10% glass cullet from waste glass in glass production is the saving of 3% of energy input for the melting process.
CO_2-BALANCE	- Glass recycling reduces the need to use primary material for glass production and results in an overall lower consumption of energy for this process. In average an equivalent of 500 kg CO_2 is saved when one ton of waste glass is recycled and used to substitute primary raw materials in glass production[7].
AIDS/ADDITIVES NEEDED	- none
HUMAN RESOURCES	- About 11 persons per shift in a multi-line arrangement, most personnel is needed for pre-sorting and control operations
SPATIAL NEEDS	- surface area in the range of 5,000 up to 8,000 m² including storage space
AFTERCARE DEMANDS	The residues from sorting normally require disposal at landfills (see the fact sheets on "Landfills for non-hazardous waste" and "Landfill for inert waste"), as far as the inert material is concerned a use for construction purposes at these landfills can be possible

[7] German Environment Agency: Umweltbundesamt Texte 46/2015: The Climate Change Mitigation Potential of the Waste Sector

OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	up to approx. EUR 12 million in total capital expenses for an average sized plant using technical arrangements as outlined above
OPERATING COSTS	Incur mainly for - personnel and energy needed - repair and maintenance: about 5 % of initial investment p.a.
POSSIBLE PROCEEDS	- The obtainable price for sorted glass on central European markets according to Eurostat has been in the range of 45–54 EUR/Mg during the first half of the year 2015
MASS SPECIFIC OVERALL COSTS	- n.a.

MISCELLANEOUS

MARKET INFORMATION		
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	Larger size sorting installations using technical arrangements as outlined above can be found in large number across Europe and in many developed countries elsewhere around the globe. In Germany such exists for example with the facilities of:	
	- Glasrecycling Nord GmbH & Co. KG, Wahlstedt	www.karl-meyer.de
	- Reiling Glas Recycling GmbH & Co. KG, Mariental	www.reiling.de
	Further locations of glass sorting plants are shown in a list of	Aktionsforum Glasverpackung
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Many of the large and medium waste management providers undertake the processing of the collected waste glass in the described manner, e.g.	
	- Alba-Gruppe	www.alba.info
	- SUEZ Deutschland	www.suez-deutschland.de
	- Remondis	www.remondis.de
	The aggregates and equipment used for the process belong to the pool of technical equipment which is generally available and in use for mechanical operations in the waste management sector. In particular these are:	
	Conveyor:	
	- Rudnick + Enners Maschinen- u. Anlagenbau GmbH, Alpenrod	www.rudnick-enners.de
	- Ludden & Mennekes, Meppen	www.ludden.de
	- Spezialmaschinen & Recyclingtechnik, Chemnitz	www.sr-recyclingtechnik.com
	Screens:	
	- Mogensen GmbH & Co. KG, Wedel	www.mogensen.de
	- EuRec Technology GmbH, Merkers	www.eurec-technology.com
	- Spaleck – Förder- und Separiertechnik	www.spaleck.de
	Baler/Comminutor/Shredder:	
	- HSM GmbH + Co. KG, Salem	www.hsm.eu
	- Bomatic–Umwelt- und Verfahrenstechnik GmbH, Hamburg	www.bomatic.de
	- Erdwich Zerkleinerungs-Systeme GmbH, Kaufering	www.erdwich.de
	- ANDRITZ MeWa Gechingen:	www.andritz.com/index/locations
	Metal separators (Fe, Non-Fe):	
	- Steinert Elektromagnetbau GmbH, Köln	www.steinertglobal.com
	- IMRO Maschinenbau GmbH, Uffenheim	www.imro-maschinenbau.de
	- Wagner Magnete GmbH & Co. KG, Heimertingen	www.wagner-magnete.de
	Sensor supported sorting (e.g. NIR devices):	
	- Tomra Systems GmbH	www.tomra.de
	- Sesotec GmbH	www.sesotec.com

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS	
Further detailed information on the processing of waste glass, sector information and contact lists to relevant firms can be obtained from:	
Bundesverband Sekundärrohstoffe und Entsorgung:	www.bvse.de
Federal Association of the German Glass Industry (Bundesverband Glasindustrie e.V.)	www.bvglas.de
Aktionsforum Glasverpackungen	www.glasaktuell.de
European Container Glass Federation (FEVE)	www.feve.org
glasstec – International Trade Fair for Glass Production	www.glasstec.de

PROCESSING & SORTING OF PACKAGING WASTE

APPLICATION OBJECTIVE	- Processing the separately collected packaging waste from households and commercial sources to generate unpolluted recyclable fractions of metals, plastics and composite materials and other marketable material streams

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging	X	Biowaste	
Paper / paperboard		Mixed household waste	X[8]	Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material	X[9]	Small-sized waste items of similar composition/material like packaging (e.g. toys)			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
No particular requirements of pre-treatment as long as the separate collection of the packaging waste or of the dry waste components at source is ensured.

Options for the utilisation of the generated output:
Part of the different fractions of recyclable material obtained in the sorting can be directly used for recycling (e.g. metals, cardboard). Especially plastic components may require further treatment and refining steps before they are suited for material recycling. Also their energetic use is possible and can have advantages.

Options for the disposal of process output and/or residues:
Sorting residues must be properly disposed of. Those with a high calorific value usually suit for producing a refuse derived fuel material which can be co-incinerated in industrial processes (see fact sheet on "Industrial co-incineration"). If not possible an incineration with energy recovery (see fact sheets on "Grate combustion" and "Fluidized bed incineration") should be considered, the inert fraction can be deposited at landfills.

Protective needs:
Of particular importance is protection from fire and the operational safety resp. accident prevention at installations with driven equipment (forklift), moving parts (conveyor belts) and loads (baled recyclables).

Potential health risks:
During sorting operations higher levels of exposure to infectious germs, spores and contaminations can occur in the direct working environment. Precautionary and protective measures such as aeration and ventilation, wearing of protective equipment and breathing masks need to be implemented to reduce the health risks for the workforce and closer surroundings.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
Installations must be well accessible and possess of good connections to main transport lines resp. routes.

Climatic conditions:
Sorting facilities have to be protected from weather effects which means that especially storage and operating areas shall be sheltered from the influence of wind and rainfall.

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[8] source separated dry fraction of the household waste only

[9] the source-separate collection of mixed packaging material may be combined with that for small-sized waste of similar nature (system of commingled collection of mainly plastic, metals and wood known in Germany as the "bin for recyclables" respectively "Wertstofftonne"-concept (www.wertstofftonne-berlin.de). Pilot tests have confirmed this option and the possibility of a subsequent separation and processing of the different fractions.

Employment potentials:
The sorting of packaging waste in many cases can be manually performed. This opens up good employment opportunities whereby it is also possible to employ personnel with lower levels of education and technical qualification.

Others:
The process can be economically viable where a high output quality is obtained and good markets exist for it. Otherwise re-financing mechanisms such as packaging fees or licensing schemes similar to the Green-dot system which is used by many European countries may have to be implemented (see the concept of „Der Grüne Punkt“/ The „Green Dot"-trademark)

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	The process generally comprises a mechanical processing with a varying degree of automation in order to make the different materials accessible to subsequent sorting operations and to separate the input into its recyclable material fractions. Basis is the purposeful arrangement of various, consecutive steps of comminution, screening and classifying by more or less sophisticated technical means and equipment. This may also include manual sorting operations.
BASIC REQUIREMENTS	- The input must be separately collected packaging not commingled with moist materials from commercial and household waste or the source separated dry fraction from the household waste
EXPECTED RESULTS	- marketable fractions of recyclable material of a defined quality - (partly) automated separation of different polymers PE, PP, PET and PS for further processing - optional: ready for use plastics granule obtained where sorting is directly combined with a finishing process
SPECIFIC ADVANTAGES	Are differently assessed depending on the employed process scheme and plant configuration *Basic configuration* - simple techniques, thus relatively moderate capital costs - very reliable, i.e. little failure prone (95% effectively available) - rather flexible and easily adjustable to market developments *Advanced configuration* - higher throughput as compared to basic configuration - more effective separation - slightly reduced personnel demands - relatively flexible
SPECIFIC DISADVANTAGES	Are differently assessed depending on the employed process scheme and plant configuration. *Basic configuration* - labour demanding (higher personnel needs) - comparatively low throughput *Advanced configuration* - more energy consuming and capital intensive - higher qualification needs of the personnel - more difficult to adjust

APPLICATION DETAILS

TECHNICAL SCHEME	In the *basic configuration,* the process consists of a mechanical processing aimed at the removal of fine materials thru screening and the separation of metal components followed by a manual sorting of the different materials. Usually an arrangement according to the following scheme applies:

Figure 4: Example of the technical arrangement to sort packaging waste in a basic configuration into various material fractions including several fractions of plastics

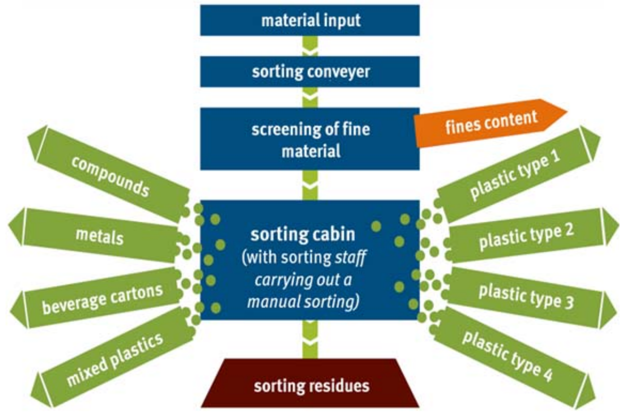
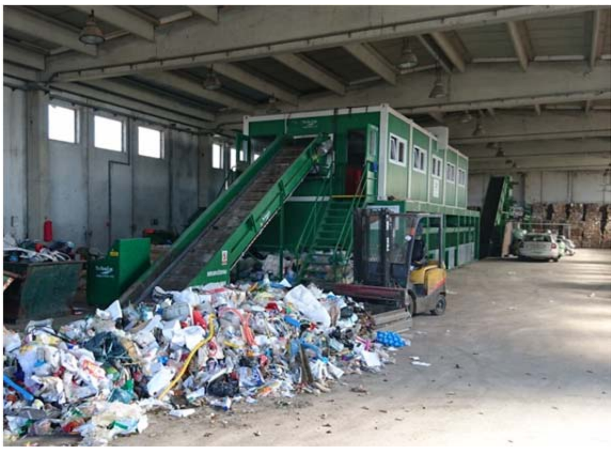
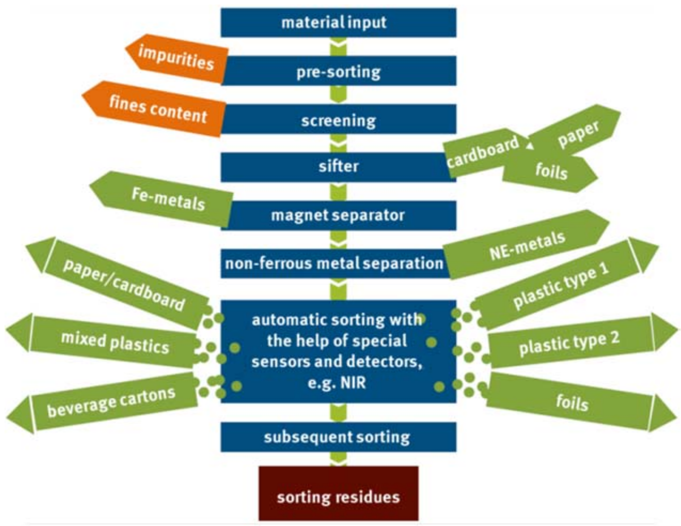


Figure 5: Example of a sorting installation in the basic configuration



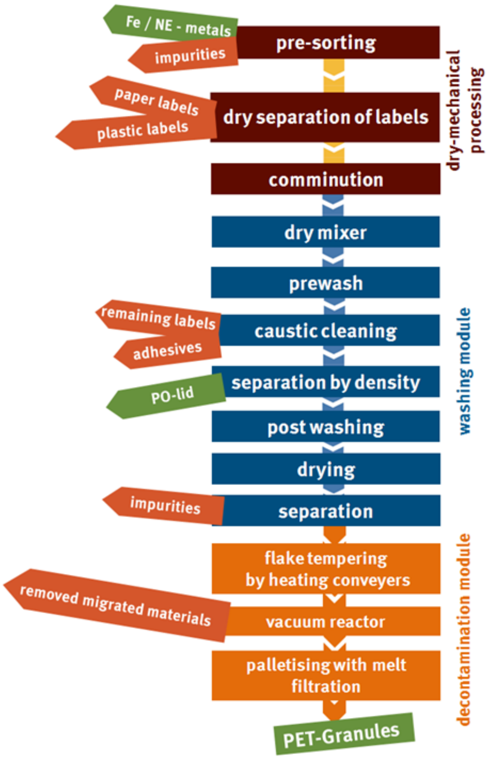
In the *advanced configuration* the process flow is similar to that of the basic configuration although more sophisticated means such as an automated sorting stage using near infrared technology and various additional separation devices (for Fe-metals, non-ferrous metals, light materials) are involved. It should be remarked that number, positioning and sequence of the individual component therein can be varied and do not follow uniform patterns. The technical arrangement commonly found in an advanced configuration can be seen in a process scheme below.

Figure 6: Example of the technical arrangement to sort packaging waste by advanced means into various material fractions including several fractions of plastics



Process of plastics finishing:
Subsequent to the sorting of the packaging into fractions of different material a refinement (finsihing) of the plastics sorted out must be performed. This step is required to obtain the ground stocks and plastic regranulates of defined quality which can eventually be reintroduced (recycled) into production. For part of the material the use as secondary raw material in production is possible at a general scale, e.g. plastic granule, aluminium, paper fibres. Some material is processed to give the feedstock in very material or product-specific recycling loops such is the case for mixed plastics or beverage container. A simplified scheme for an example of a closed loop process[10] is the one shown in Figure where pre-sorted PET-bottles are processed to recycling flakes and these are used for producing PET bottles again.

Figure 7: Recycling process of the company KRONES (modified drawing from KRONES AG, www.krones.de)



QUANTITY ASPECTS

- differ depending on the employed process scheme and plant configuration

Basic configuration
- the throughput rate usually ranges at around 1 Mg per hour

Advanced configuration
- the throughput rate usually ranges between approx. 3-20 Mg per hour

The following is a mass balance of a processing facility for source-separated recyclables in Iserlohn[11]. Obtained from an annual input of 72,000 Mg are the following material fractions:

- Recyclable output:	Ferrous metal: 8,000 Mg, Non-ferrous metal 2,200 Mg PE: 2,500 Mg, PP 5,000 Mg, PS 1,800 Mg, PET 1,400 Mg Foils 4,800 Mg Beverage carton: 5,000 Mg card-/paperboard: 1,800 Mg
- Output for energetical use:	Mixed plastics (high-calorific value): 19,000 Mg RDF feedstock (medium-calorific value): 17,400 Mg
- Sorting residues:	(low-calorific value): 2,900 Mg

[10] Krones AG: http://www.krones.com/de/produkte/abfuellung/bottle-to-bottle-pet-recyclinganlage.php

[11] INFA GmbH, Prognos AG: Recycling facility Iserlohn-Sümmernals Project of the KlimaExpo.NRW – Mass balance and impacts on climate, http://www.klimaexpo.nrw/fileadmin/user_upload/Projekte/WAA_Lobbe/Anhang_WAA_Lobbe_Klimawirkung_Mengenbilanz.pdf, last access 12.10.2015

SCALE OF APPLICATION	- Installations of the basic configuration can be small, are sometimes operated only temporary and for different material streams whereas plants of an advanced configuration are especially set up in areas with an intensified separate collection of packaging waste, usually these facilities are of large size and operated in shifts
INTEROPERABILITY	Where sorting operations are simple and focus on a few material fractions only there is the possibility to integrate the processing as a preceding step to the actual recycling operations in a production facility itself. Where the material streams and processing are complex and involve a higher degree of automation separately erected, specialized plants often give the better solution.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- Operations in the basic configuration have a comparatively low energy demand. - The energy demand in the advanced configuration rises with the number and kind of additionally installed technical devices
CO_2-BALANCE	- Recycling of packaging material reduces the need to consume primary resources for production and results in savings of energy and emissions the use of these primary resources would otherwise require. On the example of the reference plant with a throughput of 72,000 Mg/year in Iserlohn annual GHG emission savings equivalent to approx. 55.000 Mg CO_2 have been calculated. 70% of these savings result from replaced raw materials whilst 30% are derived from the energetic use of mixed plastics and RDF in substitution of conventional fuel.
AIDS/ADDITIVES NEEDED	- No auxiliary components/material needed in sorting - Water consumption and chemical additives become relevant in the finishing process with integrated wet-mechanical steps
HUMAN RESOURCES	*Basic configuration* - about 12 persons in average *Advanced configuration* - between about 7–30 persons
SPATIAL NEEDS	- Surface area of about 5,000 m² to 10,000 m² for a plant of average size
AFTERCARE DEMANDS	Impurities and residues which can make up about 40–55 % of the input stream are mostly waste that requires final disposal, the nature and combustible properties of most of these residues render incineration as the preferential option
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	*Basic configuration* - the net capital need without building and other auxiliary structures can be estimated in the range of EUR 50,000–150,000 Euro for an average processing line *Advanced configuration* - depending on the use of, for example, opto-electronic and other sensor based separation units a net investment up to EUR 13 million or above must be calculated for an average processing line

OPERATING COSTS	Vary considerably in dependence from the configuration and techniques employed.
	- indicative in the range between 150–650 EUR/Mg; including
	  - the costs for the disposal of process residues (at German price level) and
	  - the expenses for repair and maintenance which are assessed with about 6 % of the initial investment per annum

POSSIBLE PROCEEDS

Sorted fractions are marketable and fetch different prices depending on the quality and actual situation at the market. An example of prices paid in the market is the following for various types of plastic material:

Kind of plastic material	July 2015 [EUR per Mg]	July 2014 [EUR per Mg]
HDPE regrind	620	620
HDPE granule	920	920
PP baled	260	290
PP regrind	590	550
PET regrind coloured	420	410

Special financial mechanisms can be installed to compensate the costs for packaging processing and recycling, an example for that is the Green-dot licensing scheme in Germany (www.gruener-punkt.de)

MASS SPECIFIC OVERALL COSTS

n. a.

MISCELLANEOUS

MARKET INFORMATION

REFERENCE FACILITIES

(Note: the list of sites and/or firms does not constitute a complete compilation)

Applications of above outlined plant configurations and techniques can be found in a number of European countries and elsewhere in the world. Examples of the above arrangements in Germany are:

- WAA Iserlohn www.lobbe.de
- Sorting plant Leipzig www.alba.info

Further plants of this type are listed in a database of the Federal State of Brandenburg

Plastics finishing/ Flake production

- Krones AG www.krones.com
- Multipet GmbH Bernburg www.mp-bbg.eu
- Systec Plastics www.systalen.de

Many of the large and medium waste management providers undertake the processing of light waste packaging using different kinds of plant configurations. Companies belonging to this group are for example:

- SUEZ Deutschland (Suez Group) www.suez-deutschland.de
- Remondis www.remondis.de
- Alba-Gruppe www.alba.info

RECOGNIZED PRODUCER AND PROVIDER FIRMS

(Note: the list of firms does not constitute a complete compilation of companies)

The aggregates and equipment used for the process belong to the pool of technical equipment which is generally available and in use for mechanical operations in the waste management sector. In particular these are:

Conveyor/dosing installations:

- Rudnick + Enners Maschinen- u. Anlagenbau GmbH, Alpenrod www.rudnick-enners.de
- Ludden & Mennekes, Meppen www.ludden.de
- Spezialmaschinen & Recyclingtechnik, Chemnitz www.sr-recyclingtechnik.com

Sack opener:

- Matthiessen Lagertechnik GmbH, Krempe www.bagsplitter.com

Separators/Classifier and screening equipment:

- Mogensen GmbH & Co. KG, Wedel www.mogensen.de
- EuRec Technology GmbH, Merkers www.eurec-technology.com
- Spaleck – Förder- und Separiertechnik www.spaleck.de

Metal separator (Fe and Non-Fe):

- Steinert Elektromagnetbau GmbH, Köln www.steinertglobal.com
- IMRO Maschinenbau GmbH, Uffenheim www.imro-maschinenbau.de
- Wagner Magnete GmbH & Co. KG, Heimertingen www.wagner-magnete.de

	Baler/presses: - HSM GmbH + Co. KG, Salem www.hsm.eu - Bomatic–Umwelt- und Verfahrenstechnik GmbH, Hamburg www.bomatic.de - Erdwich Zerkleinerungs-Systeme GmbH, Kaufering www.erdwich.de - MeWa Recycling Maschinen und Anlagenbau GmbH, Gechingen www.mewa-recycling.de *Sensors/Detector systems:* - Tomra Systems GmbH www.tomra.de - Sesotec GmbH www.sesotec.com

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

Further **detailed information** on the processing of packaging and packaging recovery system with **links to relevant firms** in Germany are available from

- Bundesverband Sekundärrohstoffe und Entsorgung: www.bvse.de
- Website der dualen Systeme: www.recycling-fuer-deutschland.de
- Fachverband Kunststoffrecycling www.kunststoff-verwertung.de
- Industrievereinigung Kunststoffverpackungen e.V. www.kunststoffverpackungen.de

PROCESSING & SORTING OF BULKY WASTE

APPLICATION OBJECTIVE	- Processing the collected mixed bulky waste from households and commercial sources to generate unpolluted marketable fractions of wood, metals and optionally other materials for recycling or further utilization

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper / paperboard		Mixed household waste		Bulky waste	X
Lamps		Textiles		Electrical and electronic waste	
Scrap metal	X	Waste wood	X	C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	X
Hazardous waste					
Branch specific waste	X	forwarded to collection as a mix without components of hazardous nature			
Other waste material	X	commercial waste with a large proportion of recyclables but without components of hazardous nature (e.g. accumulators)			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
Beside the separate collection of the bulky waste at source or separate delivery to points of reception no further pre-treatment is necessary.

Options for the utilisation of the generated output:
The different fractions of recyclable material obtained from sorting can either directly (e.g. metals) or after further processing steps be used for recycling. Also possible is the use of certain fractions for energy production.

Options for the disposal of process output and/or residues:
Sorting residues with a high calorific value can be incinerated whereas for the inert materials a disposal at landfills is possible

Aftercare requirements:
Aftercare must be applied to sorting residues in that either an additional treatment is applied before final disposal or the common aftercare procedures are followed for landfills at which such waste is deposited.

Protective needs:
Of particular importance is noise protection, the protection from fire, and operational safety resp. accident prevention at all stages of the operations.

Employment potentials:
The sorting and processing of bulky waste in many cases can be manually performed. This opens up good employment opportunities whereby it is also possible to employ persons with lower levels of education and technical qualifications.
A special scheme for the processing of bulky waste is to commission part of the work to socially deprived people (e.g. disabled persons), persons in social support programmes or such with a limited capacity to find employment elsewhere. Their work will be to separate from the amount of bulky waste those items which may have a potential to be resold or used for other purposes (e.g. old furniture, antiquities, certain technical devices), and to repair, refurbish or dismantle them until they are fit for sale or a reuse as spare parts, in charity programmes or public institutions becomes possible.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
A good accessibility and sufficient space for temporary storage should be ensured for collection and as far as the facilities for sorting and reprocessing are concerned. Long distance transports of bulky waste are inefficient and uneconomical.

Climatic conditions:
The waste and facilities used for further processing should be protected from weather effects which means that especially operating areas and storage yards shall be sheltered from strong rainfalls and wind.

Suitable financing mechanism:
The process can be economically viable where output quality is high, re-usable items are recovered and good markets exists for recyclables as well as for second-hand products. Re-financing in general must be secured by instruments such as a tipping fee or a general charging mechanism, however. Expenses for processing are ideally incorporated in the general charges for waste services or subject of a special levy whereby latter can be charged for each unit forwarded (e.g. per m^3) or only for those units forwarded in excess to a fixed annual amount of such waste. Proceeds from the sale of refurbished and repaired components/items or from the sale of recovered spare parts should be considered in the calculation of the charge. In that way it might be possible to offer part of the bulky waste collection for free or to collect especially those items free of charge which have a potential for further utilisation or sale after their refurbishment.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	The sorting of bulky waste can be done at the place of its generation or after commingled collection at a central sorting facility. The process generally comprises various mechanical steps with a varying degree of automation with the objective to obtain material fractions of a certain purity for recycling or further utilisation. The process generally aims at the separation of wood, recyclables such as metals, paper and plastics and mixed residual fractions of high respectively low calorific value.
BASIC REQUIREMENTS	- no hazardous components and only low shares of mineral or organic substances shall be contained in the collected waste
EXPECTED RESULTS	- various material fractions (wood, metals, high calorific waste, sometimes paper) in the required purity respectively marketable quality for recycling or further utilisation - recovery of products or items with a potential for reuse or sale
SPECIFIC ADVANTAGES	- easy to implement and very reliable due to the simplicity and low capital demand of the processes - little failure prone and therefore a high general availability of the installed capacities - can be flexibly adjusted to deal with changing input or to create specific output stream
SPECIFIC DISADVANTAGES	- can be very labour demanding

APPLICATION DETAILS

TECHNICAL SCHEME	The sorting of bulky waste can be done with *rather simple methods/techniques at the place of its generation* or at the central collection points/recycling yards or by means of more advanced processes with a higher degree of automation *in specialized sorting facilities*. Principal process steps in both cases are: - pre-sorting which aims at the separation of household and electric/electronic appliances (if collected together with the bulky waste) and disturbing materials of large size from the rest of the materials, - the real (main) sorting. *Sorting at the place of bulky waste generation/collection point* Components of the collected bulky waste worth to be kept intact or maintained in their structure, which have reuse potential or require special processing (e.g. mattresses, carpets, furniture) should be isolated at source and picked up/transported to further processing in a separate manner. This method of separation is technical characterized as (and known under the term)

- *Consecutive collection ('Tandemabfuhr')*

Separating the wanted materials/items is mostly done manually. Meanwhile this collection scheme is also used when wood (as oftentimes the largest single material fraction in bulky waste) shall be separated from the remaining bulky waste at source. The separated materials/items are loaded onto different vehicles and transported to the installations where their further processing/utilization can be executed in the most appropriate way. Vehicles equipped with compacting technology shall not be used for items worth preserving or containing reusable components.

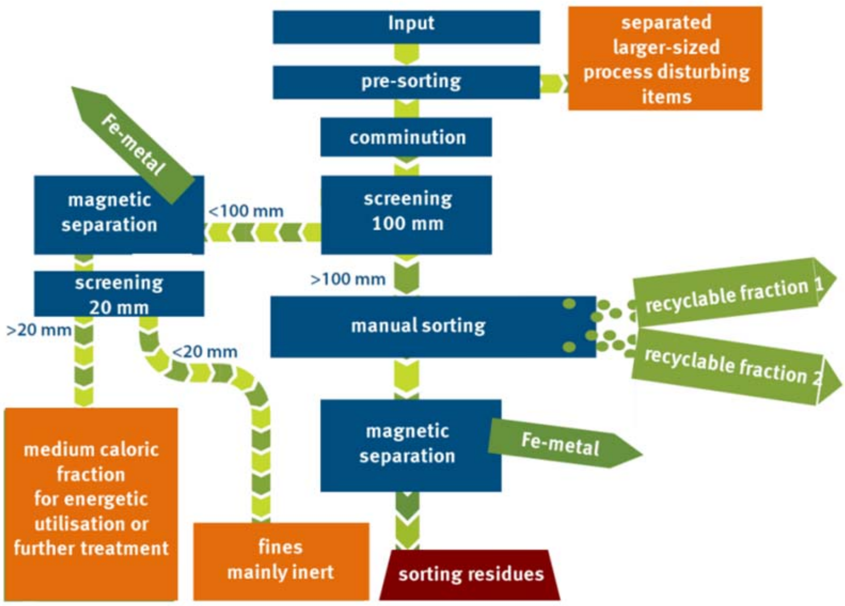
Separation at the discharge area or on a collection yard

In this sorting arrangement, bulky waste is collected, picked up and transported in a mix. Unloaded at a collection yard or processing facility, wooden materials and metals are separated manually or with the help of heavy manipulators or mobile cranes with gripper. Wood and large metal parts are taken out from the hump of bulky materials which leads to a positive sorting. From the average share of approximately 30–50 % wooden material in the bulky waste, about half of the wood can be separated by this technology.

Specialized sorting facilities

Sorting facilities able to handle bulky waste (so called mechanical processing plants) often deal with more than one material stream, aside from the bulky waste recyclable material from commercial sources is also sorted here (which to obtain economies of scale is also recommendable). The technical equipment and process arrangement in such facilities varies, mainly in dependence from the available resources (labour force) and the targeted output stream. In such schemes the pre-sorting step (to remove oversized and non-processable items) is normally followed by a screening and separation of Fe-metals. Further screening stages might be added in order to separate the fine inert from the high calorific coarse materials. The process is often split in several lines, also near-infrared (NIR) technology to separate plastics can be employed in one such line. The example of a common process scheme is shown in the following figure.

Figure 8: Example of a sorting process to generate different recyclable fractions from mixed bulky waste



QUANTITY ASPECTS

The output quality depends basically on the composition of the input. The following figures exemplify the average situation in Germany:

- Input: 100 % mixed bulky waste
- Output: 25–50% wooden material
10–20% metals
10–20% high calorific materials,
the rest being inert fine material

SCALE OF APPLICATION	- The average throughput rate in a sorting plant for bulky waste is in the range of 5–20 Mg per hour and processing line
INTEROPERABILITY	- Where sorting operations are simple and focus on a certain material fraction only (e.g. wood) there is the possibility to integrate the processing as a preceding step to the recycling operations within the production facility. Where diverse material fractions are recovered and more complex processing is required, separately erected and specialized sorting plants often give the better solution.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- Energy consumption rate is relatively low when set in relation to the processed throughput, the energy demand rises the more complex and automated process steps are involved
CO_2-BALANCE	- Secondary raw materials obtained from sorting and processing bulky waste reduce the need to consume primary resources for production whereas recycling saves energy and emissions the use of these primary resources would otherwise require. Metal recycling provides one example for this. The use of 1 Mg ferrous scrap in production avoids an equivalent of over 900 kg CO_2 emissions when compared with metal production from crude ore, in case of 1 Mg precious metal scrap the saved emission equivalent rises to 9,000 kg CO_2[12].
AIDS/ADDITIVES NEEDED	- No auxiliary material is needed in sorting
HUMAN RESOURCES	- The staff demand depends on the size of the facility, the applied process and degree of automation. The usual plant size requires up to 8 labourers, of which one is the foreman, six members of staff do the manual sorting and one operates flexibly as engine driver and machinist. - Sorting at source (incl. consecutive collection) requires a minimum workforce of 2–3 persons.
SPATIAL NEEDS	- Surface area of about 3,000 m² to 5,000 m² for an average sized sorting facility
AFTERCARE DEMANDS	Apply to impurities and residues which require further treatment (combustibles) and final disposal (inert fraction)
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- Investment needs range in the amount of 70–200 EUR per Mg and year depending on the size (throughput), applied process and technical equipment of the sorting facility - Sorting at source and at collection yards require capital investments to be made in machinery (manipulator) in particular, including the development of the yard (min. 250 m² sorting space) the investment amount is approximately EUR 150,000–200,000 in total (Price level of 2008)
OPERATING COSTS	In the range of 20–50 EUR per Mg (Price level of 2008, proceeds and disposal costs not included). The costs of sorting at source are in the range of 10–20 EUR per Mg. - The costs for the consecutive collection are about 10–30% higher as compared to the conventional pickup of mixed bulky waste (mainly due to the additional personnel and vehicles). This concept makes economically sense in areas with a high dwelling density only.

[12] German Environment Agency: Umweltbundesamt Texte 46/2015: The Climate Change Mitigation Potential of the Waste Sector

POSSIBLE PROCEEDS	- depending on the market situation from the sale of the sorted material fractions such as metals, wood and paper and from recovered items which are being sold as spare parts or for reuse after refurbishment
MASS SPECIFIC OVERALL COSTS	On average must be calculated with overall costs in the range of 50–100 EUR per Mg (depending on the amount and costs for the residues disposal, here German price level of 2008)
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	Applications of the different concepts (sorting at source vs. sorting in specialized plants) are very common and can be found in different scale everywhere in Europe and the world. Most waste management providers in Germany undertake the processing of the collected bulky waste in one or the other way and have designed and erected their own procedures, processing schemes and facilities for that. A list of sorting facilities can be found in a database of the Federal State of Brandenburg
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	The aggregates and equipment used for the processing and sorting of bulky waste belong to the pool of technical equipment which is generally available and in use for mechanical operations in the waste management sector. In particular these are: *Feed hopper, conveyor:* - Rudnick + Enners Maschinen- u. Anlagenbau GmbH, Alpenrod www.rudnick-enners.de - Ludden & Mennekes, Meppen www.ludden.de - Spezialmaschinen & Recyclingtechnik, Chemnitz www.sr-recyclingtechnik.com *Shreeder/comminutor:* - HAMMEL Recyclingtechnik GmbH, Bad Salzungen www.hammel.de *Separators/classifier:* - EuRec Technology GmbH, Merkers www.eurec-technology.com - Mogensen GmbH & Co. KG, Wedel www.mogensen.de - Spaleck – Förder- und Separiertechnik www.spaleck.de *Metal separators (Fe, non-Fe):* - Steinert Elektromagnetbau GmbH, Köln www.steinertglobal.com - IMRO Maschinenbau GmbH, Uffenheim www.imro-maschinenbau.de - Wagner Magnete GmbH & Co. KG Spann- und Umwelttechnik, Heimertingen www.wagner-magnete.de *Sensors/NIR-technology:* - Tomra Systems GmbH, Langenfeld www.tomra.de - Sesotec GmbH www.sesotec.com

Umwelt Bundesamt

BIOLOGICAL WASTE TREATMENT – ORGANIC WASTE COMPOSTING

APPLICATION OBJECTIVE

- Recovery of useful organic and inorganic substances from the biodegradable waste fraction for the generation of a usable humus by biological processes and in conjunction therewith
- a significant reduction of biodegradable waste that otherwise would have to be landfilled or become subject of other forms of waste treatment or
- the reduction of the reaction potential of organic rich waste or of the residues from biological treatment processes such as anaerobic digestion (see factsheet on "Anaerobic digestion")

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	X
Paper / paperboard	X[13]	Mixed household waste		Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood	X[14]	C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste	X	Kitchen and food residues, green waste, waste and residues from forestry, agriculture including manure and from wood, crop and/or food processing			
Other waste material	X	any source separated biodegradable material with non-hazardous content			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
The input material should come from a separate collection, it has to be examined for components which may release hazardous substances (e.g. batteries) and must be freed from them and other disturbing materials such as large foils. Large components usually contained in forest residues, pruning and garden waste must be chopped.

Options for the utilisation of the generated output:
The compost is particularly suited for agricultural applications, the use in gardening and landscaping, for fruit and special cultures, re-cultivation works and home gardening. The mainly wooden screen overflow suits well for use in thermal installations for energy production (biomass power stations). Composting residues may also be utilized as a bio filter material.

Options for the disposal of process output and/or residues:
Residues from composting processes such as foils separated during screening have to be treated with other (e.g. thermal) processes.

Aftercare requirements:
No particular measures required. A sufficient hygenization of the material usually takes place within the composting process. Regular quality control of the compost product should be ensured.

Protective needs:
The exhaust air (especially in the receiving area and from mechanical processing) must be collected and treated, in addition technical and organizational measures for the avoidance and minimisation of emissions (odours in particular) have to be undertaken.

Potential health risks:
Especially in the receiving area and during mechanical processing steps a higher risk of air contaminations with germs and spores must be observed. Technical and personal protection measures (wearing of mouth masks, suction removal and air exchange) in these places are highly recommended to avoid potential health risks.

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[13] for a limited spectrum of paper waste (e.g. no wet-resistant and technical papers) in small quantities only and never pure but together with other wet biodegradable materials resp. biomass

[14] only untreated wood waste which to separate and forward to a material recycling process is not economical or technically possible

Employment potentials:
Waste composting offers good opportunities for the employment of both, unskilled and higher qualified personnel. In the rather complex processes (e.g. tunnel composting) there is even a need for specially trained and qualified staff to take care for the facility management and operations control.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
Composting facilities can basically be used in any places, it will be an advantage however to erect them close to the places where the relevant wastes are generated and at locations that have access to the road and transportation network allowing the compost product to be more easily sold. As with any treatment facility for biological waste, a minimum distance to the nearest residential area should be maintained to avoid any potential nuisances by odours, rodents or other unwanted vermin.

Climatic conditions:
Different process arrangements (open/encapsulated) allow composting to be basically used under any climatic conditions, except of very cold climates. Especially in open processes one has to consider that high temperatures cause the waste material to quickly dry out whereas low temperatures hamper the biological degradation. Using an appropriate coverage (for example special membrane foils) can be a way to avoid such disturbances. In areas with generally high precipitation rates or seasonal intense heavy rainfalls, windrows and rotting heaps should be placed under a protection shelter in order to avoid water loggings.

Suitable financing mechanism:
Financing can be through a fee charged in conjunction with the delivery of the waste to the composting facility or collection service via the corresponding collection system (separate biowaste container). Alternatively the costs can be incorporated into the charges or a specific fee for general waste collection services or they are recovered over other (e.g. tax-based) mechanisms for waste management financing.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

Composting is an aerobic process that requires oxygen and biologically degrades respectively converts organic material under appropriate conditions to CO_2, water and humus. The consumption of oxygen is greatest during the early stages and gradually decreases as the process continues to maturity. Biological processes cause a self-heating of the input material which reaches its highest temperature profile in the early process phase (intense rotting, temperatures up to 65–75°C) and leads to the drying and the killing of pathogens and weed seeds (hygenization). Eventually the temperature curve goes down as a sign that the biodegradation is coming to an end.
The spectrum of composting techniques stretches from rather simple, open air arrangements (open windrow composting) up to highly sophisticated and controlled, encapsulated systems such as the tunnel or box composting.

BASIC REQUIREMENTS

For a quality compost, the following requirements should be ensured in the input:

- must be from source-separated organic waste (biowaste) without hazardous components
- should have a material structure that allows for a sufficient aeration as well as a
- moisture content in the range of 50–60% and a
- C/N-ratio in the range from 20:1 to 40:1
  A C/N-ratio in the range 25:1–30:1 describes the optimum for a fast composting process, but higher ratios may be possible. Overloads of nitrogen in the input material must be avoided since almost the entire nitrogen fixed in the organic material is going to be released as ammonium thru micro-biological activities. High concentrations of ammonium at a pH>7 can cause unwanted emission of ammonia.
- To kill pathogens and weed seeds in the compost material, the process must ensure temperatures of 55°C in minimum for at least two weeks or 65°C in minimum (60°C in encapsulated systems) for about one week.

The liquor collected from composting, if it cannot be returned and completely used in the process, must be adequately treated so as to comply with the legal requirements (such as described by Directive 91/271/EEC) before being released into surface water.

EXPECTED RESULTS

Output:
- Compost (humus-like product)
- Residues and disturbing components
- smaller amounts of liquors

Mature compost should meet the following parameters to ensure that it is stable and safe:
- a C/N ratio of less than 25 to be safe for agricultural use
- not re-heat over 20 °C upon standing
- reduced volume of raw organic material by at least 60 % of the input.
- low heavy metal concentrations as prescribed by international standards.

SPECIFIC ADVANTAGES

- generates a product which is scarce and highly needed in many places
- allows for a high proportion of waste diverted from final disposal with the consequence of saved capacities, costs and emissions for further treatment
- enhances other waste treatment operations thru either a drying or removal of organic matter from the waste stream
- relatively simple to perform and safe
- generally little capital intensive
- well known and also well investigated technology
- widely dispersed technique with a generally high acceptance in all areas

SPECIFIC DISADVANTAGES

- can be applied on certain organic waste components only
- requires separate collection of the organic waste fraction
- generally very space demanding and time consuming
- can cause some nuisance to adjacent areas due to occasional odour development
- high quality demands can pose problems to the marketing of the compost

APPLICATION DETAILS

TECHNICAL SCHEME

The input used for composting should be a source-separated organic waste free of disturbing and harmful components as otherwise an elution and transfer of hazardous substances during the biodegradation process into the end product cannot be excluded. Mechanical pre-treatment before the composting can improve the quality of the input further but *does not* provide a way to generate a fraction from mixed household waste that is suitable to meet the requirements and safety standards for agriculturally usable composting products.

Mechanical pre-treatment can consist of the steps

- (ii) Separation of foreign matter and contaminants
- (iii) Size reduction
- (iv) Metal separation

These mechanical pre-treatment steps are basically the same as applied in the mechanical-biological waste treatment and are therefore further described in the factsheet supplied on this particular technique (see fact sheet on "Mechanical-biological waste treatment").

Mechanical pre-treatment can also be used to attain the optimum structure and C/N ratio in the composting input by combining various organic wastes. For example, leaves (high in carbon, low in nitrogen) can be blended with food waste (high in nitrogen) to balance the C/N ratio. In this way, emissions of ammonia can be minimized right from the beginning of the rotting. Bulking agents can be added to the input if it lacks the structure to maintain adequate porosity within the compost pile.

Basically, two different technical arrangements for composting can be distinguished:

- open air (windrow) composting
- encapsulated or box composting systems

Principal differences of these arrangements are listed in the following table:

Table 3: Advantages and disadvantages of open and box composting

	Open air composting systems	Encapsulated or box composting systems
Advantages	- low capital requirements - low running costs	- optimal process control - emissions well captured - shorter rotting periods
Disadvantages	- more frequent problems with the emission of odors - longer rotting periods - without additional measures highly dependent from the local climate/weather conditions	- more capital intensive

Open windrow composting

The material for composting is set up in windrows of different size and shape. Bucket or wheel loaders are normally used to build high windrows whereas turning machines create low and wide windrows. Windrows are set up with heights between 1.80 to 3.00 m depending on the shape. Most common are windrows with a triangular, trapezoid and flat-top profile. The composting process differs in dependence from the applied method of aeration whereas the windrows can be static or physically turned either on a regular basis or when required based on temperature and oxygen requirements. Depending on the applied model about 10–60 weeks are needed for the entire rotting process to be completed.

The arrangements for windrow composting can be of the following type:

Table 4: Variants of the open windrow composting

Static method or arrangement		Dynamic method or arrangement
Passive Aeration	Active aeration	
		
Aeration due to natural heating-up (chimney-effect)	aeration with the help of air blower and piping system	aeration by way of regular turning and mixing

Typical particle sizes should be approximately 1 cm for windrow composting with forced aeration and 5 cm in case of passive aeration methods.

Figure 9: Example of an actively aerated, dynamic composting arrangement with frequent turning of the windrows (Picture source: INTECUS GmbH)

Windrows are typically used for large quantities which can require a lot of space. In addition, windrows can have odour problems and leachate concerns. Covering open windrows with a semipermeable, water-proof layer or foil (e.g. GoreTex®) is a proven way in areas facing extreme climatic conditions.

Encapsulated systems

Composting in encapsulated systems means composting in a closed environment with minimised thermal exchange with the atmosphere and various methods of aeration and mechanical turning to control the process. These systems are designed to minimize odours and process time by controlling airflow, temperature, and oxygen concentration.

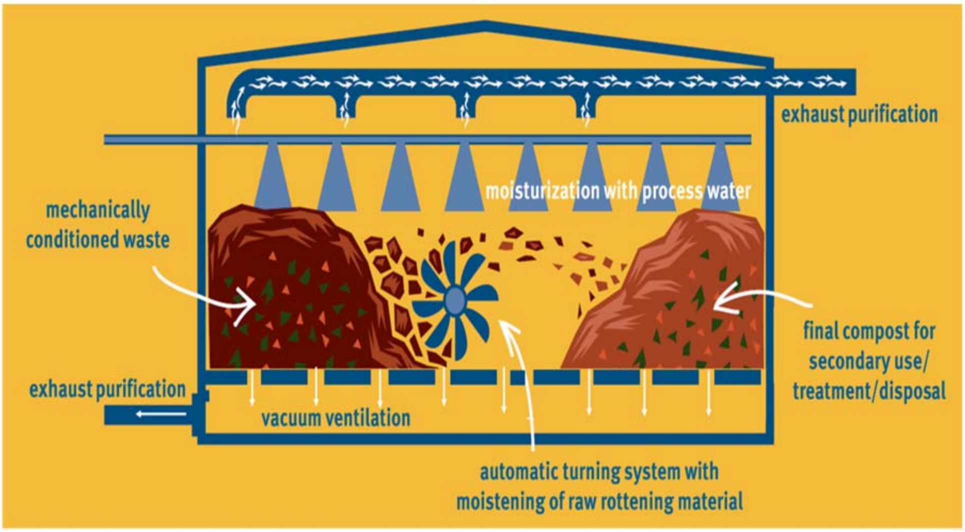
Encapsulated systems make it possible to collect gaseous emissions, odours and particulates. The active aeration, watering and mixing enable control and optimization of the rotting process, thus considerably accelerating the main biodegradation phase. Composting in encapsulated systems is more strictly divided into an intensive rotting and a maturing stage. The completion of the composting process lasts only 2 to 5 weeks for the pre-rotting, plus 7 to 26 weeks of secondary rotting.

The initial investment can be high and handling volumes are typically lower than in open windrow composting. The encapsulated composting systems can be divided into two major categories: plug flow and dynamic. A plug flow system operates on the first-in, first-out principle, whereas a dynamic system mixes the material mechanically throughout the process.

The following arrangements are common:

– *Bay composting*

Figure 10: Technical arrangement of a bay composting with trapezoid windrows (Component design according to Linde KCA)

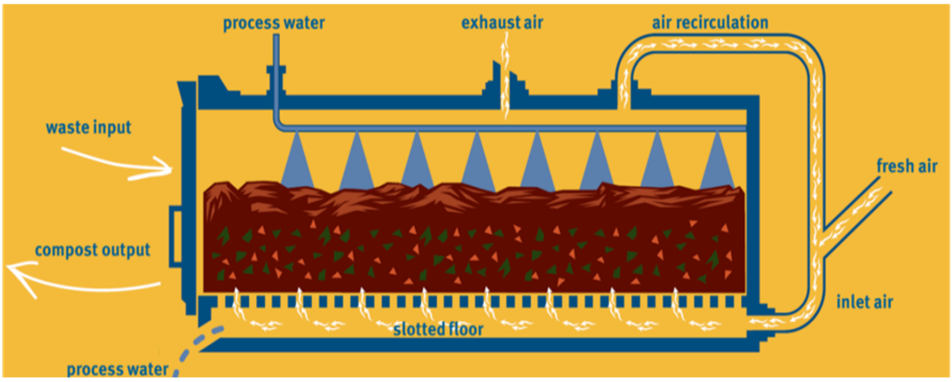


In this arrangement the advantages of a closed system are combined with windrow composting methods. In fully automated rotting bays, the organic materials are (mostly) piled into tabular heaps, force-ventilated, and automatically turned by a turning unit. The material is watered as necessary from sprayer systems set up atop the heaps or during the turning process. A perforated floor space allows the heaps to be vacuum ventilated, the exhaust air is passing through bio filters to avoid odour nuisances. In the course of rotting, the waste "wanders" from the input end to the output end of the bay. From there, it is forwarded to curing in order to become a mature compost.

– *Tunnel composting*

Tunnel reactors works similar to an enclosed bay system. The rotting takes place in fully enclosed tunnels with the waste being continuously moved through the tunnel where it is aerated and watered with respect to the achieved degree of rotting. Perforations in the floor provide for aeration, the moisture content is regulated via nozzles Exhaust air can be optimally collected and treated.

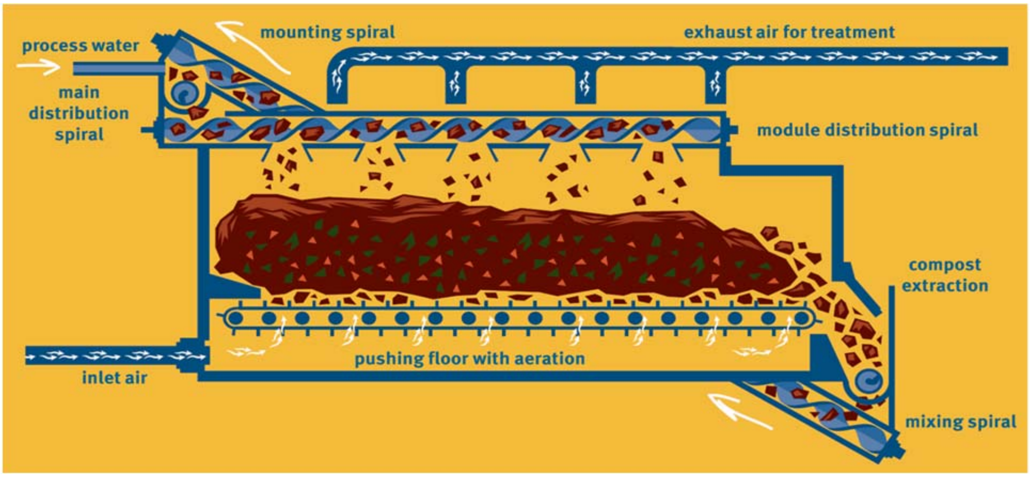
Figure 11: Technical arrangement of a tunnel composting (Component design according to Linde KCA)



– *Rotting boxes/ Rotting containers*

Rotting boxes are made out of reinforced concrete or steel. They are operated in a batch mode with a stationary or a driveable perforated floor. For controlled aeration air can be introduced via the floor and sucked off from the box from where it goes to treatment.

Figure 12: Technical arrangement of rotting box or container (Component design according to Linde KCA)

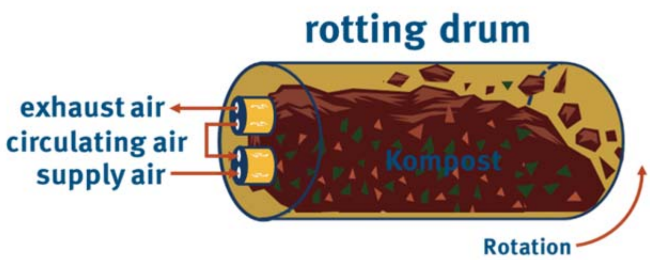


Similar to tunnel composting, intensive rotting is completed after 8 to 10 days. The rotting material tends to dry easily (this effect is specially used for biological stabilisation in the frame of mechanical-biological treatment schemes (see also fact sheet on "Mechanical-biological waste treatment").

– *In-vessel composting/composting drums*

In-vessel systems use perforated barrels or drums which can be easily turned. These drums are highly suitable for the pre-rotting as a good homogenization and mechanical disintegration can take place. However several moving parts on it lead to high wear. As such, the drums should be preferably be used for relatively short time pre-rotting. As rather simple installations drum composting can be specially suitable for small-scale applications.

Figure 13: Design and operation of a rotting drum



	Windrow composting and composting in encapsulated systems are often done in combination. Whereas encapsulated systems are best suited for the intensive rotting of the inputmaterial, open windrow composting can be well applied for secondary rotting and maturing.
QUANTITY ASPECTS	Input: - 100% biodegradable waste Output: - 10–20% screening residues from input - 35–40% finished compost product (the remaining 40–55% is the loss of weight as result of the biodegradation process and evaporation of water and from gas emissions) [15]
SCALE OF APPLICATION	The capacity of composting installations varies vastly, minimum throughput can be as low as 300 Mg/a, whereas the upper range of throughput is at around 100,000 Mg/a. Most plants in Germany have a throughput capacity between 3,000 and 10,000 Mg per year. Tunnel composting usually has a higher throughput than container composting. Tunnel composting can become economically viable with an input from about 3,000 Mg per annum. A single rotting box may have a capacity between 50 and 250m³, aerated rotting drums capacities in the range from 20 to 150 m³.
INTEROPERABILITY	Composting can be a preceding step to waste disposal operations and is then part of a mechanical-biological treatment operation (see also fact sheet on "Mechanical-biological waste treatment"). Most preferable is to establish composting as part of an integrated waste management concept which comprise of separate collection and various activities for material recovery and recycling. Compost that can be utilized as a fertilizer in agriculture and home gardens can only be obtained from biodegradable waste components separated at source!
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- Intensive rotting systems have an energy demand in the range from 15-65 kWh/Mg, whereby mechanical pre-treatment usually takes about 10 kWh/Mg. An active aeration normally causes the highest demand in energy, otherwise it is only mechanical processing which consumes a significant amount of energy, depending on the required intensity of pre-treatment this step takes for example 2–15 kWh/Mg. - The aerobic decomposition generates 0.6-0.8 g water and 25.1 kJ thermal energy per gram of organic matter.
CO_2-BALANCE	- Significant emissions of CO_2 and other (greenhouse) gases occur during the biological treatment, however, unlike in incineration or with untreated waste on landfills carbon is to a larger extent also bound for a long term in the stabilised organic material and wont thus get released into the atmosphere
AIDS/ADDITIVES NEEDED	- No other than specified
HUMAN RESOURCES	The demand on labour force depends largely from the capacity of the installation. The demand of an average plant size in Germany is about 10 persons (1 foreman, 6–8 personnel for operations/maintenance, 1 for gate control/sale). Integrating a mechanical pre-treatment, especially with manual sorting, requires a larger workforce.
SPATIAL NEEDS	The space demand for installations with an intensive rotting is in the range of 0.2–0.3 m² per Mg and year.

[15] LUBW: Composting plants for treating municipal organic and green wastes – A compilation of the installations in the State of Baden Wurttemberg (orginal title: Kompostierungsanlagen zur Behandlung von kommunalen Bio- und Grünabfällen – Erhebung des Anlagenbestandes in Baden Württemberg), July 2015

	Open systems do have a considerably higher space demand which is mainly determined by the windrow type, the windrow dimension and the applied turning method. For example a triangular shaped windrow with a basis width of 3 m requires 1.40 m²/m³. If handled without a self-propelled turning machine, the space requirements may go down to 1 m²/m³. A windrow of trapezoid shape with a basis width of 10 m and a height of 3 m requires 0.45 m²/m³. The available space often determines which arrangement/windrow type will be used. The space demand for the operations area can be broken down as follows. - 5% receipt area - 10 % storage area for compost - 10 % temporary storage are - 75 % rotting area (of which 40% are reserved for movements of equipment)
AFTERCARE DEMANDS	Aftercare measures respectively subsequent treatment must be applied on excess liquor (e.g. taken to waste water treatment) and screening residues from the process.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	The main part of the investment comprises the following positions - Costs for area purchase and development: depending from local conditions, planned capacity and technical arrangement Further must be considered capital expenses in the following minimum range (price level of 2008) - Constructional elements: 70 to 100 EUR/Mg*a costs to pave the surface of the rotting area may reach 20–45 EUR/m²; costs for a simple roof atop the rotting area may reach 70–90 EUR/m² - Machinery: 110–140 EUR/Mg*a (with purchase price of a simple turning aggregate starting at approx. EUR 2,000)
OPERATING COSTS	Are incurred for - Daily operations (consumption of fuel/electricity, insurances etc.) The minimum costs for the turning operations are -0.25 EUR/m³ if done with a turning aggregate hauled by a tractor -0.40 EUR/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) In the overall[16] for - Open windrow composting: 35 EUR/Mg *(www.kompost.de)* - Encapsulated composting: 65 EUR/Mg *(www.kompost.de)*
POSSIBLE PROCEEDS	- From the sale of the compost product
MASS SPECIFIC OVERALL COSTS	- In the range from 30–70 EUR/Mg Composting of biowaste from households generally results in higher costs (50-70 EUR/Mg) as compared to green waste (30–50 EUR/Mg). Unlike in other waste treatment plants no significant degression in the specific costs can be observed with an increasing plant size. This is because construction expenses grow almost proportional with the throughput capacity in such simple installations.

[16] H&K aktuell 03/10, p. 1-4

OTHER RELEVANT ASPECTS

Composting shall be applied under consideration of the international compost standards (such as those developed and described by the European Compost-Network ECN or in Germany by the Federal Association for Quality Assurance of Compost-BGK) in order to ensure that a safe end product is being generated.

MISCELLANEOUS

MARKET INFORMATION

REFERENCE FACILITIES

(Note: the list of sites and/or firms does not constitute a complete compilation)

Installations and applications for biowaste composting exist everywhere in the world. Germany counted 915 composting plants in the year 2010. The arrangements used by these plants for the main rotting phase was of the following division:

Table 5: Methods resp. technical arrangements used for rotting and at the composting plants in Germany (Data source: UBA: Handbuch Bioabfallbehandlung)

Container/Box	Tunnel	Trapezoid windrow	Triangular windrow	Semipermeable cover	Other forms
13 %	9 %	40 %	26 %	4 %	8 %

Examples for such facilities are:

- Humuswirtschaft Kaditz GmbH, Dresden www.humuswirtschaft.de
- Kompostwerk Hellefelder Höhe GmbH, Sundern www.kompostwerk-online.de
- Kompostwerk Olpe GmbH, Olpe www.oez-olpe.de

RECOGNIZED PRODUCER AND PROVIDER FIRMS

(Note: the list of firms does not constitute a complete compilation of companies)

Recognized producer/provider firms for components or turnkey solutions for organic waste composting are for example:

Screening, shreeding, turning equipment/air treatment systems

- Komptech Vertriebsgesellschaft Deutschland mbH, Oelde www.komptech.de
- BACKHUS GmbH, Wardenburg www.eggersmann-recyclingtechnology.com/backhus
- Doppstadt GmbH, Calbe www.doppstadt.com
- Jenz GmbH, Petershagen www.jenz.de
- Biosal Anlagenbau GmbH, Bad Lausick www.biosal.de
- EuRec Technology Sales & Distribution GmbH, Merkers www.eurec-technology.com
- J.Willibald GmbH, Wald-Sentenhart www.willibald-gmbh.de

Turnkey installations:

- Strabag Umweltanlagen GmbH (former Linde-KCA), Dresden www.strabag-umweltanlagen.com
- Komptech Vertriebsgesellschaft Deutschland mbH, Oelde www.komptech.de

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

Relevant **organisations** and contact points for **further information** about the production and use of quality compost from waste are:

- Bundesgütegemeinschaft Kompost e.V. www.kompost.de
- Arbeitskreis für die Nutzbarmachung von Siedlungsabfällen (ANS) e.V. www.ans-ev.de
- Verbände der Humus- und Erdenwirtschaft www.vhe.de
- European Compost Network ECN www.compostnetwork.info

ANAEROBIC DIGESTION

APPLICATION OBJECTIVE	- Treatment of organic wastes, sewage sludge and waste water with very high COD[17] - Reduction of the content of biodegradable organics and reactivity of the specified wastes - Energy recovery from waste

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	X
Paper / paperboard		Mixed household waste	X[18]	Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste	X	source separated waste such as catering waste, institutional and commercial food wastes, grease separation waste, manure, abattoir and agro-industrial by-products, slaughterhouse waste (after pressure-sterilization), yard and market waste			
Other waste material	X	sewage sludge, biological sludge generated by an earlier aerobic treatment, organic solids			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
The waste input should be collected separately and freed from disturbing components such as bulky parts. A comminution to obtain the required particle size may have to be performed. For specific waste (e.g. slaughterhouse waste) a pathogen elimination/hygienization might become necessary.

Options for the utilisation of the generated output:
Organic and mineral digestion residues must be drained. Where these residues originate solely from a digestion input of separately collected biodegradable waste the material can be used like compost following its hygienization or treatment in a composting process. A direct application onto farmland can be possible when certain conditions are fulfilled, in several countries this is generally permitted. Dried digestion residues are also energetically used in a number of cases.

Options for the disposal of process output and/or residues:
Other residues from digestion such as foils separated during screening have to be treated with other (e.g. thermal) processes.

Aftercare requirements:
The liquid portion of the digestion residues usually contains all dissolved substances and some particular matter concentrations which is why a further treatment is normally required, for example by way of handing the said amount over to a local waste water treatment facility.

Protective needs:
The exhaust air (especially in the receiving area and from mechanical processing) must be collected and treated, in addition technical and organizational measures for the avoidance and minimisation of emissions (odors in particular) have to be undertaken.

[17] COD = chemical oxygen demand

[18] in particular for the organic-rich fine fraction of this waste before a landfill disposal

Potential health risks:
Especially in the receiving area and mechanical processing a higher risk of air contaminations with germs and spores must be observed. Technical and personal protection measures (wearing of mouth masks) in these places are highly recommended to avoid potential health risks.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
Installations should be placed in accessible locations with a connection to the electric grid and preferably close to the places where the respective wastes are generated. Some distance to the nearest residential dwelling should be kept although smaller distances as compared to most of the alternative facilities for biodegradable waste treatment are possible

Climatic conditions:
No restrictions apply but digestion reactors may have to be insulated and heated in colder climates (especially where thermophilic processes are applied), the technology is however *not recommendable* in places with extreme shortage of water

Suitable financing mechanism:
Financing can be through a fee charged in conjunction with the delivery of the waste to the treatment facility or the collection via the corresponding collection system (separate biowaste container). Alternatively the costs can be incorporated into the charges or specific fee for general waste collection services or recovered over other flat rate mechanisms for waste management financing. Proceeds from the sale of generated electricity mark a source of income except of the electricity which is used for own purposes and reduces this way the operating costs of the respective plant.

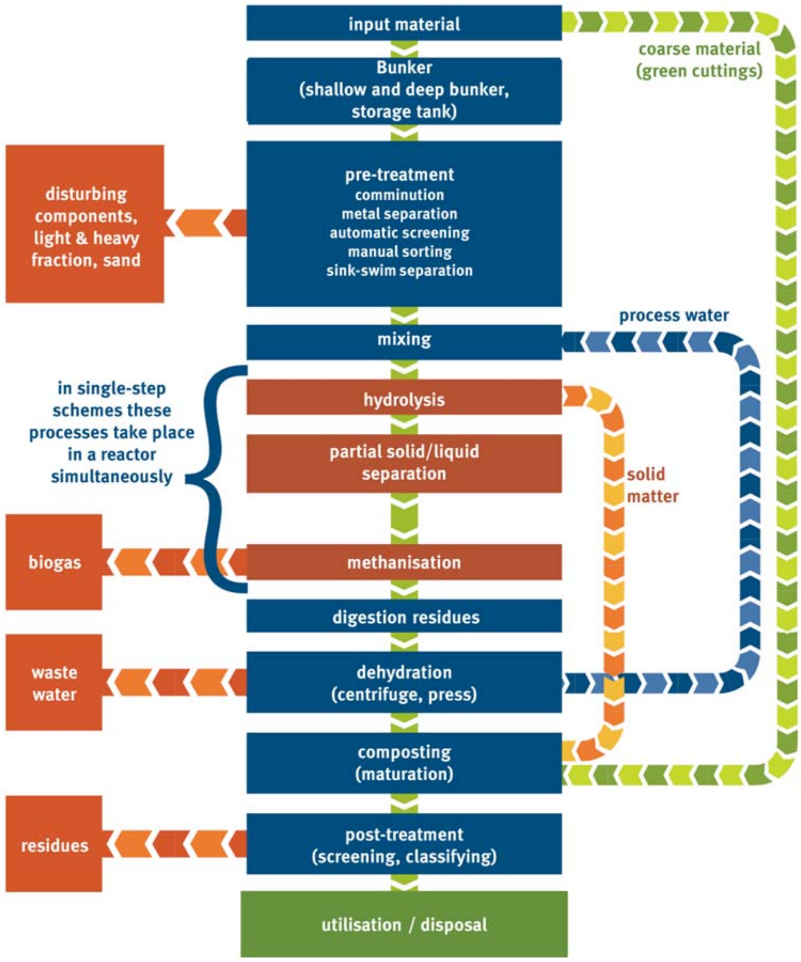
TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	Anaerobic digestion involves the gradual bacterial decomposition of organic waste material in the (relative) absence of oxygen to methane, carbon dioxide and water. This is in contrast with the process of aerobic biodegradation. Principal objectives of the process is to lower the biological activity, mass and reaction potential of the waste and to produce biogas which can be used as an energy source.
BASIC REQUIREMENTS	- Balanced composition of nutrients and process feeding to maximise biogas/ methane production - High moisture content - Absence of components that would impair process and process milieu
EXPECTED RESULTS	- Biogas to be used as a biofuel or directly for energy production *In the case of a digestion of separately collected organic waste:* - semi-solid residues (50–300 kg dry substance/Mg input) which need further treatment, normally through composting, to produce a marketable end-product for use in agriculture and landscaping *In the case of a digestion of organic-rich mixed residual waste or sewage sludge:* - a considerable lower output amount as compared to the input quantity with significantly reduced biological reactivity thus making landfill disposal after an additional rottening possible *In the case of an anaerobic waste water treatment:* - small quantities of excess sludge and surplus liquor (100–600 l/Mg input), which may provide a liquid fertilizer when dewatered or can be sent to a waste water treatment plant

SPECIFIC ADVANTAGES	- in addition to dry organic waste, moist constituents like catering waste and waste from food processing and farming can also be handled. - the biogas obtained can be used for producing electricity and heat and therefore to also generate income or to cover the treatment process' own demand on energy - the fermented substrate to some extend can be utilized in liquid or dry condition. - the technical installations takes up relatively little space. - the waste quantities to be handled by incineration plants and/or sanitary landfills and the emissions/impact they consequently cause to the environment will be lowered
SPECIFIC DISADVANTAGES	- the technology is relatively complex, the costs for construction and operation consequently can differ significantly and be quite high, depending also on the employed plant model. - an additional demand on water might arise - the process' inability to degrade lignin and cellulose pose a principal limit to the efficiency of anaerobic digestion, especially when woody biomass is present - the process is prone to disturbances and therefore requires tight control procedures which in turn demand the operating staff to have sufficient know-how (which is not very widely available yet) so as to be able to undertake appropriate adjustments and interventions quickly and whenever required to save the process from a collapse - the technology is relatively new and still expensive so that despite possible revenues from the production of energy and fertilizers the cost balance is often not neutral - Post treatment, storage and utilization of the digestion residues can be sources of significant emissions of methane, ammoniak and odors and thus a nuisance and threat to climate
APPLICATION DETAILS	
TECHNICAL SCHEME	The primary variables of the process are the method of bringing the waste in contact with the microbes, the composition and moisture content of the input (e.g. liquid, slurry or solid), and the method and degree of circulation. Anaerobic digestion generally involves the following stages: **<u>Pre-treatment:</u>** In general, source separated organic waste makes the handling much easier than organic rich waste mixtures. However, even a source-separated input material will typically require further separation to remove unwanted impurities, such as plastics, metals and oversized components. Separation can be carried out under wet or dry conditions. Following this, a further process of size reduction is used to create a more homogenous material, which enhances fermentation and facilitates processing. For the separation and size-reduction, techniques and installations can be used which are also known from the processing of the waste input to mechanical-biological waste treatment (see also fact sheet on "<u>Mechanical-biological waste treatment</u>"). **<u>Digestion:</u>** There are a number of different techniques used to effect digestion. They are usually distinguished on the basis of the operating temperature and the percentage of dry matter in the feedstock. - thermophilic plants operate at around 55°C (50–65°C), - mesophilic ones at around 35°C (20–45°C). - dry systems work with 20–40 %, wet systems with 5-20 % dry matter content. Generally speaking the higher the temperature, the faster the process, but thermophilic process may be harder to control and will need more biogas for heating to keep them at the required temperature. Dry systems are generally single-step systems. Single-step plants are not so prone to interferences like multi-step processes, but the production of biogas is lower. The following Figure depicts a general scheme applicable to single and double-step systems, for both dry and wet processes.

Figure 14: The process flows for single-step and multi-step waste digestion techniques



Some technical specifics of the different process configurations are listed below:

Wet single-step

Solid waste is slurried with the process water to provide a diluted feedstock (with a dry matter content at about 15 %) for feeding into a mixing tank digester. The process can be used for MSW on its own, but the wet process lends itself to co-digestion with diluted feedstock, such as animal manure and organic industrial waste. The high water content in the prepared suspension allows heavy material to settle and light material to float.

The suspended waste without heavy or light material is feed in a single step fermenter (37–40 °C; mesophilic conditions). The retention time is 15 to 20 days. Biogas is generated (65 % CH_4). The substrate is thoroughly mixed by biogas pressing. Fermented waste is discharged, sterilised at 70 °C and dewatered to 50 % dry matter. The drained water is being used as internal process water.

Wet multi-step

Solid waste is slurried and fermented by hydrolytic and fermentative bacteria to release volatile fatty acids which are then converted to biogas in a high-rate industrial waste water anaerobic digester. Basically, the hydrolysis and methanisation step take place consecutively in two different reactors. The system lends itself to the digestion of MSW and to the wet organic waste from food processors.

Multi-step plants are more prone to interferences as in comparison to single-step processes, but the production of biogas is higher.

The following picture shows a possible configuration of a wet digestion scheme.

Figure 15: Technical scheme for a multi-step wet digestion process (component arrangement according to Linde-KCA)

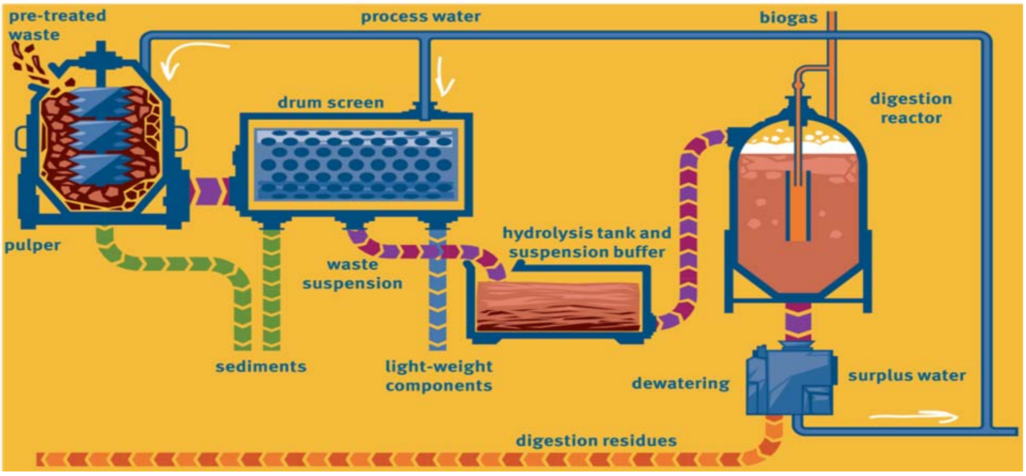


Figure 16: Real life images of key components in German plants operating a wet digestion of waste (left hand picture: Digestion reactors, Picture source: Tim Hermann; right hand picture: pre-treatment section, Picture source: INTECUS GmbH)

Dry processes

It is not always necessary but often the case that the input material is mixed with internal process water or sludge to obtain a dry matter content of 30 to 35 % before digesting. The fermentation takes place in a fermenter at 37–40°C (mesophilic conditions) or at 55–60°C (thermophilic conditions). Disturbing matter should be removed from the input before it is taken to these vessels. An additional separation of impurities from the digestion residues can be done after the anaerobic treatment. The retention time in the vessels/reactor lasts from 12 to 20 days. The remains from digestion are discharged and dewatered to 50 % dry matter. The drained water is used as internal process water. The solid matter is then taken to an additional rottening and curing under aerobic conditions for several months.

Dry continuous mode

The digestion vessel is continuously fed with a shredded and homogenized input material with a dry matter content of 20–40 %. Process water is sprayed over to inoculate the material. In both mixed and plug-flow variants, the heat balance is favourable for thermophilic digestion.

Dry batch mode

A batch is inoculated with digestate from another reactor and left to digest naturally. Leachate is re-circulated to maintain moisture content and to redistribute methane bacteria throughout the vessel.

Sequencing batch

Essentially a variant of the dry batch process, in which leachate is exchanged between established and new batches to facilitate start up, inoculation and removal of the volatile materials from the active reactor. After digestion becomes established, the digester is uncoupled from the established batch and coupled to a new batch in another vessel.

QUANTITY ASPECTS	- The anaerobic digestion process leads to a production of methane, with a theoretical methane production of 348 Nm^3/Mg of COD. Anaerobic digestion in general produces 80-140 Nm^3 biogas per Mg of organic municipal waste processed. - Biogas generation is very sensitive to the feedstock, typical is a composition in the following range: 50–75 Vol.-% methane, 25–45 Vol.-% carbon dioxide, 2–7 Vol.-% water, 20–20,000 ppm hydrogen sulphide, ‹ 2 Vol.-% nitrogen, ‹ 2 Vol.-% oxygen, ‹ 2 Vol.-% hydrogen. - The overall mass flow (in German plants) can be described as follows[19]: *Input:* 100% biowaste comprising -65% water -23% dry organic matter -12% dry inorganic matter *Output:* 5% residues from pre-treatment (sand, stones, foils etc.) 11% biogas 29% waste water 55% residues after digestion/solid output
SCALE OF APPLICATION	- The majority of installations stays in a capacity range between 500 and 80,000 Mg waste input per year
INTEROPERABILITY	In practice the following technical arrangements are common: - Anaerobic digestion makes up the biological stage in a mechanical-biological treatment process (see the fact sheet on "Mechanical-biological waste treatment") - Anaerobic digestion is taking place with a subsequent composting process for the post treatment of the digestion residues. The digestion residues can be separated into a solid and a liquid fraction, whereby the liquid residue of appropriate quality might be directly utilized in form of a liquid fertilizer whilst the solid material is further processed into a compost (see the fact sheet on "Composting"). - Anaerobic digestion is coupled with a waste water treatment facility or an integrated part of the treatment system for waste water.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- The electricity and heat which is needed to heat up the digester vessels and for the other installations is usually won from the process itself in that the generated biogas is burnt in a cogeneration unit. Own demand can make up from 5% up to approx. 60% of total production depending on various factors, inter alia, the process technology employed. Figures on energy production and own consumption per Mg of input for different process configurations are shown below in

[19] Rosenwinkel, Kroiss, Dichtl, Seyfried, Weiland (editors): Anaerobtechnik – Abwasser-, Schlamm- und Restoffbehandlung, Biogasgewinnung (3rd ed.), Springer Verlag, 2015, p. 726

Table 6: Systematic comparison of electricity production and consumption figures in the main different schemes of anaerobic digestion processes in relation to the digestion input (Data source: Final report of funded research project, no. 03KB022: Steigerung der Energieeffizienz in der Verwertung biogener Reststoffe)

Process mode			Electricity production (kWh/Mg)	Electricity consumption (kWh/Mg)
Wet process	single step	mesophilic	235	71
		thermophilic	310	71
	multi step	mesophilic	274	71
		thermophilic	N/A	N/A
Dry process	continuous	mesophilic	241	48
		thermophilic	271	48
	discontinuous	mesophilic	186	23
		thermophilic	194	23

CO_2-BALANCE

- The process itself is enclosed and atmospheric emissions should therefore hardly take place except during transfer to and from the digester. Investigations have however shown that a so called methane slip occurs (losses of methane through microscopic cracks and leakage in technical components) in the range of up to 5% of total methane production.
- Important positive climatic effects of anaerobic digestion arise from the:
  - avoidance of methane emissions from landfill disposal of untreated organic waste
  - reduced emissions due to energy substitution and lower demand on fossil fuels

AIDS/ADDITIVES NEEDED

Water: 50–200 l per Mg of waste

Auxiliary materials, to which may belong

- flocculants such as iron chloride solution or such of anionic polymeric nature
- anti-foaming products
- pH-regulating agents

HUMAN RESOURCES

- Running a digestion facility requires specially qualified personnel in particular for the facility management and operations control. Depending on the kind of process and size of the plant the personnel requirement starts in the minimum with 3 skilled staff.

SPATIAL NEEDS

Table 7: Space requirements without area for the post-rottenting of the digestion residues (Data source : UBA Texte 43/2010: Aufwand und Nutzen einer optimierten Bioabfallverwertung hinsichtlich Energieeffizienz)

Plant capacity	20,000 Mg/a	40,000 Mg/a	Space per Mg/a
Wet fermentation	4,500-5,000 m²	6,000-8,000 m²	0.15-0.25 m²
Dry fermentation - continuous	4,000-5,500 m²	5,000-6,000 m²	0.125-0.275 m²
Dry fermentation - discontinuous	2,500-3,000 m²	5,000 m²	0.125-0.2 m²

AFTERCARE DEMANDS

- Aftercare for the stabilized digestion residues dumped at landfills must be an integrated part of the landfill management procedures. However, the rejects from screening and digestion can normally be incorporated into composting or the utilization in other (e.g. thermal) processes is possible.

OPERATIONAL BENCHMARKS: COST DIMENSIONS

INVESTMENT COSTS

Table 8: Investment needs for different types digestion technology
(Data source : UBA Texte 43/2010: Aufwand und Nutzen einer optimierten Bioabfallverwertung hinsichtlich Energieeffizienz)

	Dry fermentation - discontinuous	Dry fermentation - continuous	Wet fermentation	Partial-flow fermentation
Investment costs at 20,000 Mg input /a	150 – 310 EUR/Mg	250 – 480 EUR/Mg	260 – 490 EUR/Mg	40 – 100 EUR/Mg

- Reduced input amounts let the specific costs rise due to fixed cost positions (degressive cost curve). The digestion process is still relatively expensive also for larger sized plants hence there is often no neutral cost balance despite possible revenues from the production of energy and fertilizers.

OPERATING COSTS

Table 9: Operating expenses at plants with different types digestion technology
(Data source : UBA Texte 43/2010: Aufwand und Nutzen einer optimierten Bioabfallverwertung hinsichtlich Energieeffizienz)

	Dry fermentation - discontinuous	Dry fermentation - continuous	Wet fermentation	Partial-flow fermentation
Operating costs at 20,000 Mg input /a	15–30 EUR/Mg	18–38 EUR/Mg	20–50 EUR/Mg	5–15 EUR/Mg

- Reduced input amounts let the specific costs rise due to fixed cost positions (degressive cost curve).
- Repair and Maintenance: 4–6 % of the investment costs per year

POSSIBLE PROCEEDS

- The monetary energy yield is in the range from 20 to 30 EUR per Mg of waste input. With this, 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.

MASS SPECIFIC OVERALL COSTS

- N/A

OTHER RELEVANT ASPECTS

- The co-fermentation of bio waste substrates in the anaerobic digestion towers of waste water treatment plants is gaining momentum and is meanwhile an option that more and more plants consider and some already put into practice (see the fact sheet on "Sewage sludge management"). It is for both, economic and logistical reasons an attractive and technically feasible solution

MISCELLANEOUS

MARKET INFORMATION

REFERENCE FACILITIES

(Note: the list of sites and/or firms does not constitute a complete compilation)

Digestion techniques are used everywhere in the world. Aside from the many facilities for the sole digestion of agricultural matter in Germany there are plants for the digestion of bio waste in a larger number as well. Their number is increasing. Reference facilities in Germany are for example:

- Biogas plant of the Bioverwertungsgesellschaft Radeberg mbH www.bvr-radeberg.de
- Biogas & composting plant Bützberg of the Company for city cleansing (Stadtreinigung) Hamburg www.stadtreinigung.hamburg/kompostwerk
- Biogas plant Berlin-Ruheleben of the Company for city cleansing (Stadtreinigung) Berlin https://www.bsr.de/biogasanlage-22250.php
- Biogas & composting plants in Gütersloh and Saerbeck

RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Recognized producer firms for digestion technology and plant providers for the digestion of biowaste are for example: - Strabag Umweltanlagen GmbH, Dresden www.strabag-umweltanlagen.com - HAASE Energietechnik AG, Neumünster http://www.bmf-haase.de/ - Schmack Biogas AG, Schwandorf www.schmack-biogas.com - FARMATIC Anlagenbau GmbH, Nortorf www.farmatic.de - Biotechnische Abfallverwertung GmbH & Co KG, München www.bta-technologie.de - Eggersmann GmbH, Marienfeld www.eggersmann-recyclingtechnology.com/en/ - BEKON Energy, Unterföhring www.bekon-energy.de

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

Relevant organisations and sources for **further information** on the digestion of municipal waste fractions are:

- Fachverband Biogas e.V. www.biogas.org
- Arbeitskreis für die Nutzbarmachung von Siedlungsabfällen (ANS) e.V. www.ans-ev.de
- Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung (ASA) e.V. www.asa-ev.de

MECHANICAL-BIOLOGICAL WASTE TREATMENT/STABILISATION

APPLICATION OBJECTIVE	Mechanical biological waste treatment (MBT) is applied on mixed, organic/carbon rich waste with the aim to achieve - a stabilisation and minimisation of the risk potential together with a significant weight and volume reduction thru 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, recover recyclable materials and improve the suitability for subsequent treatment processes.

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper / paperboard		Mixed household waste	X	Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood	X[20]	C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste	X	as far as they comprise biodegradable material and do not contain dangerous components or contaminations			
Other waste material	X	any biodegradable material of non-hazardous nature			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material: not required.

Options for the utilisation of the generated output:
Separated metals are returned to metal production, the high calorific material fractions can be processed and used as refuse-derived fuel (RDF) for energy recovery (see also the fact sheet on "Industrial co-incineration").
Following appropriate treatment such as an additional screening or biological stabilisation, rotting residues may also be used as landfill cover and for site remediation purposes.

Options for the disposal of process output and/or residues:
The biologically treated and stabilised material can be safely landfilled or incinerated.

Aftercare requirements:
Reduction and aftercare measures should be applied to the emissions which occur during treatment (exhaust air, wastewater). Aftercare in the frame of the usual procedures of landfill aftercare is also required in conjunction with the disposal of the process residues on landfills.

Protective needs:
Exhaust air and wastewater have to be collected and appropriately treated to protect the environment from the negative impacts that may otherwise cause to it, in addition technical and organizational measures for the avoidance and minimisation of emissions and nuisances (odours in particular) have to be undertaken. Particular precaution is required to prevent overheating and self-ignition of the waste, intense fire protection is a must.

Potential health risks:
Within the processing chain a higher risk of air contaminations with germs and spores must be observed, especially where non-encapsulated processes are taking place. Technical and personal protection measures (wearing of mouth masks) in the exposed places are highly recommended to avoid potential health risks.

[20] in small quantities only, e.g. residues from sorting without contaminations of dangerous nature, generally wood recycling or the utilisation in special energy generating facilities should be preferred

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
MBT facilities can basically be set up in any places; it will be an advantage however to erect them at locations that have access to the road and transportation network and close to the places where the relevant wastes are generated or where process residuals will be deposited. As with any treatment facility for mixed, organic rich waste, a minimum distance to the nearest residential area should be maintained to avoid any potential nuisances by odours, rodents or other unwanted vermine.

Climatic conditions:
MBT facilities can be operated under any climatic conditions provided that specific local constrains are considered in the technical settings. Exposure to temperature or moisture extremes puts some limitations to the employment of open rotting techniques for the biological treatment. Simple coverage by semipermeable membranes can be a solution, however. Insulation and/or additional heating systems might be applied to run anaerobic digestion reactors for the biological treatment under such temperature extremes.

Employment potentials:
MBT offers good opportunities for the employment of both, unskilled and higher qualified personnel.

TECHNICAL DETAILS

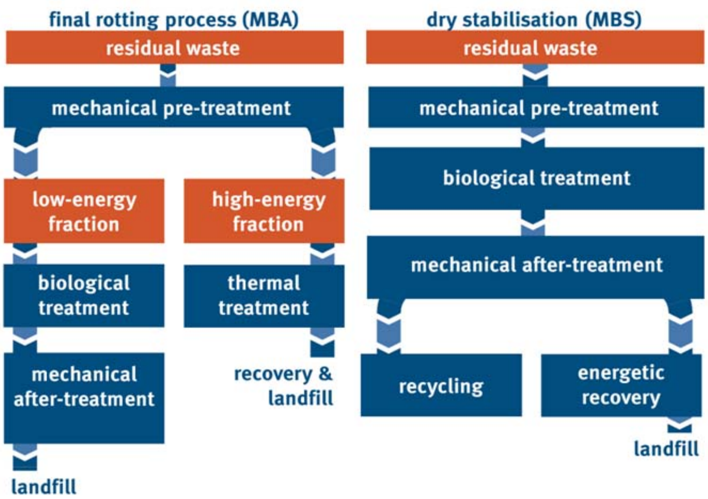
GENERAL OVERVIEW

ABSTRACT

Mechanical biological treatment comprises a combination of mechanical and biological processes that further treat mixed residual waste before disposal. The aim of this combination is to minimise the environmental impacts of deposited waste 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 and a core biological treatment. Integrated systems have been developed that combine the two 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 and can even function without any additional collection infrastructure, means they are also suited to the unsegregated household waste stream.

The main distinction between the different concepts is made on the basis of the order of the technical processes and the aim of the biological treatment. The differences lie either in a “splitting” of the waste prior to the biological treatment (so as to obtain a high calorific fraction suitable for energy generation and a low calorific fraction undergoing a final rotting before landfill disposal) or a “dry stabilisation” of the entire waste with subsequent processing.

Figure 17: Simplified schemes to distinguish the basic concepts for mechanical-biological treatment (modified illustration based on a graphic provided by Nelles, Morascheck, Grünes)



	In "splitting" (or mechanical-biological treatment = **MBT**), a derived fraction of material is treated biologically. The core biological process used in such system can be anaerobic digestion or composting or elements of both. When anaerobic digestion is used, the process is usually configured to optimise biogas production. When composting is the core technology to biologically treat the derived waste material, no biogas is produced and the rotting process used to convert the mixed waste into stabilised matter for landfill disposal. In "dry stabilisation" (or mechanical-biological stabilisation = **MBS**) the entire waste is subject to a drying process facilitated by heat generated during biodegradation. In subsequent steps recyclables and refuse derived fuel (RDF) are won from the stabilised material, meaning that only the residuals are landfilled. Principal objective of the treatment is to generate a material which can be used for energy recovery or further processed by gasification.
BASIC REQUIREMENTS	- Input must be an organic rich solid waste without hazardous components - A certain standard of emission control and treatment and other protective measures (preferably fixed in a specific regulation) should be guaranteed - Power supply
EXPECTED RESULTS	Output: - High-calorific coarse material (MBT) or combustible dry stabilate (MBS) - Stabilised rotting material (MBT) or fine fraction (MBS) that can be deposited on landfills - Recyclable materials (mainly metals) - Process residues, dust, liquor and exhaust air Quality requirements for the output: - Material which has undergone mechanical-biological treatment should be marked by a low moisture content and respiration index value when deposited at landfills (coming from biological treatment material moisture level is usually <50% and the respiration index value less than 40 mg /kg dry matter – the German landfill ordinance requires the respiration index value AT4 to be below 5 mg/kg dry matter for materials accepted at landfills). - The liquor from anaerobic digestion processes shall be suitably treated to comply with the requirements for safe release into surface waters (e.g. Directive 91/271/EEC)
SPECIFIC ADVANTAGES	- reduces the volume and reaction potential of waste that must go to landfills and therewith the landfill void space taken, the emissions of gas, leachate and odour at the landfill site - combines material specific treatment and material recovery and generates various material fractions for further use - allows for energy recovery (from generated RDF and/or from biogas generated in biological processes) - simple and little capital intensive installations can be possible
SPECIFIC DISADVANTAGES	- for the parts of the waste not completely mineralized during the process further aftercare or treatment measures must be applied, including continued aftercare for the landfills - incomplete exploitation of the energy content of the waste
APPLICATION DETAILS	
TECHNICAL SCHEME	The core technology used in any mechanical-biological waste treatment is the biological process. Biological processes can only treat the biodegradable fraction of the MSW, however. Depending on the final disposal option and the material quality they require, mechanical processes of different intensity do either precede the biological treatment stage in order to separate the non-biodegradable (recyclable/combustible) from the biodegradable material (MBS), or they follow the biological treatment and further process the output so that a use as substitute fuel or other utilisations become possible (MBS). *Mechanical treatment* Mechanical treatment usually consists of several mechanical operations. They are adapted to or applied to change the physical properties and composition of the waste input in order to facilitate its further processing and valuable materials to be possibly recovered. The minimum technical requirements for an efficient treatment comprise of installations for:

- storage and feeding
- removal of disturbing material and contaminants
- size reduction

A mechanical treatment prior to the biological stage (MBT scheme) can have the following process features:

i. Storage and feeding installations

Flat or deep bunkers are used to store the delivered waste. Flat bunkers allow disturbing bulky materials to be roughly separated by grabbing with wheel loaders or special gripper equipment. Apart from that, the delivered waste can be easily controlled any problematic deliveries can be rejected from treatment if necessary. Storing different fractions separately (e.g. dry commercial waste, bulky waste, and wet household waste) is rather easy in flat bunkers. Flat bunkers are cheaper than deep bunkers, but need more area.

In deep bunkers the waste can easily be mixed. It is however difficult to sort disturbing materials out of bulky and commercial waste in these bunkers. Deep bunkers are especially suited to store wet household waste. All dry waste should be stored in flat bunkers. Flat bunkers in this case are more suitable for combined mechanical-biological waste treatment processes.

ii. Separation of foreign matter and contaminants

In case a flat bunker is available the disturbing bulky materials[1)] can be separated quite easily with a special gripper equipment (e.g. grap dredger) or wheel loader. Other disturbing materials[2)] are separated at the feeding units or on the conveyor belt. In case of the dry bulky and commercial waste, a manual separation of disturbing materials in aerated cabins is acceptable. Due to potential health risks for the workers, such procedures are not applicable to wet household waste. Here separation by a grab dredger is the only suitable solution.

iii. Size reduction

To make packed materials accessible to further processing, generate a more homogenous waste mix and increases the reaction surface, screening of the waste and a size reduction of the overflow are undertaken. As size reduction is the most energy consuming step in the mechanical treatment process, applications only to the bulky parts of waste are also known. Bulky and commercial waste must at least be pre-shredded before reaching subsequent processes. For pre-shredding (up to a size between 250-500 mm) shearing units (rotors and in some cases guillotine shearing units), shredder and screw crusher are used. The main shredding (100 to 250mm) is done with rotor shear crushers, shredders and cascade mills. Fine shredding (‹ 25mm) is performed with cutting and hammer mills.

Additional steps/equipment for the mechanical pre-treatment may include:

iv. Metal separation

Large-sized metal parts are separated at the storage area, whereas small parts remain in the waste. Small iron parts are collected from overhead magnets from the waste stream passing through on a conveyor belt. Due to the easy removal and good recycling potential, metal separation should always be part of the process design.

v. Separation of non-ferrous metals

Also possible is the separation of non-ferrous metal, preferably from the material flow ‹ 80 mm. Usable non-ferrous metals can be sold for high prices.

vi. Separation of the overflow by screening

Where substantial amounts of plastics and wood are in the waste, a separation can be useful together with paper/cardboard in a sieving drum. Screening at a mesh size of about 100 to 150 mm usually generates a high calorific fraction (paper/cardboard, plastics and wood) in the overflow. In the screening pass flow the biodegradable waste material is concentrated.

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1) e.g. mattresses, container boxes, larger concrete or metal parts

2) e.g. containers, big plastic foils, ropes, cables, tyres, accumulators, furniture parts

An overflow that will be used to generate refuse derived fuel (RDF) need to be shredded and possibly conditioned and compacted in subsequent operations.

vii. *Separation of light and heavy fractions by classification*

A classification, for example with the help of an air classifier, to separate the high calorific fraction is less important than the screening, although with air classifying glass and stones may be discharged.

viii. *Separation by sorting*

Where dry waste contains a high amount of recyclable materials (applies mostly to commercial, C&D and bulky waste), a manual separation can be appropriate. Sorting stages are often attached to screening operations. Air classification helps segregating the waste mix and generates a separate RDF-fraction.

ix. *Further comminution*

In order to use the high calorific fraction as a fuel (see the fact sheet on "Industrial co-incineration") a further comminution is often done. High-speed crusher giver the best results here. Such installations can chop the material into pieces of 60-80 mm in size. For further comminution the waste has to be pelletised first which is very expensive.

x. *Baling*

For better storage and transportation of recovered recyclables and generated RDF-fractions (mostly consisting of plastics and paper) a press is often used for compaction/baling.

In a MBS-scheme with mechanical processing after biological stabilisation, the mechanical process comprise mainly of the steps:

- metal separation (iv),
- screening to separate the mineral fine fraction (vi),
- comminution (ix) and pelletising.

Before the biological process a separation of disturbing matter and size reduction may be necessary.

Biological treatment

Different technologies are applied for the biological treatment. Usually these are either intensive rotting/composting or anaerobic digestion methods. They are detailed in separate factsheets, namely these are the fact sheets on "Composting" and "Anaerobic digestion". Only major adjustments of these methods towards the realisation of a mechanical-biological waste treatment will be explained here.

As ***MBT-schemes*** are concerned, they are as follows:

Rotting method

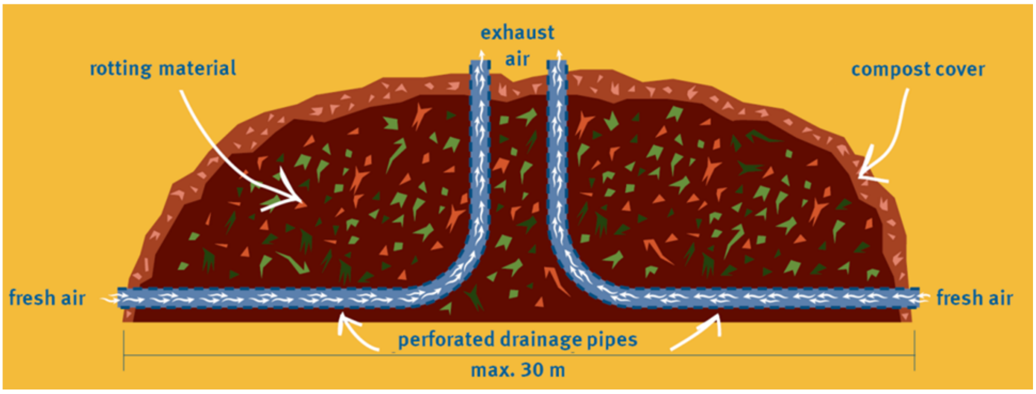
As in composting, static and dynamic methods can be used for the rotting of waste. *Static techniques* are the simplest methods for rotting. In this case the material is not turned during the process of biological degradation. For this the homogenized waste is piled into simple rotting heaps, triangle-shaped or flat-top windrows. The waste heaps are kept on an impermeable ground to avoid contamination of the ground water, proper ventilation must however be ensured to keep the heaps rotting in an aerobic state.

A simple practical method and one that already suits in areas with moderate requirements on exhaust air treatment (less fierce than is the case in Germany by now) is the Chimney draught process. In this process the perforated drainage pipes are laid tangential to the windrows. The distance between the pipes is about 3 to 4 m. The outlets of drainage pipes are laid chimney-like in the middle of the windrows. Through the biological self-heating of the rotting materials an air stream is produced. It provides for an oxygen flow through the digested material. A semipermeable cover membrane can help to keep the water content at the required level. Through the static operation 2.5 m high flat top windrows are possible.

A bio filter which consists of wood chips or already stabilised organic material or compost is spread on the top of each pile. It helps in reducing the emission of harmful substances and odour development.

In the heaps the biologically active material partly decomposes to CO_2, water and humic substances, water evaporates and leaves a biologically inactive substrate. Rotting without turning the material and without technical aid for aeration and irrigation is only used for the passively aerated biological post rotting (open air post rotting). To use the technique for the main rotting, an actively aerated method with control of water content and oxygen supply should be adopted.

Figure 18: Chimney draught process of Spillmann/ Collins



Another static method is that of *rotting boxes and containers*.

The rotting boxes are made out of reinforced concrete or steel. They have a driveable perforated bottom. They are operated in a batch mode. The boxes are supplied with air from the perforated bottom, and exhaust air is then sucked on top of the rotting material for further treatment. The intensive rotting is completed after 8 to 10 days. The technology is simple and more durable. However, rotting boxes require an input which has been intensively mechanically pre-treated. Also the rotting material tends to dry easily.

As *dynamic or quasi-dynamic methods*, rotting drums, tunnel reactors and windrow techniques with regular turning can be applied (see fact sheet on "Composting"). These suites best for the intensive rotting of the waste.

Intensive rotting technologies are the choice to implement MBS-schemes. They are applied on the entire input stream in order to biologically dry and sterilise the material and to produce in this way an output which is largely suitable for thermal treatment and combustion processes. Given the unsorted input and the high rate of emissions and leachate it produces in the early phase of treatment, fully encapsulated systems are used for the rotting process.

The calorific composition of the output material will be relatively high as both the liquid content is being reduced thru biological degradation and non-combustible materials (e.g. metals and inert materials) are separated afterwards. The calorific value of the so derived RDF type material can range between 12-16MJ/kg dependent on waste input and achieved moisture levels. There is much scope for different ways of recovering the energy from this material. These range from RDF-type combustion or co-incineration through to gasification. Most suitable is a co-incineration in an industrial plant which can readily handle fuels with higher calorific values (see fact sheets on "Industrial co-incineration")

Anaerobic digestion method

Not applicable for MBS but another option to realise the biological stage in a MBT-scheme is the method of Anaerobic digestion.

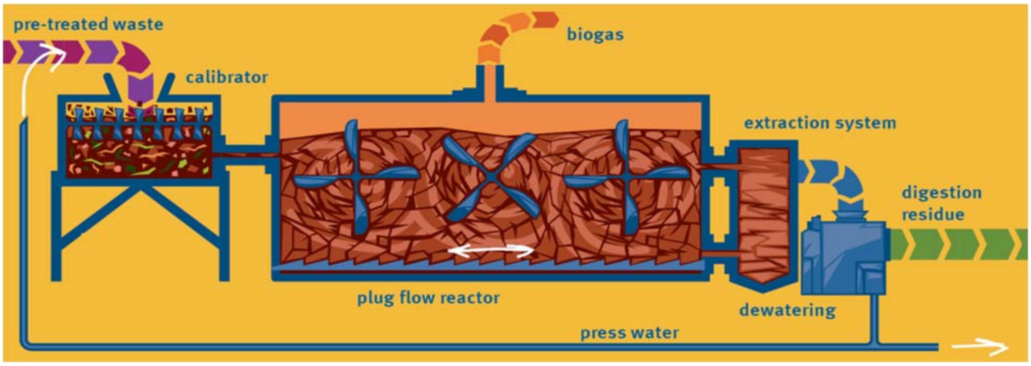
When anaerobic digestion is incorporated into the MBT, the process is usually configured to optimise biogas production. However, in some instances the technology has been configured to optimise the production of biogas and RDF. In the anaerobic digestion process biological degradation takes place in closed reactors without air supply. A difference can be made between wet and dry processes. Both process schemes are described in a separate factsheet (see the fact sheet on "Anaerobic digestion").

Because of the inhomogeneity of the input material (sediments on the one hand and fibrous components on the other hand) the dry single-step process is considered as one of the most suitable treatment methods (see Figure 3).

Advantages of the dry digestion process are:

- lower water demand
- because of the higher dry matter content sedimenting components are better integrated in the digestion material than in the wet processes.

Figure 19: Technical scheme of a dry process for anaerobic digestion (component configuration according to Linde-KCA plug flow scheme)



Digestion processes are completed after about 18–21 days and the remains dewatered in a press. The solid matter can then be further cured by composting and deposited at landfills whereas the waste water has to undergo further treatment. Due to the high COD, expensive methods for the treatment of the waste water have to be employed, however.

The treatment of residual waste by anaerobic digestion also causes specific requirements concerning equipment, personnel and plant safety. Evacuating the biogas from digestion containers operated in batch mode must be done with utmost care to avoid explosive mixtures to develop. In plug- flow operated plants corrosion-provoking compounds (e.g. chlorine, sulphur, acids) and abrasive components (e.g. minerals, metals) contribute to higher wear.

The typical problems of the treatment of residual waste by anaerobic digestion can be minimized with the following technical solutions:

- use of biogas nozzles instead of agitators (in wet process) to circulate the feedstock in the digesting vessel, this helps minimizing surface scums and wrappings on the agitators,
- prior segregation (e.g. ballistic classifier) and discharge of heavy components (sedimenting materials) and light materials (e.g. textiles and foils to avoid wrapping, occlusions and surface scum),
- adjusting to a dry matter content of 20–40 % before digestion (eliminating a demixing in the vessel), or
- a washing of the fine fraction that has been obtained after the mechanical pre-treatment to remove light materials, sand and other abrasive materials such as glass from the feedstock. The remaining material which consists mainly of biodegradable substances can be digested then in a wet process.

Generally it is necessary that exhaust air from MBT and MBS be collected and treated. Depending on the applied biological processes, the air stream and the legal provisions suitable solutions can range from simple biofilters up to processes involving the so-called regenerative thermal oxidation (RTO). Thermal processes have the advantage that organic compounds are significantly reduced. A disadvantage is the energy demand (especially if no biogas is generated in the plant itself) and the fact that the technology has still high maintenance needs.

QUANTITY ASPECTS

Input:
- 100% MSW
- water (if digestion is applied for biological treatment)

Output (taking the average waste composition in Europe as a reference):
- 2–5 % disturbing material
- 2–4 % metals (Fe and non-ferrous)
- 30–45 % high calorific material suitable for RDF production

45–65 % fine fraction subject to biological degradation

of which: 10–25% of weight get lost due to biodegradation
up to 20% of weight get lost as water
5% are converted to biogas
30–50% remain to be landfilled.

The changed order of separation and biological activity in MBS-schemes improves the recovery of non-degradable materials and therefore leads to a reduced amount of residues going to landfill.

SCALE OF APPLICATION

Mechanical-biological treatment installations operate in the following range:
- Minimum throughput: 25,000 tons/a (with simple rotting method)
- Minimum throughput: 60,000 tons/a (with anaerobic digestion)
- Upper range of throughput: 300,000 tons/a

INTEROPERABILITY

Mechanical-biological waste treatment is a complementary measure to waste disposal operations and permits the recovery of waste materials for recycling and the processing of waste in order to avail of more beneficial ways for their disposal (e.g. RDF generation). The process can thus be well combined with any other waste disposal operations above all the possibility to integrate it as a pre-treatment stage on landfills.

OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION

ENERGY BALANCE

- The overall energy demand lies between 20–70 kWh/t whereby mechanical pre-treatment normally takes the greatest share with about 10–30 kWh/t.

Table 10: Comparison of the energy consumption of different process options (source: Nagel, Nachhaltige Verfahrenstechnik, 2015)

Utility	MBT (rotting techniques)	MBT (anaerobic digestion)	MBS
Electricity	45 kWh/Mg	65 kWh/Mg	100 kWh/Mg
Heat	0	Self supply	0
Gas (share needed for RTO)	41 (39) kWh/Mg	58 (45) kWh/Mg	25 (25) kWh/Mg

MBT schemes with an integrated anaerobic digestion generate approx. 70–170 m³ biogas per Mg $_{\text{waste input to digester}}$

CO_2-BALANCE

- Studies to assess the environmental impact suggest that the landfill disposal of waste stabilized by mechanical-biological treatment results in the formation of only 10% of the landfill gases and 10 % of the leachate that a disposal of untreated waste would have caused.
- Using closed systems (box reactors/halls and systems with a purification of the exhaust air) for the biological treatment stage helps significantly to minimize GHG emissions and such to escape uncontrolled to the atmosphere.

AIDS/ADDITIVES NEEDED

- No other than specified

HUMAN RESOURCES

The demand on labour force depends largely from the capacity of the plant. The average requirements are similar to that of composting installations (see also fact sheet on “Composting”). Integrating manual sorting stages naturally requires a larger workforce.

For rather complex process arrangements specially trained and qualified staff is needed to take care for the facility management and operations control.

SPATIAL NEEDS

The minimum space demand depends from the planned treatment capacity. However, the need of additional space can be very low if the treatment is integrated into the operations of landfills. In that case it comprises the area where the windrows or rotting boxes are set up. Practically the figures provided for composting and anaerobic digestion could be used (see the fact sheets on "Composting" and "Anaerobic digestion").

OPERATIONAL BENCHMARKS: COST DIMENSIONS

INVESTMENT COSTS

The investment comprises in the main of the following cost 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 (price references as of the year 2008):

mechanical stage: constructional parts incl. storage bunker:40 EUR/Mg*a
stationary machinery: 20–80 EUR/ Mg*a
mobile equipment (vehicles): 5–10 EUR/ Mg*a

biological stage:

- rotting method: constructional parts: 70 to 90 EUR/t*a
stationary machinery: 110–140 EUR/ t*a

- anaerobic digestion: constructional parts: 50 to 60 EUR/t*a
stationary machinery: 130–180 EUR/ t*a

Overall estimates for the capital needs of complete MBT installations are in a range from EUR 12 million for a facility of 50,000 Mg per annum to EUR 40 million for 220,000 Mg/a. Very simple MBT process installations for developing countries were investigated to cost a total of EUR 15-20 per Mg input (Source: GTZ, Sektorvorhaben Mechanisch-biologische Abfallbehandlung, 2003)

OPERATING COSTS

Running costs are incurred for

- Personnel (depending on the local labour market)
- 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. wheel loader): 8–15% of the initial investment

The higher wear in digesting mixed residual waste results in higher costs for repair and maintenance of MBT installations with an anaerobic digestion as compared to digestion systems using pure biowaste.

A cost example (net costs) for a plant with an annual throughput capacity of 150,000 Mg is provided in the table below.

Table 11: Running costs EUR/Mg (source: Morgenstern: Restabfallentsorgung in Deutschland, Econum GmbH)

Cost position	Overall costs EUR/Mg	incl. variable share EUR/Mg
Personnel	6	
Repair, Maintenance	9	5
Energy, Fuels	7	7
Insurances and others	6	
RDF supply and transport (related to 50% of input)	30	30
Transport/landfill disposal residues (20% of input)	5	5
Transport/disposal other materials (7% of input)	5	5
Transport/disposal metals (3% of input)	-3	-3
Depreciation and capital services	25	
Total	90	48

POSSIBLE PROCEEDS	- Sale of recovered material, particularly metals. - supplying RDF to the market and generating revenues this way is a highly uncertain procedure, in general no positive revenues are made up to this moment.
MASS SPECIFIC OVERALL COSTS	- In the range of EUR 40–120 per Mg only for the treatment operations (possible proceeds and/or costs for the disposal of residues and supply of RDF to the incinerating industries not included). Lower waste volumes requiring landfill disposal on the other hand means a saving of costs, another benefit not expressed in monetary terms is longer landfill lifetime.
OTHER RELEVANT ASPECTS	
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	The technology has strongly evolved during the past two decades. Today, there are over 100 plants operating in Europe using some form of mechanical biological treatment on residual wastes. Germany alone has about 50 plants operating above a capacity of 20,000 Mg/a. The average capacity of such plant is 100,000 Mg/a, configurations up to 300,000 Mg annual throughput exist. Almost all large waste management providers undertake waste processing at different scale with this technology or have shares in operating plants doing such treatment. Reference facilities in Germany are for example: - MEAB mbH, Schöneiche www.meab.de - Zweckverband Abfallwirtschaft Saale-Orla, Pößneck www.zaso-online.de - MBA Lübeck www.entsorgung.luebeck.de/ueber_uns/unsere_anlagen/mba.html - MBA Neumünster GmbH, Neumünster www.mba-nms.de - WEV GmbH, Großpösna www.e-wev.de Large-scale applications which were established and set in operation under the integration of know-how or technical components from Germany can be found in many EU-countries and their neighborhood, inter alia in Italy, Bulgaria, Portugal, France, Finland or Croatia.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	MBT technology in the past has been delivered by a vast array of producers and partial equipment providers in Germany. Meanwhile the number of firms engaging in turnkey solutions for MBT plants has decreased whereas many firms have specialized in providing components suitable for MBT solutions, such as *Shreeder/comminutor:* - HAMMEL Recyclingtechnik GmbH, Bad Salzungen www.hammel.de *Separators, classifier:* - EuRec Technology GmbH, Merkers www.eurec-technology.com - Mogensen GmbH & Co. KG, Wedel www.mogensen.de - Spaleck – Förder- und Separiertechnik www.spaleck.de *Metal separators (Fe, non-Fe):* - Steinert Elektromagnetbau GmbH, Köln www.steinertglobal.com - IMRO Maschinenbau GmbH, Uffenheim www.imro-maschinenbau.de - Wagner Magnete GmbH & Co. KG Spann- und Umwelttechnik, Heimertingen www.wagner-magnete.de *Air treatment systems:* - LTB Lufttechnik Bayreuth GmbH & Co. KG, Goldkronach www.ltb.de - Dürr Systems GmbH Environmental and Energy Systems, Stuttgart www.durr-cleantechnology.com/de The overall planning is done by specialised planning bureaus or the plant operators who often care for the complete erection of the facilities too. Recognized providers in the area of turnkey solutions are for example:

	- Strabag Umweltanlagen GmbH, Dresden www.strabag-umweltanlagen.com - Komptech Vertriebsgesellschaft Deutschland mbH, Oelde www.komptech.de - HAASE Energietechnik AG, Neumünster www.bmf-haase.de - Herhof GmbH (Tochtergesellschaft der Helector S.A). www.herhof.com - AMB Anlagen Maschinen Bau GmbH, Oschersleben www.amb-group.de Providers of plant concepts and components for more simple dry stabilization techniques are: - CONVAERO GmbH www.convaero.com - W.L. Gore & Associates GmbH www.gore.com/de_de/

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

Relevant organizations and contact points for further information about the application of MBT and the technical requirements are:

- Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung: www.asa-ev.de
- Arbeitskreis für die Nutzbarmachung von Siedlungsabfälle: www.ans-ev.de
- Gütegemeinschaft Sekundärbrennstoffe und Recyclingholz e.V.: www.bgs-ev.de
- Fachverband Biogas e.V. www.biogas.org

SOLAR DRYING (PARTICULARLY IN RELATION TO SEWAGE SLUDGE)

APPLICATION OBJECTIVE	- to reduce the mass and volume and increase the calorific value of sewage sludge (in exceptional cases also of other waste material with high moisture content) in preparation to a possible thermal utilisation or before its further disposal

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	X[21]
Paper / paperboard		Mixed household waste		Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood	X[1]	C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material	X	Sewage sludge			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
A homogenous structure and high specific surface of the waste material are essential for an effective drying process. The plant input should therefore undergo homogenisation and large lumps and pieces must be comminuted.

Options for the utilisation of the generated output: most especially thermal utilisation.

Options for the disposal of process output and/or residues:
Incineration shall be the preferred method since common criteria for save landfill disposal (such as those prescribed in the German landfill ordinance – DepV) still cannot be met after this treatment. However, aside from the drying of the material there will also a biodegradation taking place through which the biological activity and reactivity of the waste will be reduced.

Aftercare requirements: usual aftercare is needed on landfills where sludge and process residues are deposited

Protective needs:
For the solar drying process exhaust air treatment is not normally required (location and capacity of the drying plant however must be duly taken into consideration). Odour development should be observed and smell reduction measures undertaken as appropriate. Leachate water will be evaporated and not accumulate in liquid form. All the foresaid goes under the provision that the solar drying is done in a (at least partly) encapsulated glass construction and on a sealed ground.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
Given the fact that for a solar drying the waste input must be spread in a rather thin layer on the ground, an area of considerable size will be needed for setting up the drying facility. A good accessibility and connections to the transportation network (roads) must be available for the delivery of the input and pickup of the dried material. The integration of the installation into a larger waste treatment facility (e.g. waste water purification plant and/or thermal treatment plant) is highly advisable.

[21] Only prunings, other woody biomass or process residues with an unfavorable moisture content for a subsequent utilization (in particular the use in thermal processes for energy recovery)

Climatic conditions:
For the effectiveness of solar drying processes are specially relevant:
- sunshine intensity and duration
- moisture saturation and temperature level of the ambient air.

It is not advisable to plan the solar drying of waste in areas where the conditions in both the above points are rather unfavourable. Air flow and moisture content of the input need to be considered as influencing factors, too.

Suitable financing mechanism:
Financing should be ensured through fees which are charged for deliveries of sludge to the treatment plant, also the collected waste water charges must incorporate the costs for the treatment of the sludge including drying.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	Solar drying is employed to achieve a reduction of the mass and volume of moist waste material, especially sewage sludge, before its further disposal. Water is evaporated thus also the calorific value of such material in preparation to a possible thermal utilisation increased. Solar radiation as a freely available energy source is predominantly used for the drying process. The drying is taking place in transparent, semi closed glass constructions, the design of which supports the heating and air circulation. The driving force of drying is the difference between the partial vapour pressure inside the waste and the ambient air. The warmer the air the more water vapour can be transported. To intensify the drying, the material is regularly loosened and turned by special devices.
BASIC REQUIREMENTS	- suitable climatic conditions (especially as sunshine intensity and duration are concerned) - transparent glass construction (shelter or walled construction) - technical devices for loosening and turning
EXPECTED RESULTS	depending on the kind and properties of the input and the climatic conditions - average evaporation rate (in Europe, according to FISCHLI 2004) up to 1000 kg/m² drying area - optimal drying result: approx. 70 % dry matter content - theoretically achievable drying result: >90 % dry matter content
SPECIFIC ADVANTAGES	- low specific energy demand - no additional energy input required (especially when operations are stopped in winter season) - simple and durable technology
SPECIFIC DISADVANTAGES	- low drying efficiency in terms of time required - high space demands - little experience with large facilities, those operating do have rather small capacities until now

APPLICATION DETAILS

TECHNICAL SCHEME	Through the solar energy entering the drying hall ambient air and the surface of the waste material are warmed up. The temperature rise forces the water to leave the material. The air gets saturated with the evaporated water and has therefore to be evacuated. A chimney effect which is produced by an open glass construction and motor driven roof ventilation flaps accelerates air circulation. However, while the surface of the waste dries up this way, the lower parts remain moist, and have to be turned. For this a turning and conveying machine is employed. Devices that have a radial velocity which is higher than the advancing speed may move the input material automatically from one end of the drying bed to the other by each run. This produces an automatic transportation of the material through the drying hall whereas appropriate equipment such as conveyor belts or shovel loaders must be used for setting up the bed.

An auxiliary heating system may be additionally installed (or needed in winter season) to speed up the drying process. An alternative to the continuous flow arrangement is to operate in a batch-mode. Here another type of turning equipment can be used.

Figure 20: Scheme for the batch mode drying concept (as offered by the Thermo-System Industrie- und Trocknungstechnik GmbH; Note that the integration of an additional heating system as shown in this picture is needed in the cold season only)

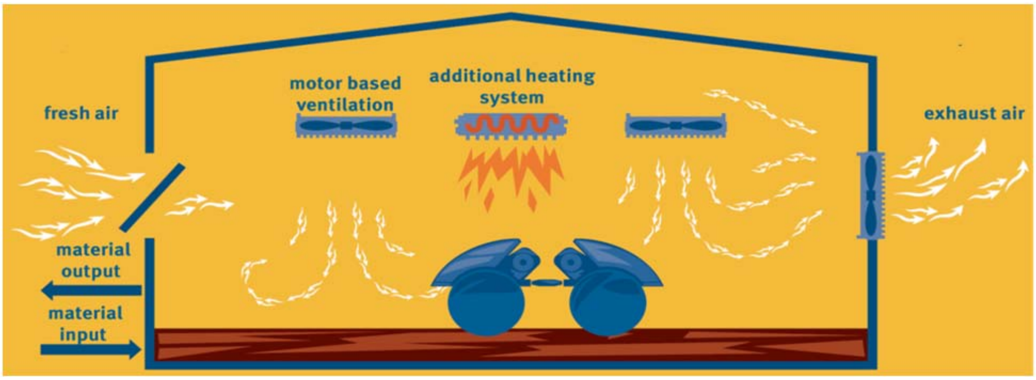
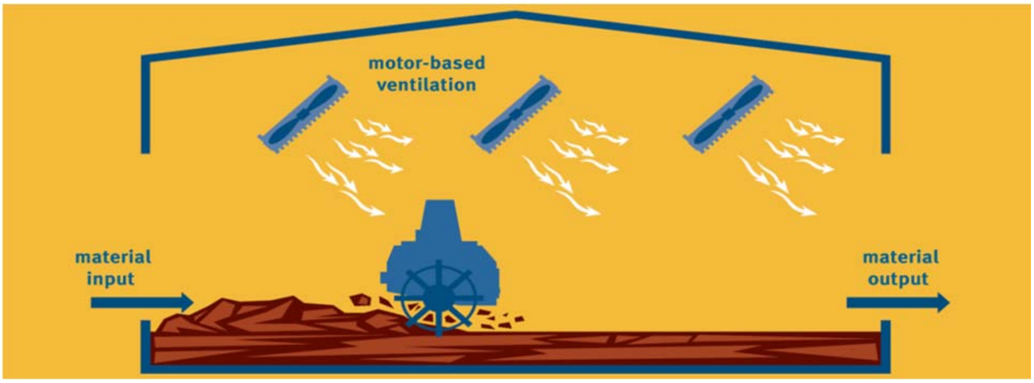


Figure 21: Scheme for the concept of a continuous flow drying (as offered by the IST-Anlagenbau)



QUANTITY ASPECTS

Input: (arbitrary example)
- liquid sludge with 1–10 % dry matter content
- pre-drained sludge 10–40 % dry matter content (usually ›20 %)

Output:
- Material with 50-90 % dry matter content but generally little carbon loss by biodegradation

SCALE OF APPLICATION

- so far applied at larger technical scale for the drying of liquid sludge and pre-drained sludge at throughput rates between 300–15,000 Mg per annum
- also applied for timber drying
- implementation at larger scale might also be possible for residual waste but has thus far been tested at pilot scale only

INTEROPERABILITY

Solar drying methods due to the homogenisation and increase of calorific value taking place suit well as a preceding step to thermal utilisation with energy recovery (see fact sheet on “Fluidized bed incineration”) and/or to provide a substitute fuel (see also fact sheet on “Industrial co-incineration”)

OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION

ENERGY BALANCE

- specific demand on electric energy: 10–30 kWh per ton of H_2O removed

CO_2-BALANCE

- subsequent utilisation of the biodegradable waste components as renewable energy source renders a positive CO_2-balance to this process

AIDS/ADDITIVES NEEDED	- appropriate technical equipment for the feeding and takeout of the material from the drying halls in dependence from the type and constitution of the material (e.g. shovel loader)
HUMAN RESOURCES	Drying designed as a self-running automated process has a small demand in labour force. Human Resources are needed for control and maintenance operations and to undertake feeding and takeout. Depending on the capacity, usually only a few persons can run such a plant.
SPATIAL NEEDS	In the average case an amount of 0.5–6 Mg sludge per m² drying area can be processed per annum without an additional demand on extra heat, climatic conditions determine whether a seasonal break is made in the operations
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	can vary strongly, technology provider/operators gave the following cost indices (in 2008): - without use of excess heat: approx. 250 EUR/m² drying area - with use of excess heat: approx.: 350 EUR/m² drying area
OPERATING COSTS	- approx. 15 EUR per ton of H_2O removed
POSSIBLE PROCEEDS	- from the fee which is to be paid for the waste treatment service - from a possible sale of the output as a fuel (in case that a positive price can be obtained at the market)
MASS SPECIFIC OVERALL COSTS	- strongly varying in dependence from the material to be dried, the efficiency of the drying process and the required quality of the output
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	The application of this technology shows worldwide growth, several hundred plants are already operated in Germany, Austria, Switzerland, France and in Australia. Reference facilities in Germany for example can be found in the following places: - Wasserverband Nord, Bredstedt www.wv-nord.de - Kläranlage Pocking www.pocking.de - Grünstadt, Rheinland Pfalz www.ebg-gruenstadt.de
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Provider firms for complete installations or components for the solar drying of waste in Germany are for example: - IST Anlagenbau GmbH, Kandern www.wendewolf.com - THERMO-SYSTEM Industrie- & Trocknungstechnik GmbH, Filderstadt-Bernhausen www.thermo-system.com - Hans Huber AG Maschinen- u. Anlagenbau, Berching www.huber.de

Umwelt Bundesamt

ENERGY RECOVERY FROM WASTE THROUGH INDUSTRIAL CO-INCINERATION *)

APPLICATION OBJECTIVE

- Thermal utilization of (usually processed) waste materials and mixtures of them in the form of refuse derived fuel (RDF) in industrial combustion processes to generate energy and substitute primary fuel materials

*) The cleaning of exhaust and flue gases as an integrated process and technology is covered by a separate description (see the fact sheet „Emission control – exhaust and flue gas cleaning“)

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging	X[1]	Biowaste	
Paper / paperboard	X[22]	Mixed household waste	X	Bulky waste	X[1]
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood	X[23]	C&D waste	X[1]
Waste oil	X[24]	Old paint & lacquer	X	Waste tyres	X[3]
Hazardous waste	X	partly, only materials with a medium to high calorific value, plants must have the adequate permissions			
Branch specific waste	X	suitable components with a medium to high calorific value and which have low or no concentrations of chlorine and heavy metals			
Other waste material	X	suitable components with a medium to high calorific value and which have low or no concentrations of chlorine and heavy metals, most especially sewage sludge, animal and bone meal, residues from commercial waste sorting			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:

The specific requirements/technical parameters of the co-incinerating facilities have to be observed and taken into account while preparing/processing the material for use as a fuel. Generally the waste must be processed in such a manner that certain specifications and chemo-physical properties are being attained, e.g. calorific value, moisture content, particle size, maximum chemical concentrations of certain elements-especially chlorine and heavy metals. The input material must also be freed from disturbing components such as large metal parts and should not contain any radioactive substances.

Options for the utilisation of the generated output:

Depending on the input material and incineration process different residues and output products are generated. Waste components accepted for co-incineration in cement kilns for a large part get incorporated and fully bound in the clinker. By-products of an incineration in power stations (such as fly ash, bottom ash, boiler sand, wall cladding, granule from the melting chamber and gypsum) are to the most part of mineral composition and suit for use in road construction, landscaping operations and the production of certain constructional elements. Combustion slags and part of the ashes can be deposited but also be used in other applications after pre-treatment.

Options for the disposal of process output and/or residues:

Most relevant are the residues from exhaust and flue gas cleaning, these must be safely deposited in facilities of the appropriate type (see the fact sheet on “Exhaust and flue gas cleaning“)

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[22] Recycling and the necessary sorting and mechanical processing this possibly requires shall be the preferred options for this waste. Industrial co-incineration is however a recommendable method for utilizing the high calorific residues and unsuitable components which remain after the sorting and processing, provided that an acceptable fuel quality and low heavy metal and chlorine concentrations can be ensured through additional conditioning and consistent control.

[23] Any possibilities for this waste to be recycled should be examined and, whenever possible and economically feasible, applied first, in particular if amounts of wood in a natural or widely untreated state are involved. Energy generating facilities specialized on the combustion of woody biomass are also more suited for utilizing this waste in an energetically effective manner.

[24] Any possibilities for this waste to be recycled or material used should be examined first and, whenever possible and economically feasible, preferred.

Aftercare requirements:
Residues which have to be deposited on landfills of the appropriate categories must be subject of monitoring and become part of the usual aftercare procedures applying to these landfills.

Protective needs:
Industrial facilities active in the co-incineration of waste materials and RDF must take special precautions for fire protection, especially in the areas for the storage and feeding of these fuels. Exhaust and flue gases from the incineration must be appropriately treated and cleaned. Protective measures must ensure that no health risks or any negative impacts on sensitive media such as the soil, ground water or sites of special value do occur. Guidance what measures and limits may apply is provided in other documents and fact sheets (see fact sheet on “Exhaust and flue gas cleaning“ and the document on ”Technology-related EU regulations” in particular the “Directive on industrial emissions”)

Potential health risks:
A release of untreated flue gases pose a health risk which can be avoided if contemporary cleaning techniques and protective measures as indicated in this fact sheet and in the fact sheet on “Exhaust and flue gas cleaning“ are employed and properly followed. Waste incinerators using state-of-the-art cleaning technologies are nowadays considered as not threatening human health any longer.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
The co-incineration of waste materials in an industrial combustion process is usually implemented in an established facility which implies that the necessary infrastructural conditions, like a good accessibility by road, railway or waterways already exist. However, extensions of the site might be necessary due to the need of space for the reception and storage for the additional fuel material. Erecting a incineration facility in or close to dwelling areas requires that minimum distances to the nearest buildings and other precautionary/protective measures need to be observed.

Climatic conditions:
No restrictions apply. To avail of industrial co-incineration as a way to produce energy and heat in regions with colder climates is highly advisable.

Suitable financing mechanism:
The additional investments and organizational measures that must be undertaken to realize the co-incineration of waste in an industrial combustion process can be recovered by way of a special fee that is charged on/collected from those who supply the waste-derived fuel and therefore ‘request’ the service of a thermal (waste) treatment. Additional financing can come from savings made by substituting a higher priced regular/conventional fuel or by selling surplus energy.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	Industrial co-incineration means to utilize (mostly pre-processed) waste material of defined composition and properties (so-called refuse derived fuel-RDF) as an alternative or secondary fuel to generate energy and heat in an industrial combustion facility. The facilities most suited for an industrial co-incineration are coal-fed power stations, cement kilns and specially designed installations for the mono-combustion of special RDF fractions, less often these are also brick or lime kilns and blast furnaces of the steel industry. By using RDF in the industry, energy is recovered from parts of the waste and primary energy resources can be saved. An industrial co-incineration can be realized following some slight modifications of the standard technology which has previously been used by the industrial facility for the storage and feeding of the conventional fuel. Ordinary techniques such as grate combustion (see fact sheet on “Grate combustion”) or fluidized bed technology (see fact sheet on “Fluidized bed incineration”) are used for the actual incineration step. Rotary kiln systems are still most widely seen when waste material is co-incinerated by the cement industry. Existing installations for exhaust gas cleaning can be further used and/ or must be upgraded/extended in dependence from the actual amount and composition of the RDF.

BASIC REQUIREMENTS

- waste material which is going to be used as refuse-derived fuel has to conform with certain, pre-defined physical and chemical properties, mainly mechanical treatment and separation techniques are applied to ensure this. The properties are determined by the special co-incineration process, the type of installation and the RDF quantities used or added in the process. The processing shall also make sure that the RDF produced from larger quantities of waste is of stable composition and quality. Some parameters for RDF standard qualities are shown in the following table.

Table 12: Common standards and requirements on RDF quality

Parameter	Unit	Power stations	Cement industry
Particle size	mm	10–25	approx. 30
Unwanted matter	-	stones, metals, wooden pieces, hard plastics, large sized items	
Ash content	% by weight (dry matter)	10–25	10–25
Moisture content	% by weight (dry matter)	10–25	10–25
Calorific value	MJ/kg	>18	>20
Chlorine	g/kg dry matter	5–15	<10
Heavy metal content	mg/kg dry matter	individual regulations (see RAL-GZ 724)	

EXPECTED RESULTS

Reduced need of conventional primary fuel
Output power stations:
- energy from waste
- usable inert by-products in the form of slags, ashes, boiler sand, gypsum
- exhaust/flue gases

Output cement kilns:
- with the persistent components and ashes from combustion being fixed in the material matrix of the cement, there are almost no residues left from the process

SPECIFIC ADVANTAGES

- substitutes primary energy sources (in connection with cost savings or even proceeds that can be made from using RDF)
- reduces the amount of waste for which other treatment and/or disposal options would otherwise have to be found, saves landfill space
- harmful content and reactivity of the waste is drastically lowered, partly a waste utilization without residues takes place
- costs less than the operation of a standard waste incinerator

SPECIFIC DISADVANTAGES

- may possibly alter product qualities (cement, bricks, steel slag)
- causes higher thermal stress and wear to industrial boiler and passages for exhaust gases
- faster deterioration of the installations in the result of rather aggressive corrosion, increased maintenance and risk of breakdowns for repair
- exhaust gas is partly of worse quality than that dedicated facilities for the mono incineration of waste produce, hence the installation of a bypass for critical heavy metals (such as mercury) will in future be needed in the cement industry
- produces reactive bottom ashes and slags
- requires additional investment + more complex management and control
- increased risk of production standstill due to problems caused from waste feed

APPLICATION DETAILS

TECHNICAL SCHEME

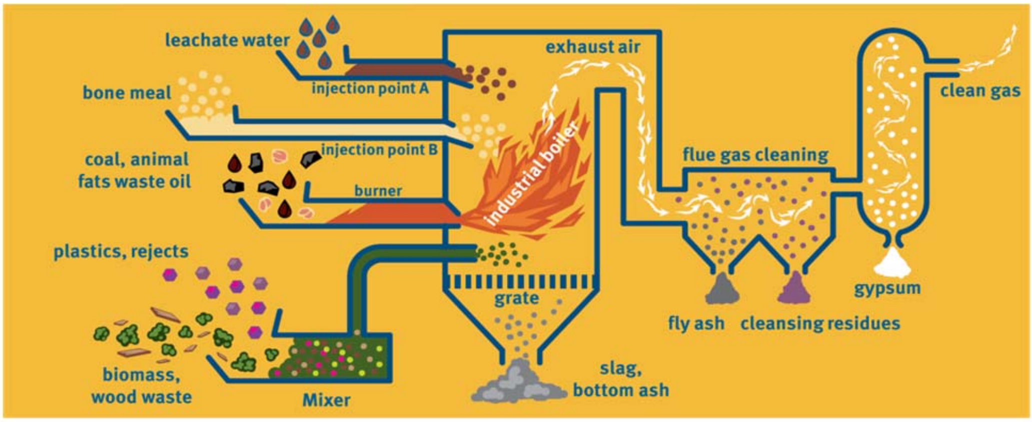
Prominent procedures for the processing of different waste materials and the options they incorporate to generate RDF are the subject of a number of separate fact sheets (see fact sheet on "Sorting and processing of bulky waste" and fact sheet on "Mechanical-biological waste treatment"). For the incineration process itself the technologies described in the separate fact sheets on grate combustion (see fact sheet on "Grate combustion") and fluidized bed combustion (see fact sheet on "Fluidized bed combustion") are of main interest.

Usually, the following arrangements can be found for industrial co-incineration:

In coal-fed power stations:

- *Option #1:* Utilization of the existing installations and their optimization for a predominant co-incineration of RDF
- *Option #2:* Thermal treatment of the RDF using gasification or pyrolysis as a preceding step before the incineration of the generated pyrolysis coke or gases in the existing boiler *(Important additional note: so far no such application ever had a confirmed full functionality at larger long-term technical scale)*
- *Option #3:* Utilization of the RDF in a fluidized bed incinerator
- *Option #4:* Utilization of the RDF in an external fluidized bed incinerator with its own flue gas treatment, use of the energy to heat the steam boiler (composite circuit).

Figure 22: Exemplary scheme for industrial co-incineration in a conventional (fossil-fueled) power station



In the cement industry:

RDF is co-incinerated in cement production at the stage of clinker production and cement making. Rotary kilns play a predominant role here. The kiln is a cylindrical vessel, inclined slightly to the horizontal, which is rotated slowly about its axis.
The material to be processed including the RDF is fed into the upper end of the cylinder. As the kiln rotates, the material gradually moves down towards the lower end, and may undergo a certain amount of stirring and mixing. The addition of RDF to the material mix influences the overall amount of fossil fuel added as well as its distribution onto rotary kiln and calcinator unit. This distribution must be known at the beginning of the process in order to ensure stable conditions and uniform quality of the end product.

An essential role in the co-incineration in cement kilns plays the element ratio and the ratio of the calorific values between conventional (fossil) and secondary (RDF) fuel. With the incineration of the latter taking place at temperatures of 2000 °C no toxic gases can form. Nitrous gases are eliminated through the DeNOx-process. The clinker reactions at 1450°C allow incorporation of ashes and in particular the chemical binding of metals to the clinker.

Drying, heating and the degassing of the volatile waste components occurs near the upper feeding slot already. The hot gases pass along the kiln, sometimes in the same direction as the process material (co-current), but usually in the opposite direction (counter-current). The ignition and incineration of these gases takes place in the calcinator. The gasification and incineration of the solid waste parts takes place near the lower exit.

The counter example is an upstream gasification unit for RDF with the subsequent use of the combustible gas in the process. This kind arrangement is used in the German cement plant in Rüdersdorf near Berlin.

QUANTITY ASPECTS / SCALE OF APPLICATION

Depending on the kind of process and facility used, a partial or full substitution of conventional fuel with RDF is achieved in a co-incineration process. Incineration technology, product requirements and RDF composition determine how large this share can be. Whereas industrial power stations substitute only 5–25% of their total rated thermal input with the help of RDF, this can be up to 75% (2014) or in single cases even more in cement kilns.

INTEROPERABILITY	Industrial co-incineration in principle is an option that can be adopted for any kind of production, energy or heat generating processes based on the combustion of medium and high calorific materials. Special installations designed to supply industrial parks or large production facilities (like paper mills) with energy from a dedicated mono-combustion of RDF fractions however become more and more popular. These installations use conventional incineration technologies like grate combustion (see fact sheet on "Grate combustion") and fluidized bed combustion (see fact sheet on "Fluidized bed combustion") but with modifications purposefully made in order to achieve high energy efficiency and cope with RDF-related specificities like aggressive flue gases and varying emission values.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- A positive balance can be obtained through the saving of primary fossil fuels and the utilization of the renewable waste components as an energy source
CO_2-BALANCE	- Reduction of CO_2-emissions up to 35 % through the partial substitution of primary fossil fuels - A complete substitution would prevent all climate damaging emissions from the combustion of the respective amount of conventional fuels and those generated during the disposal of the waste converted into RDF
AIDS/ADDITIVES NEEDED	- No additives are required to generate a suitable RDF product out of combustible waste material. However, there is a need for mechanical processing and possibly some biological treatment (drying) for which certain technical means have to be employed
HUMAN RESOURCES	- The demand on personnel in the co-incineration facility may slightly increase in order to ensure the proper handling (storage, feeding) and quality assurance procedures for the RDF material and do some additional maintenance and repair works.
SPATIAL NEEDS	- an additional storage of the RDF-material corresponding to the capacity/RDF-throughput of the facility is needed; for example silo storage is needed for animal and bone meal used in co-incineration - additional space for the reception and feeding installations of the fuel material
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	To allow for the co-incineration in an industrial facility, certain additional investments are necessary. For the most part they are in relation to: - the planning and erection of the RDF reception and storage area and installations for dosage and feeding - necessary extensions on the flue gas cleaning and emission detection and measurement The additional investments may take a range of EUR 1.3–6 million per incineration facility or EUR 25–45 per Mg of RDF used (price quotations from the year 2008). These amounts also include the costs for maintaining an adequate storage capacity and for fire protection measures.
OPERATING COSTS	The overall operating costs of the industrial plant are likely to increase in the result of a slightly increased personnel demand, additional repair/maintenance and enhanced requirements for emission treatment (e.g. bypass regulation). Possible changes with regard to the utilization potentials for certain byproducts of power stations (especially fly ashes) may lead to lower proceeds from their sale and an increase of disposal costs.

POSSIBLE PROCEEDS	Accepting waste-derived fuels for co-incineration to a certain extent can be regarded as a thermal treatment service for waste materials and also goes hand in hand with some additional risks and investments. Industrial plant operators for these reasons use to charge a fee to the suppliers of RDF, depending also on how much conventional fuel they can substitute and what the treatment of byproducts and process residues inclusive the emissions costs them. An indicative price range for the fees (established for the year 2011) collectable at the market is shown hereafter: - lignite fired power plants using the method of dust firing: 5–15 EUR/Mg RDF input - hard-coal fired power plants using the method of dust firing: partly no fees due to the higher requirements imposed on the conditioning of the RDF products - hard-coal fired power plants using fluidized bed combustion: 0 to < 10 EUR/Mg RDF input For less intensively processed RDF incinerated in dedicated incinerators with higher flexibility in terms of quality and other parameters, fees might be set at much higher levels, across Europe price quotations currently reach up to 50 EUR/Mg.
MASS SPECIFIC OVERALL COSTS	can vary greatly
OTHER RELEVANT ASPECTS	
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	The industrial co-incineration of waste material is widely applied in Germany to date and is becoming a common practice also in other countries of Europe and elsewhere in the world. Industrial facilities which are using co-incineration in Germany are for example: Cement industry - Cemex Zementwerke Rüdersdorf — www.cemex.de - Dyckerhoff Zementwerke Deuna — www.dyckerhoff.de Power stations - Kraftwerk Jänschwalde — www.vattenfall.com - Kraftwerk Werne — www.rwe.com Steel production - DK Recycling und Roheisen GmbH, Duisburg — www.dk-duisburg.de
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Provider of installations for an industrial co-incineration and/or of the necessary components in Germany are for example: - Steinmüller - Babcock Environment GmbH, Gummersbach — www.steinmueller-babcock.com - Oschatz GmbH — www.oschatz.com
ADDITIONAL REMARKS AND REFERENCE DOCUMENTS	
A relevant organization and contact point for further information concerning RDF-production and use by the industry is for example: Gütegemeinschaft Sekundärbrennstoffe und Recyclingholz e.V. (BGS). www.bgs-ev.de	

THERMAL WASTE TREATMENT THROUGH GRATE COMBUSTION *)

APPLICATION OBJECTIVE	- Reduction of the volume and risk potential of waste destined for final disposal through a mineralization, destruction of organic compounds and the capture of large parts of the harmful inorganic components in a separable fraction - Energy recovery from waste *) The cleaning of exhaust and flue gases as an integrated process and technology is covered by a separate description (see the fact sheet „Emission control – exhaust and flue gas cleaning“)

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper / paperboard	X[25]	Mixed household waste	X	Bulky waste	X[1]
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood	X[26]	C&D waste	X[1]
Waste oil	X[27]	Old paint & lacquer	X	Waste tyres	
Hazardous waste	X	partly, only combustible fractions			
Branch specific waste	X	combustible fractions			
Other waste material	X	combustible fractions			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
Input material must be freed from disturbing components such as large metal parts and should not contain any radioactive substances (entrance control !), a crushing of bulky waste items might be necessary.

Options for the utilisation of the generated output:
Combustion ashes and slag after a further processing can be used in other applications. The processing involves the removal of metals from the slag and a comminution/homogenization so that the material can be used for construction purposes (e.g. in road construction).

Options for the disposal of process output and/or residues:
Landfilling combustion residues (ashes and slag) is generally possible. Residues from exhaust and flue gas cleaning however must be handled as hazardous material and need to be deposited in facilities which are suitable and approved for this type of material. Preferred options for this are stowage-mines or underground deposits (see fact sheet on „Hazardous waste landfill“).

Aftercare requirements:
Residues which have to be deposited on landfills of the appropriate categories must be subject of monitoring and become part of the usual aftercare procedures applying to these landfills.

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25 Recycling and the necessary sorting and mechanical processing this possibly requires shall be the preferred options for this waste. Grate combustion should be applied to treat only the combustible residues which remain after the sorting and processing of this waste.

26 Any possibilities for this waste to be recycled should be examined and, whenever possible and economically feasible, applied first, in particular if amounts of wood in a natural or widely untreated state are involved. Energy generating facilities specialized on the combustion of woody biomass are also more suited for utilizing this waste in an energetically effective manner.

27 in small quantities only , any possibilities for this waste to be recycled or material used should be examined first and, whenever possible and economically feasible, preferred. Other forms of thermal utilization should be considered as well, e.g. an industrial co-incineration (see also fact sheet on „Industrial co-incineration“).

Protective needs:
Exhaust and flue gases from the incineration must be appropriately treated and cleaned. Protective measures must ensure that no health risks or any negative impacts on sensitive media such as the soil, ground water or sites of special value do occur. Guidance what measures and limits may apply is provided in other documents and fact sheets (see fact sheet on "Exhaust and flue gas cleaning" and the document on "Technology-related EU regulations" in particular the "Directive on industrial emissions"). To erect an incineration facility in or close to dwelling areas requires that minimum distances to the nearest buildings and other precautionary measures, especially such serving noise protection, need to be observed.

Potential health risks:
A release of untreated flue gases pose a health risk which can be avoided if contemporary cleaning techniques and protective measures as indicated in this fact sheet and in the fact sheet on "Exhaust and flue gas cleaning" are employed and properly followed. Waste incinerators using state-of-the-art cleaning technologies are nowadays considered as not threatening human health any longer.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
To allow for economical operations of waste incineration plants a minimum throughput capacity (approx. 50,000 Mg/a) shall be ensured. Areas with a concentration of waste generation (i.e. especially in or nearby large cities) are therefore favorable places for this type facilities. Such areas do also offer the necessary infrastructural conditions, like a good accessibility and connection to road, railway or waterways, and the possibility to supply nearby users with the electric energy and/or steam produced. An increase in traffic movements in the area of the plant must be considered.

Climatic conditions: No special restrictions apply.

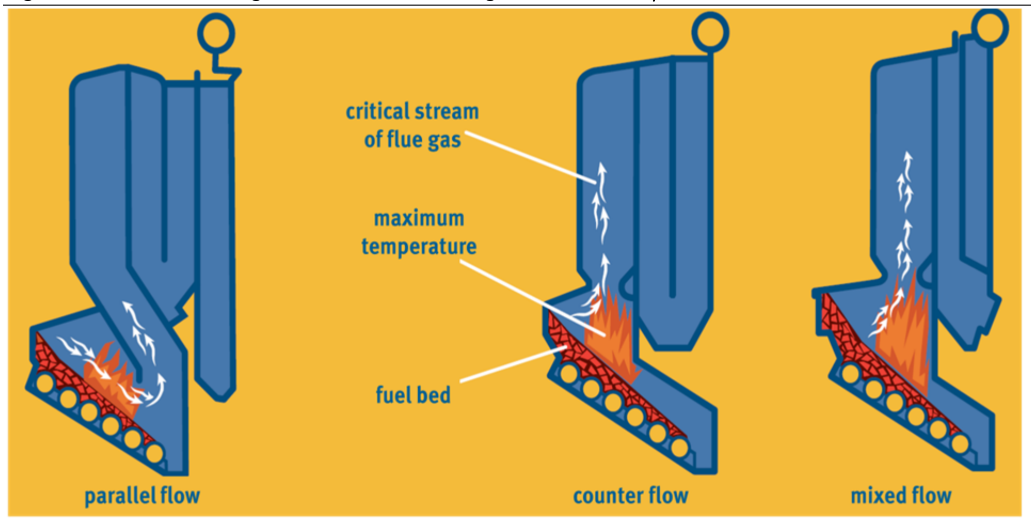
Suitable financing mechanism:
The incineration of waste should be financed by charges imposed to the generators of the waste. Introducing an incineration tax or additional waste treatment fee specifically for the combustible waste may help to ensure that only the non-reusable, non-recyclable parts of the waste are forwarded to incineration, both are also instruments for an additional financing of the treatment.

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	Grate combustion is one of the most widely applied incineration techniques, which in the way presented hereafter, is also used for the mass combustion of mixed commercial and municipal solid waste and provides the leading technology in this segment in the world. Grate combustion can be used for an energy recovery from waste especially in combination with combined power and heat production. Opposite to other incineration techniques, the waste is burnt here on a grate in the combustion chamber.

BASIC REQUIREMENTS	- Quality requirements for the input stream:
	  - Net calorific value: - >6MJ/kg to 12 MJ/kg and above in the case of air-cooled grate bars
	    - 6MJ/kg to 25 MJ/kg in the case of water-cooled grate bars
	  - Particle size: <300 mm, in exceptional cases up to 1000 mm
	- Integrated emission control and exhaust gas cleaning (see fact sheet on "Exhaust and flue gas cleaning")
	- there should preferably exist:
	  - a possibility to supply surplus thermal energy (steam or warm water) or cooling produced out of it to external users
	  - alternatively or supplementary: a connection to feed electrical energy into a public grid

EXPECTED RESULTS	Output: - slag - caldron dust - exhaust gas Quality requirements for the output: - slag: C ‹ 3% by weight, in modern systems the ignition loss of burnt out slag comes to less than 0.5 percent by weight
SPECIFIC ADVANTAGES	- Reliable and long proven technology which provides for a reduction of the hazardous potential and reactivity of waste destined for final disposal in combination with the highest possible volume reduction (security of disposal) - Possibility to recover the energetic content of the waste for the generation of electricity and heat/cooling - Possibility to recover ferrous and non-ferrous metals by way of processing the combustion ashes/slag - Treatment of harmful waste fractions and components resulting in the discharge and elimination of pollutants and hazards from recycling circuits
SPECIFIC DISADVANTAGES	- Investment intensive (especially to comply with environmental protection needs) - occasionally greater problems of acceptance and the need to overcome these within the population
APPLICATION DETAILS	
TECHNICAL SCHEME	In grate combustion the waste is incinerated all around the clock and hence continuously fed by feeding systems onto the grate whereas the incoming waste arrives at the plant discontinuously (mostly during daytime only). To make sure that a certain stock of input is permanently available, a deep-bunker is always set before the grate combustion. This installation also ensures the waste mix to become more homogenous (also in terms of a stable and balanced calorific value) at the time it is fed into the combustion chamber. Combustion on the grate takes place at temperatures of 850 to 950°C. At the end of the moving grate, the burnt out residues drop into a slag extractor filled with water. The flue gases generated in combustion mostly reach an after-burning chamber where they burn out completely at 850° C. In the subsequent steam boiler, the flue gas is cooled to 200°C to 240°C and overheated steam (max. 40 bar, 400° C) is produced. The steam can be used to generate electricity, for district heating and to make process steam out of it. Presently, numerous systems of grate combustion are available on the market. They vary in their way of flue gas distribution and how the waste is transported on the grate. There exist three principal alternatives of how flue gases are distributed. Figure 23: Alternatives for gas flow distribution in a grate combustion process 

	For the variants of parallel gas flow, counter flow and mixed flow the main waste transportation and gas flow routes are shown in the graphic. - *Parallel flow* turns out to be advantageous in connection with waste of high calorific value (>9 MJ/kg). The incompletely burned flue gas is forced to pass the zone with the highest temperature so that an improved burnout is reached. Thus, an after burning chamber may be unnecessary. Various surveys have shown that the burnout of flue gas and slag is better in parallel flow systems than in others. - *Counter flow* turns out to be advantageous in connection with waste of lower calorific value. Drying and firing of waste is supported by high flue gas temperatures. A possible danger is that the flue gas is badly intermixed, such that an after burning chamber is absolutely necessary. - *Mixed flow systems* constitute a compromise for plant layout if a wide range of calorific values has to be dealt with. The grate system on which the waste is transported should be such as to allow good poking (circulation). There exist three different grate systems. - On a *stoker with reciprocating grate bars*, grate bars transport the waste. Thus, an inclined grate area is not needed although offered by some manufacturers. Increasing grate motion leads to faster transport. This will allow to control the waste retention time in the furnace and to adapt to fluctuations in load. Stokers with reciprocating grates are at present the most important grate type used in new plants. - On *reversed feed grates*, gravitation enables the transport of waste. Thus an inclined grate area is necessary, since the grate bars and the waste move in opposite directions. Reversed feed grates are particularly suitable for wet waste. Water-cooled grate bars can be used for both grate systems. - On *roller grates*, it is a combination of gravitation and roller motion that enables the transport of waste. Roll rotation transports the waste downwards an inclined grate area. Faster rotation leads to faster transport but not to better circulation of the bed, however.
QUANTITY ASPECTS	Input: - Municipal solid or household-like commercial waste - water (for cooling and steam generator), the minimum demand of fresh water is 1 m³/h per Mg/h throughput Output: - 200–350 kg slag/Mg input - 25 to 40 kg caldron dust and ashes from gas cleaning per Mg input (source: VDI 3460) - 4,500 to 6,000 m³ exhaust gas/Mg input - water (from steam generator)
SCALE OF APPLICATION	For economical operations the capacity of an incineration plant should reach 50,000 Mg/a in the minimum which is equivalent to 6.5 Mg/h throughput. On the leading end can be found capacities of 225,000 Mg/a which is equivalent to 30 Mg/h throughput per incineration line. There is practically no limit as to the number of lines installed in a plant. The largest plants have currently a capacity of 800,000–1,000,000 Mg/a. New water-cooled grate systems allow to handle high calorific wastes with a heating value up to 16 MJ/kg. In previous grate fired plants the calorific value of the waste had to be kept down to approx. 12 MJ/kg. Otherwise the thermal loading of the grate system would have been too high resulting in a drastically shortened life time of the grate.

INTEROPERABILITY	A grate combustion in principle can be combined with all processes for a preceding treatment of wastes, given that its general objective is to mineralize any combustible waste components which cannot otherwise be used or recycled and to recover the remaining energy content. An asset is the possibility that synergies with processes marked by a high demand of thermal energy can be create and their supply with steam and power arranged. Waste incinerators can also assume the function of a source for base load supply for district heating/cooling networks. - The incineration process in any case must be combined with an exhaust gas cleaning because the untreated flue gas from the grate combustion of waste usually contains harmful components in considerable extent (see fact sheet on "Exhaust and flue gas cleaning").
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	

ENERGY BALANCE	Energy balance of a practical case example (established 2010, by Alwast, Riemann[28])
	Input:
	- Mixed municipal solid waste (MSW) 100 %
	- Supporting energy, e.g. natural gas ‹ 3 % of MSW input
	Output:
	- Exhaust and firing losses: 18%
	- Steam: 82%, from which
	  - 1,6% own steam consumption
	  - up to 29% turned into electricity,
	    →81% fed to the electricity grid
	    →19% own consumption
	  - up to 69% waste heat
	Combinations of electrical and thermal energy supplies are possible and desirable but the rule is that the more thermal energy is supplied the less electric current can be generated. Typical combinations found in average sized plants are for example: 5 % electricity plus 35 % heat supply or 10 % electricity plus 20 % heat supply. Contemporary plants achieve to have a higher efficiency and better power ratios, depending also on the location and user structure.

CO_2-BALANCE	- A positive balance can be obtained through the saving of primary fossil fuels and the utilization of the renewable waste components as an energy source
AIDS/ADDITIVES NEEDED	- fuel oil or natural gas for start up and shut down operations and for support heating when temperatures in the afterburner section go down - for exhaust gas cleaning: adsorbents and further chemical reagents (among others lime, liquid ammonia, for more details see fact sheet on "Exhaust and flue gas cleaning")
HUMAN RESOURCES	- a minimum of 15 skilled persons per incineration line including exhaust gas cleaning per day for the 24h/7 days operation mode, at least 1 engineer and 2 foreman should be among the staff, additional personnel for maintenance, cleaning services and gate control, especially qualified personnel is needed for the technical management - the number of incineration lines is less influencing on the staff count than t he exhaust cleaning system applied

SPATIAL NEEDS	Minimum space demand is in the range of:
	  - approx. 10,000 m² for a throughput rate of 50,000 Mg/a
	  - approx. 30,000 m² for a throughput rate of 200,000 Mg/a

[28] Verbesserung der umweltrelevanten Qualitäten von Schlacken aus Abfallverbrennungsanlagen, Texte 50/2010, Umweltbundesamt (Hrsg.), http://www.uba.de/uba-info-medien/4025.html.

OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- can vary strongly in dependence on the applied technology and process equipment and could reach amounts in the range from approx. EUR 50 million to EUR 200 million (and above) for new constructions. - The specific investment costs for ten comparable incineration plants built after 2005 in Germany with grate combustion techniques ranged between approx. 350 EUR/Mg input and 600 EUR/Mg input per annum (including the exhaust gas cleaning system). Further indices can be obtained from the reference literature and sources listed below.
OPERATING COSTS	- vary strongly and had been in the range of 34 EUR/Mg to 102 EUR/Mg input in the year 2010 when comparing the figures from six plants in Germany Repair and maintenance - for each structural element approx. 1% of the initial investment - machinery and electronic: 3 - 4% of the initial investment Personnel costs - depending on the price on the local labour market Further indices can be obtained from the reference literature and sources listed below.
POSSIBLE PROCEEDS	- from the supply of electricity and steam/warm water
MASS SPECIFIC OVERALL COSTS	- for rough orientation in the range of 80–150 EUR/Mg (inclusive the exhaust gas cleaning); higher capacity of the plant, less sophisticated exhaust gas cleaning procedures and equipment and a good market situation for the sale of electricity and steam normally improve the cost ratio significantly

OTHER RELEVANT ASPECTS

MISCELLANEOUS

MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	The incineration of solid mixed municipal and commercial wastes under the application of grate combustion technology is in worldwide use and has strongly evolved recently. Today, there are over 100 plants in Germany (state of 2016) burning different kind waste materials with this technique. Reference facilities in Germany are for example: - Magdeburg Rothensee (650,000 Mg/a, 4 Lines) www.mhkw-rothensee.de - Hamburg Borsigstraße (320,000 Mg/a; 2 Lines) www.mvr-hh.de - TREA Breisgau (175,000 Mg/a, 1 Line) www.eew-energyfromwaste.com Other countries where waste incinerators are operated on a large scale with this type of process are: France, Switzerland, Netherlands, Austria, Italy, China, Japan and Scandinavia.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Recognized producer/provider firms for grate combustion technology and related plant components are for example: - MARTIN GmbH für Umwelt- und Energietechnik, München www.martingmbh.de - Steinmüller - Babcock Environment GmbH, Gummersbach www.steinmueller-babcock.com - Oschatz GmbH www.oschatz.com - Hitachi Zosen Inova Kraftwerkstechnik GmbH, Landsberg www.hz-inova.com

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

As important reference documents on this combustion technique are available:

VDI 3460 and Reference Document on the Best Available Techniques for Waste Incineration

Further information and compilations on relevant details and plants can be obtained from:
- ITAD – Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland e.V. www.itad.de
- CEWEP – Confederation of European Waste-to-Energy Plants www.cewep.com

Umwelt Bundesamt

THERMAL WASTE TREATMENT THROUGH FLUIDIZED BED INCINERATION *)

APPLICATION OBJECTIVE	- Reduction of the volume and risk potential of waste destined for final disposal through a mineralization, destruction of organic compounds and the capture of large parts of the harmful inorganic components in a separable fraction - Energy recovery from waste *) The cleaning of exhaust and flue gases as an integrated process and technology is covered by a separate description (see the fact sheet „Emission control – exhaust and flue gas cleaning“)

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper / paperboard		Mixed household waste	X	Bulky waste	X[29]
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood	X[30]	C&D waste	X[1]
Waste oil	X[31]	Old paint & lacquer	X	Waste tyres	
Hazardous waste	X	partly, only combustible fractions			
Branch specific waste	X	appropriate combustible materials, especially small-sized material mixtures (e.g. rejects of paper mills)			
Other waste material	X	appropriate combustible materials, especially dewatered or partially dried sewage sludge			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
Input material must be freed from disturbing components such as large metal parts and comminution may have to be employed to get particles which are of appropriate size for the fluidized bed incineration. Any radioactive substances must be excluded (entrance control!)

Options for the utilisation of the generated output:
Combustion ashes and slag after a further processing can be used in other applications, for example in construction. There exists however less options to use the materials from fluidized bed incineration compared to the ashes resulting from grate combustion (see details in the fact on „Grate combustion“).

Options for the disposal of process output and/or residues:
Landfilling combustion residues (ashes and slag) is generally possible. Residues from exhaust and flue gas cleaning however must be handled as hazardous material and need to be deposited in facilities which are suitable and approved for this type of material. Preferred options for this are stowage-mines or underground deposits (see fact sheet on „Hazardous waste landfill“).

Aftercare requirements:
Residues which have to be deposited on landfills of the appropriate categories must be subject of monitoring and become part of the usual aftercare procedures applying to these landfills.

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29 Recycling and the necessary sorting and mechanical processing this possibly requires shall be the preferred options for this waste. Fluidized bed incineration should be applied to treat only the combustible residues which remain after the sorting and processing of this waste.

30 Any possibilities for this waste to be recycled should be examined and, whenever possible and economically feasible, applied first, in particular if amounts of wood in a natural or widely untreated state are involved. Energy generating facilities specialized on the combustion of woody biomass are also more suited for utilizing this waste in an energetically effective manner.

31 in small quantities only , any possibilities for this waste to be recycled or material used should be examined first and, whenever possible and economically feasible, preferred. Other forms of thermal utilization should be considered as well, e.g. an industrial co-incineration (see also fact sheet on „Industrial co-incineration“).

Protective needs:
Exhaust and flue gases from the incineration must be appropriately treated and cleaned. Protective measures must ensure that no health risks or any negative impacts on sensitive media such as the soil, ground water or sites of special value do occur. Guidance what measures and limits may apply is provided in other documents and fact sheets (see fact sheet on "Exhaust and flue gas cleaning" and the document on "Technology-related EU regulations" in particular the "Directive on industrial emissions"). To erect an incineration facility in or close to dwelling areas requires that minimum distances to the nearest buildings and other precautionary measures, especially such serving noise protection, need to be observed.

Potential health risks:
A release of untreated flue gases pose a health risk which can be avoided if contemporary cleaning techniques and protective measures as indicated in this fact sheet and in the fact sheet on "Exhaust and flue gas cleaning" are employed and properly followed. Waste incinerators using state-of-the-art cleaning technologies are nowadays considered as not threatening human health any longer.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Infrastructural conditions:
To allow for economical operations of waste incineration plants a minimum throughput capacity (approx. 50,000 Mg/a) shall be ensured. Areas with a concentration of waste generation (i.e. especially in or nearby large cities) are therefore favorable places for this type facilities. Such areas do also offer the necessary infrastructural conditions, like a good accessibility and connection to road, railway or waterways, and the possibility to supply nearby users with the electric energy and/or steam produced. An increase in traffic movements in the area of the plant must be considered.

Climatic conditions: No special restrictions apply.

Suitable financing mechanism:
The incineration of waste should be financed by charges imposed to the generators of the waste. Introducing an incineration tax or additional waste treatment fee specifically for the combustible waste may help to ensure that only the non-reusable, non-recyclable parts of the waste are forwarded to incineration, both are also instruments for an additional financing of the treatment.

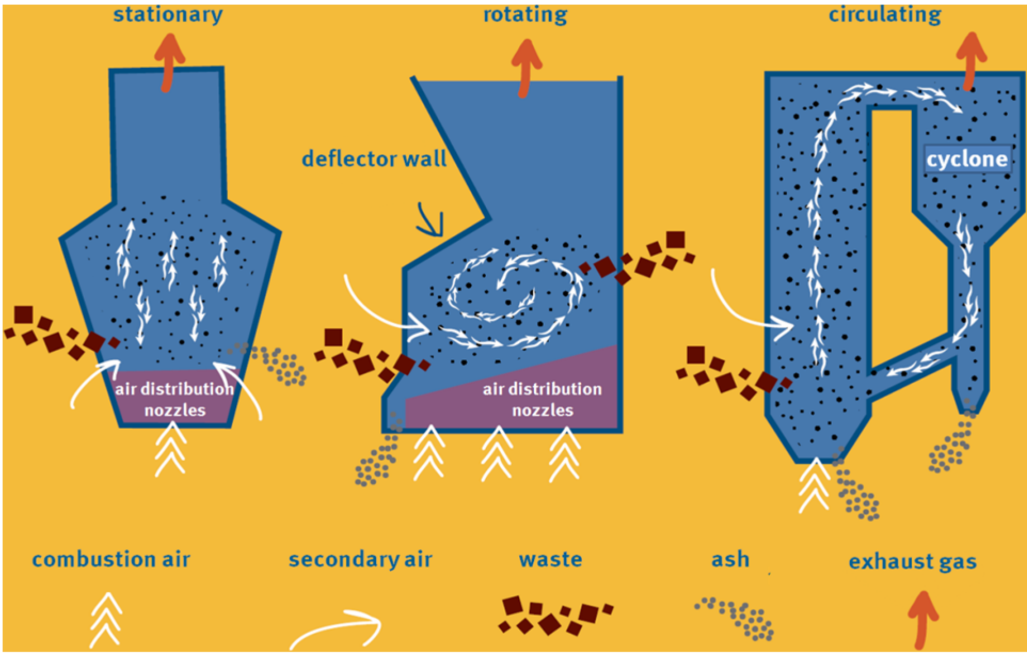
TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	Fluidized bed combustion is used in modern incinerators and power plants as a particularly efficient and low-emission technology. Fluidized beds suspend solid fuels (which is waste in the specific case looked at here) on upward-blowing jets of air during the combustion process. The result is a turbulent mixing of gas and solids. The tumbling of the waste material provides more effective chemical reactions and heat transfer. Fluidized-bed combustion evolved from efforts to design a combustion process with minimized pollutant emissions and a reduced need for very cost intensive external emission controls (like for example scrubbers). The use of this technique is meanwhile often seen for the combustion of dried sewage slude (see the fact sheet on „Sewage sludge treatment“) and is further very common for the thermal utilization of refuse-derived fuel (RDF) products (see the fact sheet on „Industrial co-incineration“).
BASIC REQUIREMENTS	- The process must be controlled in a way that temperatures remain below a level where ashes sinter and noxious nitrogen oxides can form - Pretreatment of the waste has to ensure that the process input is a small-sized (approx. 50 mm) mixture of waste with rather homogenous physical properties - The average heating value of the input can be up to 20 MJ/kg for a stationary fluidized bed combustion process and go up to 35 MJ/kg for circulating bed combustion.

EXPECTED RESULTS	Output: - Ashes with no or little slag (reaching a carbon content in the range of 0.5% or ignition loss of less than 0.5 % by weight) - Caldron dust - Gaseous emissions (exhaust/flue gas) - Low NO_x –formation and reduced binding of heavy metals in the ashes due to comparatively low process temperature
SPECIFIC ADVANTAGES	- Process is less sensitive to changes in the calorific value of the waste and can be used for the incineration of sludge and paste-like substances in particular - Low or reduced denoxification demands in result of little pollutant generation due to incineration at rather low temperatures, - Good burnout results - Technology qualifies for high heat power output (for circulating bed combustion up to 1000 MW_{th}) and high calorific input material (for circulating bed combustion up to 35 MJ/kg) - Capital requirements in comparison to other techniques often lower
SPECIFIC DISADVANTAGES	- Process is marked by a lower throughput as compared to other techniques - Higher probability of wear and tear in the combustion chamber and the boiler due to the high quantity of abrasive material (sand) in the fluidized bed, - The binding of heavy metals into the ashes occurs to lower extent, - Possible risk of a formation of laughing gas (N_2O) in the exhaust gas stream - Problems of general public acceptance may exist here and there and must be overcome
APPLICATION DETAILS	
TECHNICAL SCHEME	In the fluidized-bed combustion, mostly crushed waste is brought into a fluidized-bed of inert matter where it is incinerated at comparatively low temperatures (750–850°C). High detention time, large specific surfaces, and good heat transmission lead to a good burnout (remaining content of carbon ‹ 0.5% by weight). The combustion temperatures well below the threshold where nitrogen oxides form, lead to a comparatively low NO_x formation, developments of nitrous oxide (laughing gas) as highly active greenhouse gas must be observed, however. The low process temperature also guarantees that ashes do not sinter so that heavy metals are bound into the ash to a lower degree. The mixing action of the fluidized bed brings the exhaust gases furthermore into contact with a sulfur-absorbing substance, such as limestone or dolomite. With this a high degree of the sulfur pollutants can be captured inside the boiler by the sorbent. Fluidized-bed combustion systems fit into essentially two major groups, atmospheric systems (FBC) and pressurized systems (PFBC). PFBC systems operate at elevated pressures and produce a high-pressure gas stream at temperatures that can drive a gas turbine. Steam generated from the heat in the fluidized bed is sent to a steam turbine, creating a highly efficient combined cycle system. Basically, there are three different procedural types of fluidized bed systems which are distinguished by the directing of the flue gas stream. The three types are - stationary - rotating and - circulating fluidized bed. In the *stationary fluidized bed* the bed height is constant. There are basically no diagonal transports in the fluidized bed. The stationary fluidized bed is mostly used for sewage sludge. It is especially useful for the burning of wastes with a low calorific value (6.5 to13 MJ/kg). Certain conditions provided (heating surfaces are present in the fluidized bed) waste with a calorific value of up to 18 MJ/kg can also be incinerated efficiently. In the *rotating fluidized bed* the bed is also a stationary one. However, a rotation along its own axis takes place so that a diagonal mixing occurs. The rotating fluidized bed is put into place for wastes with higher calorific value (7 up to max. 20 MJ/kg). Sludge can be burned, too.

Figure 24: Variants of directing the gas stream in different fluidized bed systems



In the *circulating fluidized bed* the bed height is not constant. Instead bed ash and bed sand constantly leave the furnace through a high air velocity. These bed materials are separated in a cyclone and for the most part returned to the furnace. The high air velocities allow the use of high calorific waste.

QUANTITY ASPECTS

Input:

- solid and paste-like waste material
- sand/inerts (bed material)
- water (steam generator), the fresh water demand is about 1 m^3/h per Mg/h throughput in the minimum

Output:

- 200 to 250 kg bottom ash/Mg input
- 50 to 100 kg cyclone ash/Mg input
- 5 to 20 kg caldron dust/Mg input
- 4,500 to 5,500 m^3 exhaust gas/Mg input
- water (from steam generator)

SCALE OF APPLICATION

- Applications of this technology at the moment are seen in a capacity range
  - starting from 4 Mg/h up to 150,000 Mg per line and annum for RDF fractions
  - between approx. 5,000–75,000 Mg dry matter per annum for sewage and industrial sludge

INTEROPERABILITY

Fluidized bed combustion is meant for the treatment of combustible waste materials which cannot otherwise be used (e.g. waste ‹30 mm, sludge). Thus a fluidized bed combustion can be combined with all preceding measures and processes for waste treatment.

It is useful to establish synergies with processes with a high demand of thermal energy (e.g. paper mills who in return can feed most of their process residues into such facilities). Alternatively there should be the possibility for the incinerating plant to supply surplus thermal energy (steam or warm water) to external users or to feed electrical energy into the public grid.

- The incineration process in any case must be combined with an exhaust gas cleaning because untreated flue gases may contain harmful components (see fact sheet on "Exhaust and flue gas cleaning").

OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION

ENERGY BALANCE

Energy balance for an example from practice (state of data 2010)

Input: -fuel (waste), auxiliary energy, e.g. natural gas < 3 % of the fuel input

Output: -electricity; maximum output 20 % (considering own process demands)
-thermal energy; maximum output up to 60 %

Combinations of electric and thermal energy supplies are possible and desirable but the rule is that the more thermal energy is supplied the less electric current can be generated.

Table 13: Example for the energy flows in a monovalent sewage slude incineration using fluidized bed technology (Source: Franck, Monoverbrennung von Klärschlamm, 2015)

Parameter	Unit	Absolute value range	
Throughput	$Mg_{dry\ matter}$/annum	35,000	2,000
Pre-heating of air stream	°C	120	200
Turbine power output in extraction mode operation	MW_{el}	1.4	-
Net electricity output turbine	MW_{el}	0.4	-
Energy demand sludge drying	MW_{th}	7.0	0.430

CO_2-BALANCE

- A positive balance can be obtained through the saving of primary fossil fuels and the utilization of the renewable waste components as an energy source

AIDS/ADDITIVES NEEDED

- Sand
- Caustic lime
- Hearth furnace coke
- Fuel oil or natural gas for startup and support heating

HUMAN RESOURCES

- a minimum of 10–15 skilled persons per incineration line including exhaust gas cleaning per day for the 24h/7 days operation mode, at least 1 engineer and 2 foreman should be among the staff, additional personnel for maintenance, cleaning services and gate control, especially qualified personnel is needed for the technical management

SPATIAL NEEDS

- The minimum space demands are at about 5,000 to 10,000 m² depending on throughput capacity

OPERATIONAL BENCHMARKS: COST DIMENSIONS

INVESTMENT COSTS

A specific investment in the range of EUR 180–400 per $Mg_{Dry\ matter}$ provides a reasonable estimate for large-scale plants engaged in the exclusive incineration of sewage sludge with the help of fluidized bed incineration technology. The following table lists the investment costs for comparable plants of larger and smaller size designed for the incineration of sewage sludge with the help of fluidized bed incineration technology.

Table 14: Investment costs for sewage sludge incinerators of different size with fluidized bed technology (Source: Franck, Schröder: Zukunftsfähigkeit kleiner Klärschlammverbrennungsanlagen, 2015)

Parameter	Larger-sized plant	Smaller-sized plant
Annual throughput capacity	35,000 $Mg_{dry\ matter}$/a	2,000 $Mg_{dry\ matter}$ /a
Process technology	24,150,000 EUR	3,590,000 EUR
Construction engineering	5,150,000 EUR	880,000 EUR
Electronic measurement and control technology	2,250,000 EUR	1,130,000 EUR
Incidental expenses	3,200,000 EUR	1,000,000 EUR

OPERATING COSTS	- vary strongly and particularly in dependence from the market prices for operating supplies (such as auxiliary fuels) and the local labor costs. - For the plant examples in above table the amount of EUR 5.5 million (larger-sized plant with 35,000 Mg sludge$_{dm}$ annual capacity) respectively EUR 1 million (smaller-sized plant with 2,000 Mg sludge$_{dm}$ annual capacity) can be given as orientation values Repair and maintenance - for each structural element approx. 1% of the initial investment - machinery and electronic: 3–4% of the initial investment Further indices can be obtained from the reference literature and sources listed below.
POSSIBLE PROCEEDS	- from the supply of electricity and steam/warm water
MASS SPECIFIC OVERALL COSTS	Costs are supposed to be in the same range as in the case of grate combustion (see the fact sheet on "Grate combustion"). Possible savings may arise from the reduced denoxification demands. There might be slightly higher costs due to the increased risk of wear and tear and particular pre-treatment needs for the input, however. Especially where fine material such as dried sludge or undersized screening material <30mm from the mechanical treatment are burnt, cost savings between 20-30% as compared to grate combustion become possible with the fluidized bed technology An example for the incurring costs in Germany is: - Input dried sludge or waste material <30mm: 80 to 120 EUR/Mg, less sophisticated exhaust gas cleaning procedures and equipment and a good market situation for the sale of electricity and steam normally improve the cost ratio significantly
OTHER RELEVANT ASPECTS	
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	The incineration of appropriate waste materials, sewage sludge and refuse derived fuel products in particular with fluidized bed technology has strongly evolved recently and is meanwhile in worldwide use. Germany by now has plants with a total capacity above of 2 million Mg annual throughput in operation with fluidized bed technology (state of 2016). Some reference facilities in Germany are for example: - TEV Neumünster: circulating fluidized bed, 150,000 Mg annual throughput - RDF incinerator in the industrial park Höchst www.infraserv.com
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Recognized producer/provider firms for grate combustion technology and related plant components are for example: - Eisenmann SE, Böblingen www.eisenmann.com - Küttner GmbH & Co. KG www.kuettner.de - Strabag Umwelttechnik GmbH www.strabag.de
ADDITIONAL REMARKS AND REFERENCE DOCUMENTS	

As important reference documents on this combustion technique are available:

VDI 3460 and Reference Document on the Best Available Techniques for Waste Incineration

Further information and compilations on relevant details and plants can be obtained from:

- ITAD – Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland e.V. www.itad.de
- CEWEP – Confederation of European Waste-to-Energy Plants www.cewep.com

Umwelt Bundesamt

EMISSION CONTROL THROUGH EXHAUST GAS CLEANING (AND THE CLEANING OF FLUE GAS FROM THE INCINERATION OF WASTE IN PARTICULAR)

APPLICATION OBJECTIVE	- Emission abatement through the treatment and cleaning of the exhaust gases (in particular flue gases) from waste incineration processes (see also fact sheets on the different incineration technologies; "Industrial Co-combustion", "Grate combustion", "Fluidized bed incineration")

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper / paperboard		Mixed household waste		Bulky waste	
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer		Waste tyres	
Hazardous waste					
Branch specific waste					
Other waste material	X	Exhaust gas from the incineration of waste			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pre-treatment of the input material:
The protection of the atmosphere from pollution and the precautionary principle require a treatment of gaseous and particle emissions from incineration processes as they may contain hazardous and potentially harmful substances. The treatment and cleaning of exhaust gases (especially the flue gas) is therefore a necessary, process-integrated component of waste incineration. An optimally controlled and managed incineration process can reduce the hazard risk and toxicity of the emissions considerably, making waste incineration even to one of the cleanest technologies of waste disposal in the overall.

Options for the utilisation of the generated output:
Part of the residues from exhaust gas cleaning can be recycled or further utilized (e.g. FGD gypsum)

Options for the disposal of process output and/or residues:
An essential portion of the substances washed and filtered out in the cleaning process as well as other cleaning residues require special handling due to harmful substance concentrations and hazardousness. The disposal must be undertaken at specially secured landfills for hazardous waste, a preferable option are underground storages (see fact sheet on "Landfill for hazardous waste")

Aftercare requirements:
The reaction products with problematic toxic and leachable substances (heavy metals, dioxines/furans, PAHs) as obtained in dry and semi-dry exhaust gas cleaning lead to the need for diligent aftercare which a proper post-treatment and disposal in appropriate underground storage facilities can provide (see fact sheet on "Landfill for hazardous waste"). The same applies for the evaporation residues from wet gas cleaning techiques. Aftercare measures for deposited gas cleaning residues must comply with the specific rules for the used disposal facilities.

Protective needs:
The handling of exhaust gas cleaning residues must be undertaken with the necessary precaution and protection to which belong the encapsulation and/or immobilization of the filter dust, ashes and scrubber residues.

Potential health risks:
A release of untreated flue gases pose a health risk which can be avoided if contemporary cleaning techniques and protective measures as indicated in this fact sheet are employed and properly followed. Waste incinerators using state-of-the-art cleaning technologies are nowadays considered as not threatening human health any longer.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION

Exhaust gas cleaning is an integrated part of any waste incineration process. Whatever conditions and restrictions influence these processes must be considered for the exhaust gas cleaning as well which is why this fact sheet should be always studied and used in combination with the information provided on the different incineration techniques (see fact sheets on "Industrial Co-combustion", "Grate combustion", "Fluidized bed incineration").

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

Exhaust gas cleaning systems serve the abatement of the hazard potential of emissions resulting from waste incineration processes and the best possible reduction of the harmful substances they contain. To the typical air polluting substances forming during the incineration processes belong:

- particulate matter, dust (PM),
- carbon monoxide (CO),
- nitrous oxides (NO_x),
- sulphur oxides (SO_x),
- halogen hydracid (HCl, HF),
- organic pollutants (e.g. PCDD/F) and
- heavy metals (e.g. Hg, Cd, As).

Effective exhaust gas cleaning systems may include dry, semi-dry and wet cleaning techniques. Wet techniques can be operated with or without the generation of waste water amounts. The cleaning effect results from the combination with flue gas desulfurization (FGD) technologies, PM control technologies, and flue gas NO_x removal and comprise several devices such as afterburners, spray quench, baghouse, electrostatic precipitators, fabric filters, wet scrubber and catalytic converters. These systems are connected to the flue gas stream and exhaust manifolds of the incineration facilities

BASIC REQUIREMENTS

Exhaust gas cleaning systems must be set up and operated with permitted technologies and have to become part of the overall plant permitting procedure. European plants are not allowed to transgress with the treated and cleaned exhaust gas the emission values as contained in the European Directive on Industrial Emissions (see fact sheet on "Technology-oriented regulations"). These values prescribe the minimum achievable standard.

Table 15: Critical emission values (limiting values) for exhaust gases from incineration processes in the EU

Parameter	Daily average in mg/Nm³ dry (at 11 Vol.-% O_2 dry)
Total dust	10
TOC	10
HCL	10
HF	1
SO_x	50
NO_x	200–400
CO	50
Hg / Sum of Cd + Tl	0.05 / 0.05
Sum of Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V	0.5
Dioxine and Furans	0.1 ngl-TEQ/Nm³ dry (at 11 Vol.-% O_2 dry)

EXPECTED RESULTS

- a cleaned stream of exhaust gases resulting in maximum emissions as stipulated (see for example Table 15) when released over the chimney and other exhaust manifolds of the incineration facility, therefore not harming human health, other organisms and the environment
- residues, which need to be properly disposed of with respect to their load of harmful substances and toxicity, especially:
    - caldron dust, slag and ashes, filter dust
    - reaction products resulting from acid gas scrubbing
    - heavy metal-containing sludge (from gas washing/wet scrubbing)
    - loaded absorbents (e.g. activated charcoal)
    - FGD gypsum

SPECIFIC ADVANTAGES

Exhaust gas cleaning
- makes an environmentally benign incineration of waste possible
- supports environmental and climate protection efforts
- rises the general acceptance for waste incineration processes and therewith allows that these processes can be applied on larger industrial scale as an option for the save waste disposal in combination with energy recovery

SPECIFIC DISADVANTAGES

- Exhaust gas cleaning is an expensive process and creates particular aftercare needs for the process residues

APPLICATION DETAILS

TECHNICAL SCHEME

Significant concentrations of different harmful pollutants would be discharged to the environment with the flue gas forming during the combustion process in waste incineration facilities if no gas cleaning would be undertaken. The main purpose of exhaust gas cleaning is therefore to eliminate to the most possible extent the pollutants which can be contained in these gases as indicated in Table 16 below. Exhaust gas cleaning systems concentrate especially on the abatement of air-borne emissions and a separation of harmful components from the exhaust gas stream in such a way that certain legal standards, like the EU and other countries have fixed them, are being reliably met. These systems are therefore an obligatory and directly integrated part of incineration facilities for waste as shown below in Figure .

Effective gas cleaning is no uniform procedure. All processes and techniques described hereunder can be employed in a wide variety of combinations. This is making it possible to set up a process chain for the gas cleaning adapted to the different kinds of incineration input, the combustion throughput and technology employed and the specific location of the plant.

Figure 25: Example of a waste incineration scheme with the different technical components for exhaust gas cleaning directly connected to the process

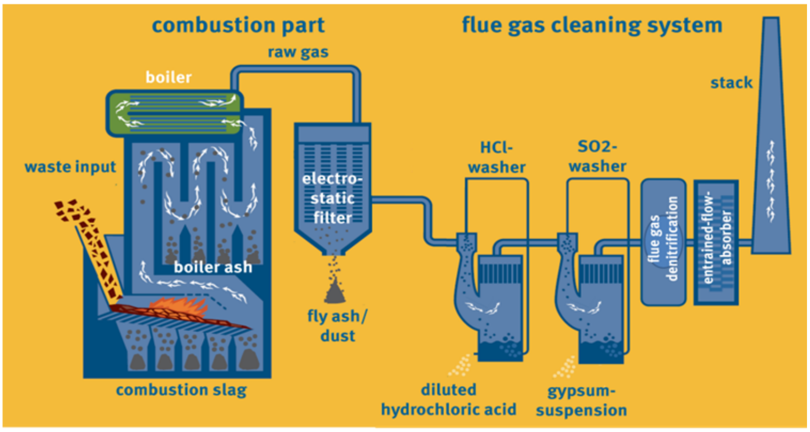


Table 16: Pollutant concentrations in the raw gas of a MSW incinerator (Source: Thomé-Kozmiensky, Löschau, 2014[32])

Polluting substances	Raw gas concentration as obtained from household waste incineration in modern facilities [mg/Nm³ dry]	
	Total range	Daily average
Total dust	800–5,000	2,500
HCl	200–2,500	1,500
HF	2–100	15
SO_2	200–1,000	600
Heavy metals	1–35	1–35
NO	Fluidized bed incineration 180–250 Grate combustion < 450	Grate combustion 350
Dioxine/Furans	1–3 ng TE	2 ng TE

[32] Immissionsschutz, Band 4. TK Verlag Neuruppin, 2014

The separation/capture of the polluting substances listed in Table 16 works as follows:

a) *Dust*

The dust contains mainly volatile heavy metals as well as a large amount of organic compounds. The content of dioxins/furans is especially large. To eliminate dust, mainly fabric filters and electrostatic precipitators are used. In single cases there are also mass force separators (such as gravity separators, cyclones or multi-cyclones) for the pre-separation of particles and wet scrubbers (venturi scrubber) in use. The following Table 17 provides an overview of the principle characteristics of these techniques.

Table 17: Principle characteristics of dust removal techniques (Source: Thomé-Kozmiensky, Löschau, 2014[1])

Separator technique	Total separation efficiency	Achievable dust content in the cleaned gas	Separable grain size x_p	Application
	%	mg/Nm³ tr.	µm	
Gravity separator	‹60	1,000	›10	Pre-separation of coarse dust
Centrifugal separator: cyclone/multicyclone	80/95	300/150	›5/›5	Pre-separation of coarse dust
Electrostatic precipitator - dry	80–99.9	25	›1	Dust extraction
Electrostatic precipitator - wet	90–99.9	‹5	›0.05	Aerosol removal
Dry separation filter fabric filter	›99.9	‹2	›0.1	Dust extraction
Wet scrubber venturi scrubber	›99.9	‹5	›0.05	Aerosol removal

b) *Acid noxious gases HCl, SO_2, HF*

Acid noxious gases can be eliminated from the exhaust gas by means of dry, semi-dry, or wet techniques. The cleaning residues from wet techniques accumulate in a diluted or suspended form (diluted hydrochloric acid, gypsum suspension) whereas in the dry and semi-dry systems they are collected in a dry solid state (e.g. natrium chloride). A dry system is characterized by spraying for example lime or sodium bicarbonate into the flue gas stream, which is passing through a quench before. The polluted matter will be eliminated by a fabric filter.

To the semi-dry systems belong the spay absorption with hydrated lime and the conditioned dry gas cleaning process with sodium bicarbonate or hydrated lime in a powdered form. The following Table 18 provides an overview on key parameters of the different systems.

Table 18: Cleaning concepts for acid noxious gases in an overview (Source: Thomé-Kozmiensky, Löschau, 2014[1])

Parameter	Wet scrubbing		Spray absorption	Conditioned dry cleaning process	Dry cleaning process	
Adsorbents	H_2O CA(OH) or $CaCO_3$	H2O NaOH	$Ca(OH)_2$	$Ca(OH)_2$	$Ca(OH)_2$	$NaHCO_3$
Physical state of the adsorbents	liquid (suspension)	liquid (solution)	liquid (suspension)	solid (powder)	solid (powder)	
Temperatur of the gas in the reactor	saturation temperature (approx. 50–60 °C)		coal: ~70°C biomass: ~100°C waste: ~140°C	coal: ~70°C biomass: ~100°C waste: ~140°C	boiler outlet temperature	
Introduction of the adsorbents	spraying		spraying	additional spraying of water	none	
Main reaction products	HCl $CaSO_4$	HCl Na_2SO_4	CaCl, $CaSO_4$, $CaSO_3$	CaCl, $CaSO_4$, $CaSO_3$	CaCl, $CaSO_4$ $CaSO_3$	NaCl Na_2SO_4
Physical state of reaction products	liquid (suspension/ solution)		solid (dust)	solid (dust)	solid (dust)	

c) Nitrogen Oxides

In case a removal of nitrogen oxides cannot be avoided by pyrotechnical measures, there exist mainly two processes for the removal of nitrogen oxides from the exhaust gas:

- SNCR process (Selective Non Catalytic Reduction) and
- SCR process (Selective Catalytic Reduction).

The *SNCR-process* reaches an elimination rate of NO_x of 50 to 60 % (in the most contemporary installations and under optimal conditions also up to 85%) by spraying a nitrogen compound (mostly urea or NH_3) through a nozzle into the hot flue gas (at around 850–1100°C, preferably at 950°C). It takes approx. 1 kg of ammonia to eliminate 1 kg of nitrogen oxide from the exhaust gas.

In the *SCR-process* or Selective Catalytic Reduction the flue gases are dusted off and freed from acid noxious gases first. Then nitrogen oxides are destroyed catalytically at 180 to 450°C, with the optimal range for the temperature being between 350 °C and 400°C. The same catalytic agents can be used to destroy dioxins too, if their contact surface is sufficient. The elimination rate of NO_x can go above the average of 90–92%. The demand of ammonia needed for the reduction at the catalytic converter theoretically amounts to 0.388 kg per 1 kg of nitrogen oxide eliminated from the exhaust gas.

Neither the SCR nor the SNCR generates residues, however a loss of ammonia must be observed and measures undertaken to keep this loss below the legally prescribed limits (in Germany currently prescribed in the 17. BImSchV). Both processes are summarized in the following Table 19.

Table 19: Characteristics of the two principal processes for the elimination of nitrogen oxides from exhaust gas

	SNCR	SCR
Concentration of NO_x in the cleaned gas	< 150 mg/m³	< 80 mg/m³
Advantages	- reasonably expensive - good cleaning efficiency - reduces the De-Novo-Synthesis and therewith formation of Dioxins/Furans	- very high cleaning efficiency - can be used to destroy Dioxins and Furans directly
Disadvantages	- the temperature window when the reduction agent must be sprayed into the gas stream can be easily missed in boilers with a fluctuating temperature distribution - the SNCR-process might not be effective enough to reach the prescribed values for the cleaned gas in cases where the original NO_x-rates in the raw gas are extremely high	- high costs for the maintenance of the catalytic converter - regular control and maintenance work becomes necessary due to the load of (non-removed) dust, this lowers the effective operating hours and thus the throughput - prone to react with gas components (e.g. heavy metal components) with the effect that the catalytic converter can be „poisened“ and suffer in its functionalitiy

d) Heavy metals and Dioxins

Dioxins, furans, and heavy metals that pass through the scrubber can be eliminated from the exhaust gas by activated carbon, activated coke, or activated carbon-lime-mixtures. Two processes are available:

- fly-flow adsorption (adding activated coke–lime and mixing it with the flue gas) and
- fixed bed adsorption (rarely in use, because of high costs and vulnerability to failures)

Heavy metals (especially mercury and cadmium) as well as dioxins/furans that pass through scrubber systems can be eliminated from the exhaust gas with the help of activated carbon/hydrated lime suspension. Very reliable as a cleaning process has proved fly-flow adsorption working on the basis of a coke or lime/sodium bicarbonate mixture brought in contact with the exhaust gas. Fixed bed adsorption is rarely used mainly due to the higher costs and more difficult handling of the process. The main features of both processes are summarized in Table 20 below.

Table 20: Processes used for an adsorption of heavy metals and dioxins/furans during exhaust gas cleaning

	Fly-flow adsorption	Fixed bed adsorption
Concentrations in the cleaned gas: - Dioxins - Heavy metal	‹‹ 0,1 ng TE ‹ 0,1 mg	‹‹ 0,1 ng TE ‹ 0,1 mg
Temperature	max. 150 °C	max. 150 °C
Advantages	- good cleaning efficiency - reasonably expensive	- very high cleaning efficiency - non-sensitive to a variation of the gas concentrations
Disadvantages	- Risk of slip-through (under high loads)	- Risk of fire - expensive - high CO-emissionen during start-up operations
Adsorbents and residues of them	activated carbon or coke partly in a mix with lime and/or sodium bicarbonate	activated carbon or coke

Activated carbon or coke bind heavy metals (primarily mercury and cadmium) as well as dioxins/furans. Next to this, a slight up-concentration of sulfur and chorine can be achieved. As a rule, these materials are returned to the boiler, as long as Hg and Cd are precipitated in flue gas precipitation (e.g. an acidic scrubber).

QUANTITY ASPECTS

The possible reduction rates for the different pollutants in the exhaust gas are described above in conjunction with the different cleaning techniques employed

SCALE OF APPLICATION

- A cleaning of the exhaust gases from combustion processes has to be an integrated part to all kinds of waste incineration facilities according to legal requirements. See therefore also the fact sheets on the different incineration technologies; “Industrial Co-combustion“, “Grate combustion“, “Fluidized bed incineration“

INTEROPERABILITY

- Techniques that provide for a cleaning of the exhaust gases can be integrated to any combustion system, including thermal facilities not using waste as an input material

OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION

ENERGY BALANCE

CO_2-BALANCE

- both determined by the applied combustion process and the intensity of the emissions resulting from it

AIDS/ADDITIVES NEEDED

- sodium bicarbonate, limestone/powdered limestone or lime hydrate (slaked lime) to absorb respectively reduce acid pollutant gases
- Coal, coke from lignite for the absorption of heavy metals and dioxins: ‹0.8 kg/Mg waste input
- Urea or ammonia water (25%) for NO_x-reduction)
- Water

HUMAN RESOURCES

- The gas cleaning process does not rise the personnel demand in addition to the staffing requirements of the incineration facility where it is operated, however there is an additional disposal need for the residues from exhaust gas cleaning which must be attended and causes personnel to work on

SPATIAL NEEDS

- The additional space demand for boiler installations including the appropriate exhaust gas cleaning systems is substantial when compared with the system proper for the ordinary combustion. When dimensioning the area some reserve space should be considered for upcoming measures to retrofit or upgrade the gas cleaning system.

OPERATIONAL BENCHMARKS: COST DIMENSIONS

INVESTMENT COSTS

Dry and quasi-dry exhaust gas cleaning systems 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 exhaust gas cleaning system.

Capital investment per unit to be set up (average price range established in 2008):

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

- Construction costs : 4,500,000 EUR
- Equipment : 13,000,000 EUR
- Additional expenses, financing: 3,500,000 EUR

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

- Construction costs : 7,500,000 EUR
- Equipment : 20,000,000 EUR
- Additional expenses, financing: 5,500,000 EUR

The total system investment (capital expenses) taking a dry sorption exhaust gas cleaning in different configurations as an example can be in the range from EUR 8 million (with SNCR) to EUR 12 million.

The investment required to set up a SCR or SNCR system of different efficiency can differentiate as follows:

Table 21: Investment costs for SCR and SNCR gas cleaning processes (Source: Beckmann, 2011[33])

SNCR process	NO_x-cleaned gas concentration	mg/Nm³ dry	200	150	100
	Total investment	EUR	265,000	280,000	525,000
SCR process	NO_x-cleaned gas concentration	mg/Nm³ dry	150	100	50
	Total investment	EUR	2,280,000	2,308,000	2,365,000

OPERATING COSTS

- The running costs strongly depend on the market prices for cleaning agents and auxiliary materials. The following Table 22 displays some orientation values for operating materials despite of the fact that prices for them often fluctuate on the market

Table 22: Cost examples for operating materials in gas cleaning processes (Source: Beckmann, 2011[2])

Material	Price
Sodium bicarbonate (98 mass-% $NaHCO_3$)	230 EUR/Mg
Activated coke	420 EUR/Mg
Ammonia water (25 mass-% NH_3)	100 EUR/Mg
Dilution water (Deionat)	4 EUR/Mg
Disposal costs for gas cleaning residues	135 EUR/Mg

- Repair and maintenance costs: for each structural element approx. 1% of the initial investment; for machinery and electronic parts: approx. 3–4% of the initial investment
- The overall operating expenses taking a dry sorption exhaust gas cleaning in different configurations as an example can be in the range of approx. EUR 1.5–2.3 million per annum

POSSIBLE PROCEEDS

- From the sale of FGD gypsum and hydrochloric acid (in a cleaned state) which are both by-products from exhaust gas cleaning

MASS SPECIFIC OVERALL COSTS

- are included in the figures provided for the different waste incineration technologies; see therefore also the fact sheets on “Industrial Co-combustion“, “Grate combustion“, and “Fluidized bed incineration“

[33] Beckmann: Beschreibung unterschiedlicher Techniken und deren Entwicklungspotentiale zur Minderung von Stickstoffoxiden im Abgas von Abfallverbrennungsanlagen, Umweltbundesamt 2011, http://www.uba.de/uba-info-medien/4196.html

OTHER RELEVANT ASPECTS	
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(Note: the list of sites and/or firms does not constitute a complete compilation)*	- See the fact sheets on the different incineration technologies; "Industrial Co-combustion", "Grate combustion", "Fluidized bed incineration"
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(Note: the list of firms does not constitute a complete compilation of companies)*	Recognized producer/provider firms for exhaust gas cleaning technology and components in Germany are for example: - LAB GmbH, Stuttgart www.labgmbh.de - MARTIN GmbH für Umwelt- und Energietechnik, München www.martingmbh.de - ENVIROTHERM GmbH, Essen www.envirotherm.de - Hitachi Zosen Inova Kraftwerkstechnik GmbH, Landsberg www.hz-inova.com - Steinmüller-Babcock Environment GmbH, Gummersbach www.steinmueller-babcock.com

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

Further information and compilations on relevant details and plants can be obtained from:

- ITAD – Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland e.V. www.itad.de
- CEWEP – Confederation of European Waste-to-Energy Plants www.cewep.com

PHOSPHOROUS RECOVERY FROM MUNICIPAL SEWAGE SLUDGE

APPLICATION OBJECTIVE:	- After-treatment of municipal sewage sludge or of the ash remaining from the monovalent incineration of sewage sludge in order to recover phosphorous as an increasingly scarce resource

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper/paperboard		Mixed household waste		Bulky waste	
Lamps		Textiles		Electrical & electronic waste	
Scrap metals		Wood waste		C&D waste	
Waste oil		Old paint & lacquer		Waste tires	

Hazardous wastes		
Branch specific waste	X	potentially feasible with excess liquid manure, meat-and-bone meal, other phosphorous containing organic matter
Other waste materials	X	Sewage sludge from municipal wastewater treatment respectively ash from monovalent sewage sludge incineration

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION:

Pre-treatment of the input material:

The phosphorous in products from the wastewater treatment is chemically differently bound which is why pretreatment steps are required for its recovery. A large portion of the phosphorous is present in dissolved form so that a particulate condition must be induced by way of chemical precipitation or through a biological accumulation in the sludge while passing a plants biological treatment stage. The recovery process can be initiated then in the sense of a special extraction of phosphorous with the phosphate-enriched suspensions. Prerequisite for recovery procedures applied on sewage sludge ash is a preceding monovalent sludge incineration.

Options for the utilization of the generated output:

Recovered phosphorous compounds which passed a cleaning and possibly another form of processing have a relatively broad range of use. Depending on the recovery process various products for different applications are obtainable. Calcium phosphates are won in wet-chemical and from thermochemical processing. They are generated by precipitation or crystallization and also by a thermochemical accumulation in the product. Calcium phosphates are used as slow-release fertilizers mainly, thus substituting certain amounts of mineral fertilizers made from raw phosphate of sedimentary origin. Aluminium phosphate and iron phosphates are won in wet-chemical processes and by thermochemical treatment. Their usage as a fertilizer is limited, however. Elemental phosphorous for industrial applications and heavy metals for zinc and copper smelting can likewise be generated.

Aftercare requirements:

Remaining sewage sludge can be treated and mineralized in monovalent or co-incineration plants. Residual ash and process remains can ideally be utilized like residues from other combustion processes, for backfilling operations or otherwise they must be disposed of on hazardous waste landfills.

Protective needs:

Handling sewage sludge due to the high bacterial load of wastewater is at any time associated with a health risk. Depending on the operation, there can be a risk during the process of phosphorous recovery from operating aids and auxiliary agents and the harmful effects going out from them for health. In addition, the resultant products are directly dangerous to health and in some cases highly flammable and eutrophic. Precaution and personal protection measures are to be applied correspondingly.

Financing options:

Phosphorous compounds which can be obtained from recovery processes have the quality of fertilizers with good plant availability. This renders them to products the plants can sell to earn income for refinancing parts of the investment. Fee systems established for the wastewater collection and treatment services form an additional instrument for refinancing. European and national support schemes are occasionally in place to help financing the development and implementation of phosphorous recovery. Combining new investment projects for wastewater treatment with phosphorous recovery can be an asset when applying for international donor assistance.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION:

Points of application:
The potential, effort and efficiency of phosphorous recovery differ, inter alia in dependence from the starting point of treatment. An orientation might be found in the following characteristic values:

Extraction site	Total load of phosphorous (relative to incoming load)	Phosphorous concentration	present as
Effluent discharge	10 %	‹ 0,8 mg P/liter	dissolved + particulate
Sludge water	in the moment of precipitation: ‹ 5% biological P-elimination: up to 50 %	‹ 20 mg P/liter up to 400 mg P/liter	dissolved + particulate
Digested sludge (at 30 % dry residues)	90 %	›10–approx. 20g P/kg sludge	biologically and chemically bound
Ash	90 %	approx. 60 g P/kg ash	chemically bound

Data source: Study Phosphorous recovery from waste water and sewage sludge, TBF + Partner AG, Zurich 2015 + empirical data UBA

Infrastructural conditions:
Plants for phosphorous recovery should be set up near the points of sludge generation (thus mostly in the wastewater treatment plants) to keep the costs for logistics as low as possible. For the operation of the plants an access to the grid is important. In addition, appropriate storage areas are needed for the different material flows.

Climatic conditions:
of no influence

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

In sewage sludge the phosphorous is bound chemically and biologically. Three technical options have gained greater interest for the recovery of phosphorous in the process of handling sewage sludge thus far. These are:
- the wet-chemical processing and disintegration of the sewage sludge or sewage sludge ash with the help of caustic and acid products (e.g. Seaborne-process);
- a direct form of extraction and utilization from the digester sludge (e.g. Airprex-process);
- the thermochemical recovery of the phosphorous out of the sewage sludge ash.

BASIC REQUIREMENTS

- At the inflow to the wastewater treatment plant phosphorous is partly dissolved and partly in a chemically or biologically bound state. The particulate phosphorous can be extracted by sedimentation. A large part of the phosphorous is however present in a dissolved form. Since an elimination of phosphorous from wastewater is generally advisable, this part needs to be converted in a particulate state, too. This can be achieved by chemical phosphate precipitation based on the addition of precipitating agents, or by biological phosphate fixation through above-average phosphorous uptake of specialized bacteria in the biological stage of the sewage plant. Depending on the recovery method the sludge thus generated can be treated for the purpose of phosphorous extraction before respectively after the digestion process or after drying.
- In case of an application of recovery procedures on sewage sludge ashes is required the preceding monovalent incineration of sewage sludge and, if necessary, the briquetting or palletisation of the ashes.

EXPECTED RESULTS

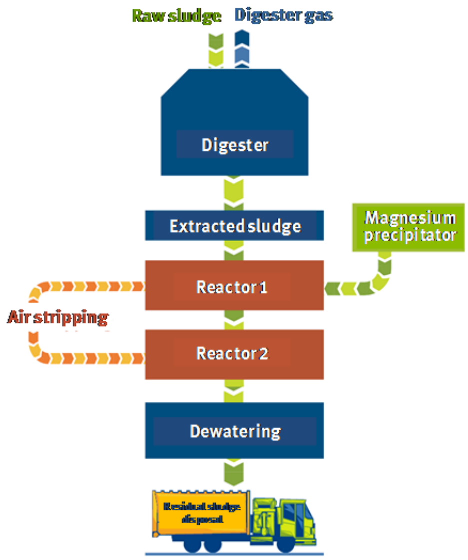
- A substantial phosphorous elimination from sewage sludge or sludge incineration residues is taking place while at the same time industrially usable phosphorous respectively phosphates that have fertilizing quality can be obtained. With that a scarce raw material resource is protected and an eutrophication of water bodies prevented.
- The phosphorous loads in municipal wastewater treatment plants have their origin largely in human faeces, since phosphate-free detergents have meanwhile penetrated the markets. This makes it highly unlikely that phosphorous loads in municipal wastewater will decline in the future.

SPECIFIC ADVANTAGES	- The recovery of phosphorous from sewage sludge allows the direct sludge use in a fertilizing function on land as method which for several reasons is not effective and any longer advisable (loads of hazardous, groundwater-polluting and endocrine disrupting compounds; limited plant availability of nutrient content) to be ceased. All processes described here provide products of fertilizing quality and with lower pollution than conventional mineral fertilizers produced from raw phosphate of sedimentary origin (inter alia less cadmium and uranium). - The elimination of phosphorous has a positive impact on the further processing of the sludge, e.g. the efficiency of dewatering. - Installations for phosphorous recovery can often quite easily be retrofitted in the plants and integration into the wastewater or sludge treatment process is therefore possible. In addition, the installations are not only suitable for sewage sludge but other phosphorous potentials can be tapped with them as well. - In the thermal process is effected a simultaneous energetic and material use of the sewage sludge, a lasting destruction of organic pollutants is achieved as well.
SPECIFIC DISADVANTAGES	- The construction and operating costs differ widely and can be very high depending on the type of plant. - Incompatibilities can happen. Some processes are applicable in combination with specific plant configurations only. The process management is very complex and demanding. - The phosphorous recovery rate of each process differs greatly and can in some cases also yield relatively small results. Optimization is taking a long way. - Long-term valid conclusions concerning the economic efficiency of the various processes have not been derived yet because the experiences gained are rather limited and nearly on the pilot stage so far.
APPLICATION DETAILS	
TECHNICAL SCHEME	Processes for the recovery of phosphorous can be integrated at different stages of municipal wastewater and sludge treatment. Portions of the dissolved phosphorous in the wastewater and most of the colloidal, fine particulate phosphorous load are incorporated into the activated sludge or excess sludge leaving the cleaning system, the phosphate released during the decomposition of organic substances in the digester for the most part is bound by flocculating agents. That is why the currently established methods for phosphorous recovery concentrate on the said suspensions mainly. The type of chemical bonding and concentration of phosphorous in the medium to which the technical measures for its recovery will be applied is critically important to achieve a high recovery rate. In Europe only a few process operators today can assert the economic viability of the applied phosphorous recovery processes, there are many more processes however that are just at the pilot stage and have not yet achieved market maturity. Now here further specified shall be processes which are applied on either the drained digested sludge or on the ashes from sludge incineration and already proved to yield reliable results over time. <u>Phosphorous recovery from digested sewage sludge in the wastewater treatment process</u> Applied here are processes that work with crystallization and precipitation of the dissolved phosphorous, incompatibilities with other P-elimination must thus be observed. To the methods which right now are conceivable as reliably functioning and expandable recovery approaches from dewatered digested sewage sludge belong the following two processes: **AirPrex®-Process:** This process is based on the precipitation of magnesium ammonium phosphate (MAP) and was originally developed by the Berliner Wasserbetrieben (BWB) for preventing MAP-incrustations in pipelines of sewage plants. It is applied after the anaerobic stabilisation prior to dewatering. Sludge from the digester is fed directly to a multi-stage reactor system and subjected to air stripping. While carbon dioxide escapes the pH is raised and magnesium chloride added. MAP which precipitates during this process in crystalline form can be removed at a later stage from the sludge. It can be further processed into a product with proven potential as an agricultural fertilizer. For a successful process, the pH, phosphorous content and the quantity and type of precipitating agent must be precisely synchronized.

TECHNICAL SCHEME – CONTINUATION

The following figure illustrates the process in a simplified manner.

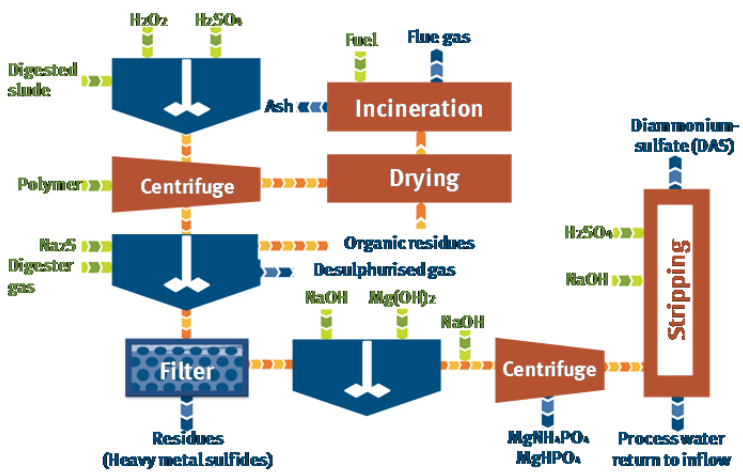
Figure 26: Basic configuration for the application of the AirPrex®-Process *(modified illustration of BAFU, 2009)*



The plant in Berlin realized -depending on the aeration effort- a recovery rate of phosphorous between 3.5% and 8 % of the phosphorous load on the wastewater intake of the plant.

Seaborne-Process:
This relatively complex and expensive process has been successfully adopted at the wastewater treatment plant in Gifhorn, Germany. Right after the digestion step, a separation of heavy metals and nutrient recovery is performed in two cycles. In the first process step heavy metals and nutrients are remobilized by adding sulphuric acid to the sludge and decreasing its pH-value. The solids are separated using a centrifuge and filter system. Biogas from the digester is then passed through the liquid phase in a reactor. Hydrogen sulphide in the biogas reacts with the heavy metal ions in the liquid to heavy metal sulphides. These precipitate from the liquid and are removed. The digester gas is desulphurised by that and better usable now in co-generation units. The next cycle serves the nutrient recovery. After the addition of sodium hydroxide (to adjust/raise the pH-level) and magnesium oxide as precipitating agent, ammonium, magnesium and phosphorous crystallize to MAP. The precipitate is separated from the liquid by a centrifuge and dried. Surplus nitrogen is separated as di-ammonium sulphate (DAS) in a stripping process. MAP and DAS can be used in agriculture. The following is a simplified process illustration:

Figure 27: Simplified illustration of Seaborne-Process *(modified graphic of BAFU, 2009)*



Good progress towards industrial-scale application and hence likewise considerable as alternative options in future are also processes such as Ostara Pearl®, NuReSys® oder Fix-Phos.

TECHNICAL SCHEME - CONTINUATION

Recovery of phosphorous from the ashes of sewage sludge

The type recovery processes depicted hereafter can be done with the ashes from the mono-valent incineration of sewage sludge only. Basically two approaches have emerged for that until to date. These are the wet-chemical processing and the thermal extraction. The phosphorous in the ash is chemically bonded in the form of iron-, aluminium and calcium phosphates. Latter is the most common compound. The content of phosphorous in the ash from sewage sludge is usually in the range of 5–10 % (in average 64 g P per kg ash). In the most favourable case a recovery rate of up to 90 % can be achieved by selected applications.

Wet-chemical processing methods:

In the wet-chemical approach, phosphorous is dissolved from the ashes by an acid suspension, for example with sulphuric acid. Problematic hereby is that parts of the heavy metals are also brought into solution with this. They can subsequently be precipitated, for example as sulphides and separated from the dissolved phosphate, however. Depending on the pH the phosphates then fall out during the neutralization as aluminium phosphate, iron phosphate and calcium phosphates. Calcium phosphates will be mainly won if the pH is raised with lime. On a good way to a larger-scale implementation and thus considerable as alternative options for acid hydrolysis processes are the Stuttgarter Process as well as the Tetraphos and the Budenheim Carbonic Acid Process.

Thermal extraction methods:

To describe this method two processes can be referenced, both which have evolved from the pilot stage in the past to processes which reached an industrial application in the meantime.

ASH DEC (Outotec)-Process:

The advantage of this proven technique lies in the separation of a small side stream of a heavy metal concentrate from the main material flow, while the phosphorous-rich stream is converted into a useful product. The ash is homogenized with alkaline chloride in an intensive mixer and then pelletized. Composition and dosage of the additives are essential parameters, which help the calcium and aluminium phosphates to be turned into soluble phosphate compounds and toxic substances to be removed via the gas phase. The pellets are placed in a thermal reactor and exposed to temperatures around 1000°C for 30 minutes. 99 % of the heavy metals, especially mercury, cadmium and lead, react at this temperature with the additives and evaporate. The concentration of other heavy metals which are permitted as trace elements for agricultural use are also lowered this way. 97 % of the ash input is converted into a directly usable P-rich granulate. 3 % of the ashes are kept back as a metal concentrate from a multiple stage flue gas cleaning system. A disadvantage of this process is the high energy demand. A snapshot of the original pilot installation can be seen below.

Figure 28: ASH DEC-pilot installation in Leoben, Austria, 2008 *(photo courtesy of Outotec GmbH & Co. KG)*

TECHNICAL SCHEME - CONTINUATION	**Mephrec®-process:** The Mephrec-Process enables the recovery of phosphorous in a metallurgical process which does not only suit for sewage sludge but other material containing phosphorous too (e.g. meat-and-bone meal). Slightly dried sewage sludge (e.g. 25% dry residues content) alone or in mixture with sludge ashes or meat-and-bone meal of sufficiently high P_2O_5 content put in briquette form is exposed to a high-temperature (2.000 °C), oxygen driven melt-gassing process in a shaft furnace. The resulting phosphate slag is granulated in a water-bath and gives a ready-to-use fertilizer. High-melting heavy metals are removed in a separable metal alloy, whereas low-melting metals such as (zinc, cadmium, mercury) evaporate and deposit in an adequately installed flue gas cleaning system.
QUANTITY ASPECTS	Depending on the process, different mass flow proportions can be observed. The technical publication *“Sewage sludge management in Germany“* of September 2013 provides the following orienting values: - The AirPrex®-Process supplies about 2 Mg MAP/day at an input of 100m³/h - The Seaborne® process supplies from an input of 120 m³ digestion sludge per day an average quantity of 1.3 Mg MAP/day, equivalent to an annual quantity of phosphorous of about 60 Mg. - Wet chemical processes with MAP as a precipitate enable a recovery of approximately 40% to 70% of the phosphorous contained in the inflow to the wastewater treatment plant. - Thermo-metallurgical processes enable almost a complete recovery (‹90%) of the phosphorous contained in the inflow to the wastewater treatment plant. - Thermochemical processes of the company Outotec (formerly Ash Dec), based on a phosphorous content of around 9% in the plant inflow, were generating about 10,000 Mg/a phosphorous fertilizer at an input of 12,000 Mg/a sewage sludge ash within the framework of the EU project SUSAN. - The Mephrec® process as a metallurgical process offered by the company Ingitec from Bavaria generates from approximately 60,000 Mg/a sewage sludge (25% dry residues content) the quantity of 12,000 Mg/a of a directly usable phosphorous-rich granule (slag). This ultimately corresponds to a phosphorous substitution of about 500 Mg/a. * *Conversion of phosphorous shares from P_2O_5 = 43,64% and MAP = 12,62%*
INTEROPERABILITY	- Phosphorous recovery processes are generally well integrable into the overall processes of wastewater treatment plants, the necessary technical installations can be additionally erected respectively retrofitted to existing processing lines directly on-site. - As a recommended option for sewage sludge disposal monovalent incineration can be coupled with phosphorous recovery and thus simultaneously implemented.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	- The energy demand depends on the chosen process of phosphorous recovery and can be significantly high. For the ASH DEC (Outotec)-Process an energy consumption of 400–850 kWh per ton of ash has been earmarked. Co-generation with digester gas and sludge incinerating processes can supply (parts) of the energy needed.
HUMAN RESOURCES NEEDED	- Operating plants with installations for phosphorous recovery requires qualified and well trained personnel especially in the fields of process management and monitoring. The exact staffing requirements depend on the plant size and the level of process automation. - Normally, a large part of the processes can be handled from ordinary plant staff, provided that adequate supervision and training is ensured.
AIDS AND ADDITIVES NEEDED	- Depending on the process, various chemical additives for precipitation and extraction of the phosphorous are needed; see details provided for the above described processes.

SPATIAL NEEDS	- Depending on the process. Crystallization and precipitation processes generally have a small space requirement. In contrast, acid digestion methods need relatively more space. - The space requirement moreover is related to the treated substrate(s). The smaller the volume flow to be treated, the lower the required reactor volumes and therefore also the space requirements. - Installations for phosphorous recovery often can be directly integrated to the plant/ site.
AFTERCARE DEMANDS	- Process residues such as remaining sludge amounts and residual ash must be treated and disposed of in accordance with regular provisions and standards.
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- Highly variable. The capital investment for the referenced plant in Gifhorn, Germany, (user of Seaborne process), planned with a maximum daily MAP output of about 1.3–1.8 tons/day and realized in 2007, amounted to 7.6 million EUR in total (incl. demonstration and optimization). From this amount 4 million EUR were allocated to equipment and installation engineering. - For processes adopting the wet-chemical approach on sewage sludge ashes a total investment of about 11 million EUR at an annual treatment capacity of 15,000 tons is generally earmarked. - The known value range for investments into phosphorous recovery installations is stretching from 6 to 20 million EUR. (based on diverse sources/notifications available up until 2014)
OPERATING COSTS	- Operating costs respectively the costs needed for chemicals are the main cost drivers for most of the processes. Process costs are generally quite high and the recovered products therefore in most cases not yet competitive with the prices to purchase conventionally extracted phosphorous. - The process costs to precipitate MAP were seen at about the level of 3–4 EUR /kg P in 2010. - For the wet-chemical processing yearly operating costs up to 5.80 EUR/kg per dissolved phosphorous are reported, mainly as a result of the high chemicals consumption during extraction *(based on diverse sources/notifications available up until 2014)*. Process optimization is meanwhile allowing to realize significantly lower costs.
POSSIBLE PROCEEDS	- Income can be generated from the sale of the recovered phosphorous compounds (mostly fertilizer products). The annual revenue of the Ash Dec plant was expected to lie in a range between 4–12 million EUR.
MASS-SPECIFIC OVERALL COSTS	- A fairly young record of industrial testing and limited experience in realizing continuous recovery operations still renders the costs of recovery processes a subject to considerable uncertainty. The costs of phosphorous recovery by crystallization and precipitation processes are generally below those for acid hydrolysis and thermochemical recovery. Overall, the recovery costs are significantly higher than the cost of conventional phosphorous fertilizers. - Beside pure process expenses also the savings wastewater treatment plants can make from phosphorous recovery must be included in a comprehensive cost balance. Possibly the lowest overall recovery costs can be attained with the relatively expensive thermochemical processes when such possible savings are duly taken into consideration. Saved costs for sewage sludge disposal hereby play a fundamental role.
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(important note: the list does not constitute a complete compilation)*	According to the information source referenced below as [1] following plants in Germany are known or have envisaged to run a phosphorous recovery in the frame of their permanent operations. - Wastewater treatment plant Gifhorn (Seaborne-Process, MAP-precipitation), since 2007 - Wastewater treatment plant Waßmannsdorf, Berliner Wasserbetriebe (Airprex-Process) - Wastewater treatment plant Offenburg, Baden-Wurttemberg (Stuttgarter Process)

	- Wastewater treatment plant 1, City of Nuremberg (Mephrec-Process, melt-gassing process of sludge briquettes –currently in the stage of planning)
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	To the providers and technology developers of the described process applications belong the following firms: *Seaborne -Process*: - Oxytabs (former Seaborne), D-24768 Rendsburg *AirPrex®-Process*: - Pollution Control Service GmbH, D-22143 Hamburg www.pcs-consult.de *Mephrec®-Process* - Ingitec®Engineering GmbH, D-04178 Leipzig www.ingitec.de *Ash Dec-Process*: - Outotec GmbH & Co. KG: www.outotec.com/en/About-us/Acquisitions/ASH-DEC/

REMARKS AND FURTHER REFERENCE DOCUMENTS

Further details and supporting information on phosphorous recovery from sewage sludge can be obtained, among others, from:

- [1] Publication "Sewage sludge management in Germany" from January 2015 http://www.umweltbundesamt.de/en/publikationen/sewage-sludge-management-in-germany
- [2] Technical Guide on the treatment and recycling techniques for sludge from municipal waste water treatment from May 2015 https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/technical_guide_on_the_treatment_and_recycling_techniques_for_sludge_from_municipal_waste_1.pdf
- The German Association for Water, Wastewater and Waste e. V. (DWA), http://en.dwa.de/ with its DWA-library http://en.dwa.de/dwa-library.html

Temporary waste storage and final disposal

The traditional and widespread practice of waste disposal in landfills is more and more replaced by advanced waste treatment processes. The shift towards biological and thermal waste degradation methods is associated with the benefits of energy recovery from the waste materials, the segregation of recyclables and the reduced volume of solid waste that has to be deposited. The move away from landfilling is a necessary step for sustainable waste management but requires a consequent thinking in material loops and strict legal enforcement. The landfill directive which became the legislative backbone for this vision in the member states of the European Union stipulates that biodegradable waste for landfilling shall be gradually reduced and that waste must be pre-treated for this before being landfilled Further to this, a closure of all landfills as far as possible is envisaged in the medium perspective which says that all efforts must be directed on getting the total waste amounts reduced and all materials that arise as waste treated and eventually utilized.

A consequence of these provisions is that more and more wastes are being processed to permit their further utilization, whereas sufficient capacities shall be established for the treatment and utilization of processed wastes. Sufficient capacities for treatment and utilization cannot be guaranteed all the time and there can be circumstances that supplies or intermediate product amounts exceed the regularly available space of storage. For this it is essential that techniques and facilities for the <u>temporary storage of waste materials</u> are at hand or developed.

Even if wastes will increasingly be utilized and treated in a way that very little remains from them as non-usable residues, landfills are and for further decades will remain the last resort for an ultimate disposal of waste and waste residues in an environmentally relatively safe and controllable manner. In order for this to be achieved, three different categories of landfills are prescribed as the standard European countries have to ensure:

- landfills for non-hazardous waste,
- landfills for hazardous waste and
- landfills for inert waste.

The first category is the <u>landfill for non-hazardous wastes</u> like i.e. mixed domestic and commercial waste without higher concentrations of environmentally harmful or hazardous substances. This landfill category is the most extensively used method for the deposition of the residuals, which remain after the treatment of household and commercial wastes. It should be considered that a pre-treatment of materials, especially of the organic fraction, cannot totally eliminate the generation of greenhouse gases and leachates in the landfill body. It is for these reasons that landfills must be erected with the necessary precautions and equipment to collect and treat these emissions and prevent hazardous substances to penetrate into the soil and aquifer. In addition, measures for the aftercare are required over a period of at least 30 years.

The second landfill category is <u>landfill for inert wastes</u>. This kind of landfill has been defined as a place where mineral wastes or waste of completely inert character are deposited. As such the facilities use to serve especially for the deposition or storage of excavated soil, mining material and C&D waste of inert nature (e.g. stone, concrete, sand and mixtures of it).

The third category is the <u>landfill for hazardous wastes</u>. This landfill type is exclusively reserved for waste material which carries a potential risk or contains substances which can be harmful for the environment. For these reasons special protection and aftercare measures are being imposed for the establishment and operation of such landfills. Generally, landfills intended for hazardous wastes must be engineered with dual liners and related containment systems to protect the land and groundwater. State requirements regulate the monitoring and aftercare of such landfills. A complete list of precautionary measures is contained in the Landfill Directive for the European member states. As part of it all hazardous wastes shipped to these landfills has to be manifested so that it is possible to trace the waste from its place of origin to the place of final disposal. A standard waste acceptance procedure is laid down so as to avoid any risks.

As a general rule landfills shall only accept the wastes they are assigned for, i.e. hazardous waste landfills hazardous waste, landfills for non-hazardous waste non-hazardous municipal waste and landfill sites for inert waste inert waste only. Not to be accepted in a landfill of the above types should be:

- liquid waste,

- flammable waste,
- explosive or oxidizing waste,
- hospital and other clinical waste which is infectious,
- used tires, with certain exceptions and
- any other type of waste which does not meet the acceptance criteria set by the law.

Specialized treatment technologies that may have to be used prior to disposal in landfills include stabilization and neutralization of hazardous and non-hazardous sludge, soils, slurries, liquids, powders and dusts.

Various proprietary stabilization techniques are used for metal-bearing waste rendering an insoluble, solid material for safe landfill disposal. These treatment methods must be considered for special cases and are not a subject of this documentation.

Remark: Detailed descriptions of the technology and equipment referenced in the text are provided with the following factsheets.

Table 1: Overview of related factsheets

Related factsheets
Storage: Temporary waste storage
Final disposal: Landfill for inert wastes Landfill for non-hazardous wastes Landfill for hazardous wastes

Umwelt Bundesamt

TEMPORARY WASTE STORAGE

APPLICATION OBJECTIVE:

- The objective of this technique is a temporary storage of waste material awaiting further treatment. The temporary storage may be needed to buffer capacity bottlenecks in the subsequent treatment lines (long-term storage sites) or set up in case of plant inspections or breakdowns (short-term storage sites).

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packaging		Biowaste	
Paper/paperboard		Mixed household waste	X	Bulky waste	X[1]
Lamps		Textiles		Electrical & electronic waste	
Scrap metals		Wood waste		C&D waste	
Waste oil		Old paint & lacquer		Waste tires	
Hazardous wastes					
Branch specific waste	X				
Other waste materials					

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION:

Pretreatment of the input material:
The material subject to a temporary storage must be down-sized to give it a manageable composition. Alternatively, a pre-treatment of the required type may have been performed in conjunction with upstream treatment processes already (e.g. MBT).

Options for the utilization of the generated output:
in accordance with the utilization processes following

Aftercare requirements:
restoration of the storage area into the original state and conditions

Protective needs:
An air and water-resistant wrapping of the waste material should be ensured. Once put to storage the material must be monitored for gas generation and temperature development. The storage ground is to be sealed and a general protection against fire hazards must be undertaken.
The loose storage in open heaps or storage of unwrapped bales is not advisable as there is a great danger of self-ignition and fire hazards due to the exposure to air and available concentrations of oxygen.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION:

Infrastructural conditions:
A good accessibility to the storage site should be ensured. Permitted landfill sites do generally offer the necessary conditions for a temporary storage particularly the storage of untreated MSW.
A minimum requirement for the storage in wrapped bales is the availability of a staple geological underground with a sealed surface.

Climatic conditions:
basically there are no limitations, however, temporary waste storage sites in warm climates and with a high exposure to sunlight do have a higher risk of self-ignition and fire outbreaks

Availability of (qualified) workforce:
no extra need of specially qualified personnel

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[1] only shredded bulky waste

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

Temporary waste storage facilities can be necessary for waste like untreated MSW or high-calorific waste due to an unexpected shortage of available treatment capacity as a result of plant inspections or breakdowns. The storage in wrapped bales described more thoroughly in this fact sheet is widely approved. Also possible is the temporary storage of untreated MSW in thin-layers with high built-in density and covering on landfill sites. This procedure is similar to the disposal of waste in thin-layers on a sanitary landfill (see also fact sheet on "Landfill for non-hazardous wastes"). Strictly not advisable is the storage in open heaps and unwrapped bales due to the extreme fire hazards because of the influence of oxygen.

BASIC REQUIREMENTS

- area on staple ground and with a sealed surface or regular landfill site
- waste material which is not bulky and ready to be compacted

EXPECTED RESULTS

- Output: waste material suitable for further processing or treatment, which can be recycling or thermal utilization

SPECIFIC ADVANTAGES

- avoiding the disposal or utilization in third-party facilities

SPECIFIC DISADVANTAGES

- additional cost
- demand on area
- decrease of the suitability of high calorific waste for thermal utilization, after-treatment is necessary

APPLICATION DETAILS

TECHNICAL SCHEME

Table 1: Differentiation of the main baling techniques used to facilitate a temporary waste storage

Round bales	Square-shape bales
Bale properties:	
- better compaction - better protection of the outer surface by complete wrapping with geotextiles - more complicated transportation and storage due to the round shape of the bales - bales easier to re-open - weight: 400-1,450 kg per bale	- less complicated transportation and storage due to the square shape of the bales - higher storage density - lower stability of the bale because of wire winding and outer foil layer as the only means for baling
Machinery/equipment needs	
- wrapping station - portable, mobile - stout machine w./ low abrasion - energy consumption: approx. 1,5 kWh per bale - throughput 20-35 bales per hour - no need of machine chassis	- container or channel compactor - often static - usually high abrasion - energy consumption: approx. 15 kWh per bale - throughput 20-30 bales per hour - need of machine chassis or container

Baling of the material can be done at the place of its generation or directly at the storage site. The material must be down-sized prior to baling in order to give it a good handling and to avoid damages at the baler and the wrapping. Baling can be performed by means of round bale wrapping or a compression into square-shaped bales.

Especially long-term storage sites (storage time › 1 year) should have a base sealing made of asphalt to protect the underground from possible leachate outflow. This has the additional advantage of good accessibility of the site also in the case of rainfall and a generally weak underground. The storage at a regular landfill site with drainage and leachate collection (see fact sheet on "Landfill for non-hazardous wastes") can be an alternative. Leachate collection can be done via collection troughs set up on the baseline sealing. From there, the leachate flows into a collection basin or a leachate treatment station.

TECHNICAL SCHEME - CONTINUATION	Sections where the piling up of bales has come to an end shall be covered with a PE-foil to divert precipitation water away from the bales and obtain an additional protection against UV-light. An earth cover can be additionally installed (see pictures below). Both measures can prevent or reduce the occurrence of airstream channels which pose a potential risk for self-ignition and fire outbreaks. Figure 1: left: foil covering /right: additional earth covering (Picture source: INTECUS GmbH)   The total height of the storage pile is determined from the length of the crane cantilever arm or gripper arm used for the storage operations and the static properties of the bales. To date, storage sites with a maximum height of the pile equivalent to twelve bales set up one above the other have been erected. The storage site must be divided into fire protection zones (each of a maximum area size of 2,000 m²) with fire proof embankments in between. The erecting of these fire embankments shall be completed simultaneously as the piling of bales progresses.
QUANTITY ASPECTS	**Input** - solid waste material - wrapping film, geo-textile, wrapping wire - PE foil and soil for covering **Output** - solid waste material - used soil from covering - used wrapping film, waste from geo-textile and PE foil, scrap wire
SCALE OF APPLICATION	The range of applications of this technology goes from a minimum of 1,000 tons/a (storage during plant inspections nearby the plant) up to a maximum of 400,000 tons/a.
INTEROPERABILITY	A temporary waste storage might be necessary before the waste material can be forwarded to further treatment or final disposal. Prior to the erection of the storage site it has to be ensured that the treatment or disposal capacities needed for the waste are eventually available once the permitted storage time comes to an end. Unnecessary storage or storage over very long periods must be strictly avoided.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	Input: fuels/energy needed for operation of the technical equipment and security measures
CO_2-RELEVANCE	- low emission on CO_2 and methane may occur but are negligible in quantity
AIDS AND ADDITIVES NEEDED	- wrapping film, geo-textile, wrapping wire - PE foil and soil for covering
HUMAN RESOURCES NEEDED	- 2 persons for baling and admission into the storage facility - additional personnel for monitoring and gate control
SPATIAL NEEDS	Baling equipment: Round bales: 18x3x5 m Square-shaped bales: 35x5x6 m Storage area: 0.1–0.8 m²/Mg (depending on the material features, overall design, storage height and fire protection needs)

AFTERCARE DEMANDS	- controlled dismantling - Renaturation of the storage site or re-establishment of original conditions
OPERATIONAL BENCHMARKS: COST DIMENSIONS	
INVESTMENT COSTS	- usually low as the temporary character of the storage facility allows for the renting of the equipment and storage area
OPERATING COSTS	- 20 to 50 EUR/Mg in dependency of amount and type of stored wastes (status of 2008)
POSSIBLE PROCEEDS	- only in cases where temporary storage is undertaken for third parties in the form of kind of a reception charge or “tipping“/treatment fees
MASS SPEC. OVERALL COSTS	- 20 to 50 EUR/Mg in dependency of amount and type of stored wastes (status of 2008)
MISCELLANEOUS	
MARKET INFORMATION	
REFERENCE FACILITIES *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	The erection of temporary waste storage facilities is a measure which is very commonly performed by large waste disposal companies or facility operators when they fall short of available treatment capacities or it comes to facility breakdowns or inspections. Actual applications of this technique can best be requested from organizations of the said type, directly. Temporary waste storage facilities can be found around the world, Germany had a total erected capacity in the range of 2–4 million tons in 2006 for a short period, since 2009 all temporary storages were shut down. To refer here to a specific facility will not be helpful since their character is a temporary one and the removal of the site very likely after some time.
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Producer/provider firms for: *Press- and baling equipment:* - Schuster Engineering www.schusterengineering.de - EuRec Technology Sales & Distribution GmbH www.eurec-technology.com - PTF Häusser GmbH www.ptf-haeusser.de *Wrapping foil:* - FRANPACK GmbH www.franpack.de - Manuli Stretch Deutschland GmbH www.manulistretch.com - R&S Kunststoff-Verarbeitungs GmbH www.rs-kunststoffverarbeitung.de *Bale manipulator and gripper equipment:* - C. Steffenewers GmbH & Co.KG www.steffenewers.de - Kurschildgen GmbH Hebezeugbau www.tigerhebezeuge.de - Kock & Sohn www.kock-sohn.de - Liebherr-International Deutschland GmbH www.liebherr.com

Umwelt Bundesamt

LANDFILL FOR INERT WASTE

APPLICATION OBJECTIVE:	-Landfill/Deposit site for waste material of inert/mineral type with no potential danger for the environment -Inexpensive, controlled deposition of materials that require few measures to ensure the protection of the environment.

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X[2]	Light-weight packaging		Biowaste	
Paper/paperboard		Mixed household waste		Bulky waste	
Lamps		Textiles		Electrical & electronic waste	
Scrap metal		Wood waste		C&D waste	X[2]
Waste oil		Old paint & lacquer		Waste tires	
Hazardous waste					
Branch specific waste	X	e.g. certain plastic materials which cannot be recycled or otherwise treated			
Other waste material	X	such as excavated soil and solid waste consisting of earth and earth-like products, concrete, cured asphalt, rock, bricks, and land clearing debris or mineral residues and slags from other treatments			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION:

Aftercare requirements:
Aftercare comprises first of all safeguarding of the area, regular inspections and monitoring of the wells and other control facilities.

Protective needs:
Protection against the release of harmful substances into water, soil or air, measures to prevent unauthorized access and use of the facility

Financing options:
Financing can be supported by a landfill tax, fees and charges

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION:

Infrastructural conditions:
For the erection must be considered that this type facilities
- do have high spatial needs with specific geological and hydrogeological requirements
- must be erected/located in sufficient distance to dwelling areas
- need to be accessible via roads or railway

Climatic conditions:
- no limitations regarding the erection and operations due to climatic influences

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT	These landfills are designated areas and rather simple engineered facilities for the deposition of mineral matter or materials that are inert in their character and pose no potential danger for the environment. Often this can be excavated sites or abandoned quarries or open pit mines which meet the basic geo-hydrological requirements.

[2] only temporal deposition, options that lead to the material recycling or thermal utilization of this waste should be prioritized

BASIC REQUIREMENTS	Requirements of location: Suitable geological and hydrological conditions with - an underground that should have a permeability of 10^{-7} m/s or lower in an undisturbed state (underground protection) and a thickness of more than 1 meter - a mineral drainage layer of at least 30 centimeter - sufficient distance to the groundwater table.
EXPECTED RESUTLS	- long lasting and controlled deposition of waste materials with only few needs for special protective measures
SPECIFIC ADVANTAGES	- rather easy to realize and inexpensive - to be covered with a recultivation layer after closure - very little aftercare needed
SPECIFIC DISADVANTAGES	- space demanding

APPLICATION DETAILS

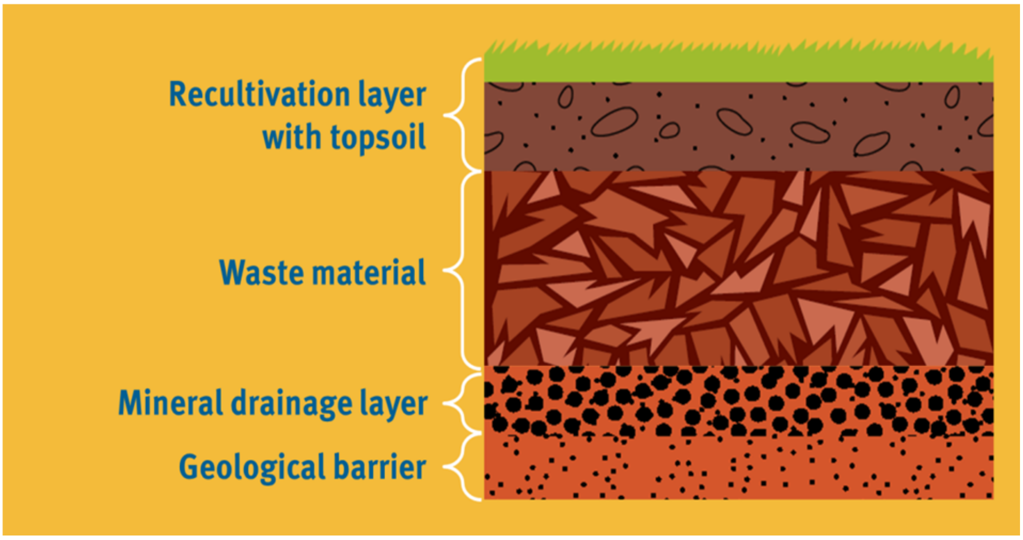
TECHNICAL SCHEME

Landfills for inert waste shall consists of minimum 3 operational areas:
- area of entrance
- area of storage
- working area

In addition, following constructional measures are mandatory to operate a landfill for inert waste:
- area shall be fenced to prevent an access of unauthorized persons,
- access roads shall be designed for heavy goods vehicles,
- measures shall be applied that prevent an inflow of surface water of neighboring sections into the landfill body, especially during heavy rain (e.g. ditches)

The basic structure of a landfill for inert waste is presented in Figure 1.

Figure 1: Basic structure of landfill for inert waste (according to German landfill ordinance)



Once the deposition of waste material is completed in a certain section of the landfill or in the overall, a surface sealing should be erected in the following way:
- if necessary a leveling layer of 0.5 meter thickness
- recultivation layer of 1.0 meter thickness that consists of soil and, if necessary, a drainage layer of 0.3 meter that is situated below the recultivation layer

SCALE OF APPLICATION	The location of the deposit/landfill should be chosen to allow active operations for at least 10 years, better 15–20 years, in order to ensure the amortization of the investment for the erection and closure of the site (Access roads, drainage system, fencing, weighing platform, etc.). Size of the area and of the installations must be determined depending on the local circumstances, size of the collection area resp. the quantity of material to be deposited
INTEROPERABILITY	A landfill for inert waste serves the safe storage and long lasting deposition of materials that pose almost no risk to the environment. Such facility can be combined with any suitable installation for the pre-treatment of materials to be deposited.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	Input: - energy, e.g. fuel for landfill equipment, electricity Output: - no possibility for energy recovery due to the mineral input material which generates no or very little landfill gas
CO_2-RELEVANCE	- not of relevance since no gas emissions or very low amounts can be expected
AIDS AND ADDITIVES NEEDED	- cover and sealing materials as specified above
HUMAN RESOURCES NEEDED	Personnel requirements depend on the size of the facility. The operator of a landfill ensures at any time that adequate qualified staff is available to control and monitor the operational processes and to prevent accidents and to limit possible accident consequences. The staff shall periodically take part in trainings (at least every 2 years). For a facility with an annual receipt of approx. 500,000 Mg, the number of personnel needed is in the range from 8–10 persons, with at least 1 chief engineer, 3 qualified staff for registration (weighing) and receiving control, 3 engine mechanics/drivers plus a number of helpers.
SPATIAL NEEDS	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. As an exemplary figure a deposit area of 42,000 m² and a total operation area of 55,000 m² are given for a landfill with a capacity of 340,000 m³ and about 30,000 Mg annual receipts 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, additional space shall be considered for - supply networks (fresh water, electric power), - road connections, railroad or waterways and - leachate catchment, groundwater control and green belts Not actively operated parts/completed cells must be properly covered.
AFTERCARE DEMANDS	The landfill area should be enclosed by a fence, regular inspections and monitoring shall be undertaken.

ORIENTIERUNGSWERTE FÜR DIE ANWENDUNG: KOSTEN	
INVESTMENT COSTS	The investment needs depend from the local conditions and planned capacity of the site, above all the costs for the - acquisition and preparation of the area, - construction: The construction costs should be well below that of a sanitary landfill for mixed waste (See also fact sheet "Landfill for non-hazardous waste") - equipment: usually wheel loader(s) and weighing at the entrance gate
OPERATING COSTS	The operating costs depend from the planned capacity of the site and the equipment used. Running, maintenance and personnel costs are supposed to be well below that of a landfill for non-hazardous waste, especially due to the very limited aftercare demands. (See fact sheet "Landfill for non-hazardous waste")
POSSIBLE PROCEEDS	- from tipping fees and possible landfill taxes
MASS SPECIFIC OVERALL COSTS	- According to European experience and current pricing levels the overall costs should not exceed the amount of EUR 10 per Mg of material deposited (as of 2008).
OTHER RELEVANT ASPECTS	
	During the search and selection of the appropriate location, sufficient spatial resources shall be considered as reserve which – in the case of an advanced state of technology – at a later date can be used to set up the corresponding recycling facilities close to the material deposits.

MISCELLANEOUS

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: - Zweckverband für Abfallwirtschaft Kempten, Deponie Steinegaden www.zak-kempten.de - Boden- und Bauschuttdeponie "Sundern – Meinkenbracht" der Sauer & Sommer Straßen- und Tiefbau GmbH www.sauer-sommer.de - Deponie Dersenow der RBS Bodenverwertungs GmbH www.rbsfirmengruppe.de
RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Numerous firms in Germany 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: Laying 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

LANDFILL FOR NON-HAZARDOUS WASTE

APPLICATION OBJECTIVE:	- Landfills for non-hazardous wastes with safe and controlled deposition of wastes, which only require a minor effort to ensure an adequate protection of the environment

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass	X[3]	Light-weight packaging	X[1]	Biowaste	X[4]
Paper/paperboard	X[1]	Mixed household waste	X	Bulky waste	X[1]
Lamps		Textiles		Electrical & electronic waste	
Scrap metals		Wood waste		C&D waste	
Waste oil		Old paint & lacquer		Waste tires	
Hazardous wastes	X[5]				
Branch specific waste	X	e.g. certain plastic materials which cannot be recycled or otherwise treated			
Other waste materials					

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

Pretreatment of the input material:
A pre-treatment (thermal or mechanical-biological treatment processes) should be undertaken to minimize the environmental impacts originating from landfills, in particular from greenhouse gas emissions and leachate. Several European countries, including Germany, have made this a pre-condition before any waste containing biodegradable materials is allowed to be landfilled.

Aftercare requirements:
Aftercare comprises first of all safeguarding of the area, regular inspections and monitoring of the wells and other control facilities.

Protective needs:
Protection against the release of harmful substances into water, soil or air, measures to prevent unauthorized access and use of the facility.

Financing options:
Financing can be supported by a landfill tax.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION:

Infrastructural conditions:
The establishment of a landfill for non-hazardous waste should include following considerations:
- high spatial needs with specific geological and hydrogeological requirements
- strategic placement in sufficient distance to dwelling areas
- need to be accessible via roads or railway

Climatic conditions:
- no limitations regarding the establishment and operations due to climatic influences

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[3] Amounts to be deposited depend from the achieved status of separate collection; a certain proportion of these materials is contained in the ordinary household waste, however. Options for the recovery of these materials, the material recycling and or utilization should in any way be prioritized

[4] Amounts to be deposited depend from the achieved status of separate collection; a certain proportion of these materials are contained in the ordinary household waste, however. To minimize the environmental impacts going out from landfills these wastes must become subject to recycling or at least pre-treated before landfilling.

[5] Only possible if wastes are stable and inert and acceptance criteria of landfills for non-hazardous substances are met

TECHNICAL DETAILS

GENERAL OVERVIEW

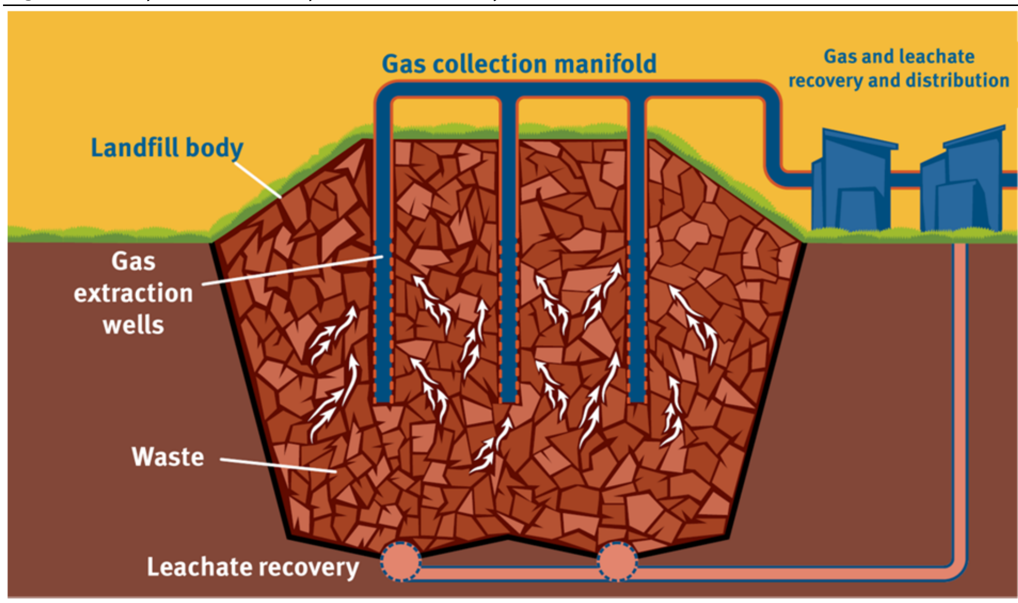
ABSTRACT	Sanitary landfills are specially engineered areas with appropriate facilities for disposing of non-hazardous solid waste in a systematic and controlled manner on land with the purpose of eliminating public health and environmental hazards and avoidance of soil or groundwater contaminations. In a sanitary landfill the solid wastes are spread in layers, compacted to the smallest practical volume, and covered by material applied at the end of each operating day.
BASIC REQUIREMENTS	Requirements on location: Suitable geological and hydrological conditions with - an underground that should have a permeability of a kf-value ≤ $1*10^{-9}$ m/s in an undisturbed state and a thickness of at least 1 meter (base sealing) - sufficient distance to the groundwater table, Underground protection with base sealing and drainage layer
EXPECTED RESULTS	Eliminating public health and environmental hazards and minimizing nuisances that go out from waste materials thru a long lasting, controlled deposition without contaminating surface or groundwater resources.
SPECIFIC ADVANTAGES	- safe deposition of solid waste material - prevention of harmful emissions by the way of special protection measures such as base liner, surface sealing and collection systems for effluents and gases - long lasting safety through aftercare and safety measures such as mineral coverage - economically advantageous as opposed to other, more expensive treatment options
SPECIFIC DISADVANTAGES	- requires long lasting control and aftercare - generation of greenhouse gases - behavior of the waste in the deposit is rather uncertain

APPLICATION DETAILS

TECHNICAL SCHEME

A sanitary landfill is engineered in a way that the necessary precautions are taken for the sealing of the landfill basis and surrounding soil body and the drainage of the landfill body. Moreover, technical components for leachate and landfill gas collection and treatment are installed. Figure 1 illustrates the basic arrangement of these technical installations.

Figure 2: Principal technical components of a sanitary landfill for non-hazardous waste

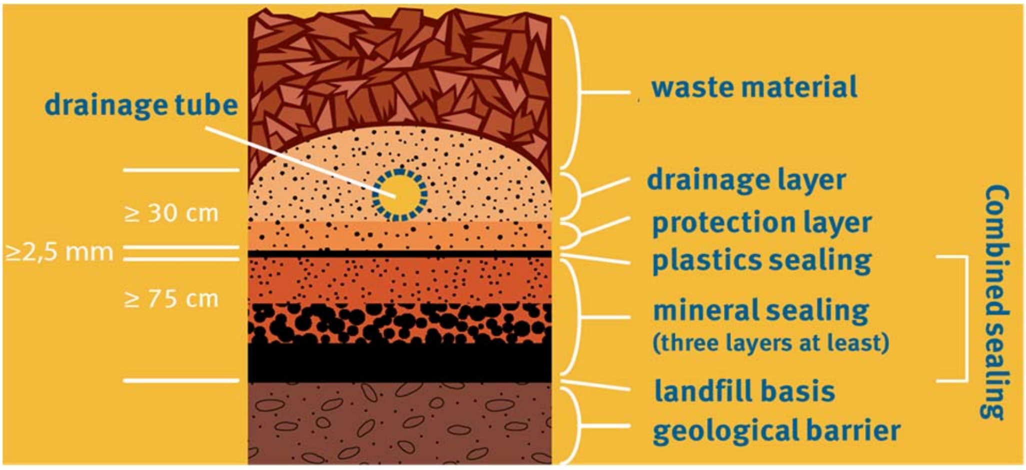


TECHNICAL SCHEME - CONTINUATION

Construction of a combined base sealing

Figure 3 shows the construction principle of a combined base sealing for a sanitary landfill. The sealing is erected atop the basis of the landfill.

Figure 3: Construction of a combined base sealing [according to German Landfill Ordinance]

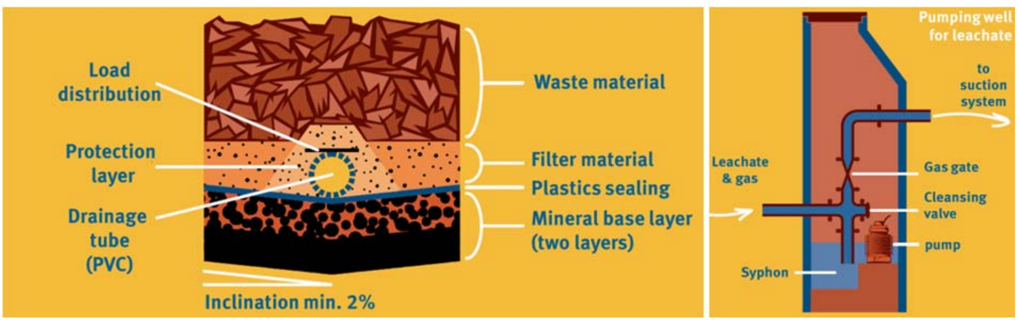


The lower portion of the sealing is made up by three mineral layers (clay) with a total thickness of about 0.75 m covered by a plastics sealing (HDPE) with a minimum thickness of 2.5 mm. The permeability index should be at kf ≤ $5*10^{-10}$ m/s. The plastic sealing should be protected from a layer of fine sand or similar material. Thereupon, a drainage layer that consists of gravel or other crushed stone material with a permeability index of kf ≤ $1*10^{-3}$ m/s shall be erected. Within, drainage tubes for the collection of gravitational water are being integrated.

Construction of a drainage system

Figure 4 shows technical installations for the collection of leachate. Collection systems consists of floor drainage, controlling and monitoring wells, pumping stations (collector and suction box) and storage basins (reaction and sedimentation pool). Collection systems are used to remove leachate from the landfill body and to prevent the development of exorbitant hydrostatic pressures on the base sealing and therewith damages on it.

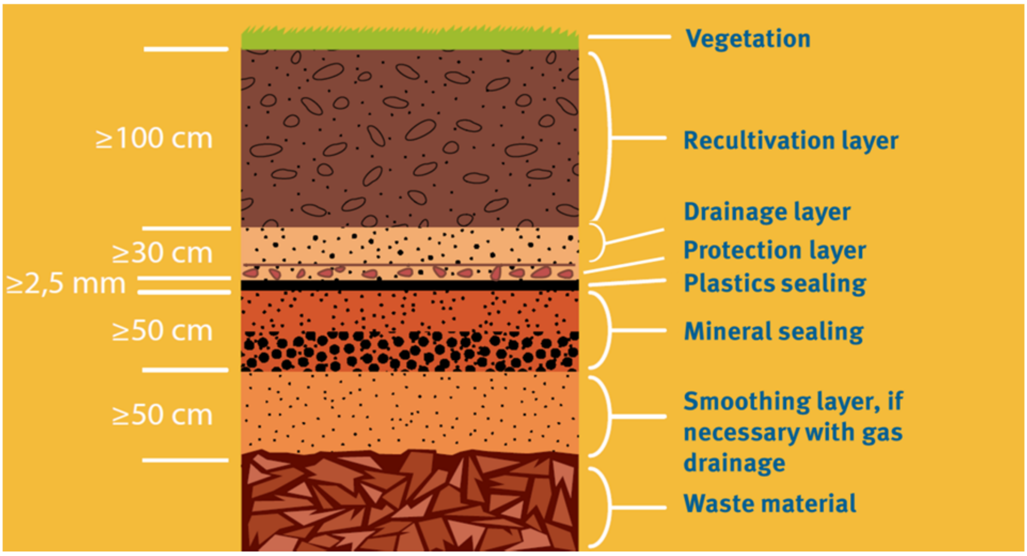
Figure 4: left: drainage system / right: Pumping well for gravitational water and leachate



Construction of the surface sealing

Figure 5 shows the possible construction of the surface sealing. Once the deposition of waste material is completed in a certain section of the landfill or in the overall, a surface sealing should be erected in the following way:

- 0.5 m thick smoothing layer,
- 0.3 m thick layer from gravel or similar material for gas drainage,
- 0.5 m thick mineral layer (or similar sealing) with a permeability of kf ≤ $5*10^{-9}$ m/s, covered by a plastic sealing,
- 0.3 m thick drainage layer with a permeability kf ≤ $1*10^{-3}$ m/s,
- recultivating layer from arable soil of 1 meter thickness

TECHNICAL SCHEME - CONTINUATION	Figure 5: Construction of a combined base sealing (according to German Landfill Ordinance) 
SCALE OF APPLICATION	The location of the deposit/landfill should be chosen to allow active operations for at least 10 years, better 15–20 years, in order to ensure the amortization of the investment for the erection and closure of the site (access roads, drainage system, fencing, weighing platform, aftercare measures etc.). Size of the area and of the installations must be determined depending on the local circumstances, size of the collection area resp. the quantity of material to be deposited.
INTEROPERABILITY	A landfill for non-hazardous, mixed waste serves the safe storage and long lasting deposition of these materials. Such facility can be combined with any suitable installation for the pre-treatment of the materials send to final disposal.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	Input: - energy, e.g. fuel for landfill equipment, electricity Output: - electric energy from the utilization of collected landfill gas and also thermal energy in the case of a cogeneration system
CO_2-RELEVANCE	Due to the emissions of landfill gases to be expected (methane, CO_2, H_2S), a negative balance occurs. Landfilling of not pretreated municipal solid waste is being considered as large contributor to the greenhouse effect, especially if effective gas collection systems are not in place.
HUMAN RESOURCES NEEDED	Personnel requirements are depending from the size of the facility. For a facility with an annual receipt of approx. 500,000 t, the number of personnel needed is in the range from 12–14 persons, with at least 1 chief engineer, 3 qualified staff for registration (weighing) and receiving control, 3 engine mechanics/drivers plus a number of helpers. If a treatment plant for the collected leachate and gas generators are in place further personnel will be needed, including at least 1 chief engineer, 2 qualified staff for machine/plant operations, plus several helpers. Further staff for gate control and administration may be needed.
AIDS AND ADDITIVES NEEDED	- Cover and sealing materials as specified above

SPATIAL NEEDS	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 approx. 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
AFTERCARE DEMANDS	Aftercare comprises first of all safeguarding of the area, regular inspections (in annual and half year-intervals) and monitoring of the wells and other control facilities. These measures must principally be undertaken as long as a potential danger still exists. Monitoring should last for at least 20–30 years after the closure of the landfill. 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.

OPERATIONAL BENCHMARKS: COSTS DIMENSIONS

INVESTMENT COSTS	Investment costs for a landfill are highly dependent on the planned volume of waste to be deposited and the corresponding requirement on space whereby the geomorphological conditions (pit or heap-shape, hillside or valley deposit) do also have an impact. To give an orientation for a basic, average sized landfill can be cited investments values (state of 2008) for the following components and examples: - Construction and technical installations inclusive debt service: approx. EUR 12 million - For capping and sealing additional costs in the range of EUR 40–60 per m² can be expected
OPERATING COSTS	The total annual operating costs (*Status 2008*) for an average landfill are estimated with: - Running costs: approx. EUR 400,000 - Repair and maintenance: approx. EUR 1.2 million - Personnel + administration: approx. EUR 250,000
POSSIBLE PROCEEDS	- from tipping fees, possible landfill taxes and generated energy from landfill emissions that is feed to electricity grid
MASS SPECIFIC OVERALL COSTS	The following overall estimates can be used as indicative figures of total costs (status 2008):

Annual receipt of material for deposition [m³/a]	50,000	250,000
Estimated investment for:		
Landfill allocation survey, underground expertise, permitting	EUR 2.6 million	EUR 8 million
Construction planning, supervision and quality assurance	EUR 77 million	EUR 133 million
Operating equipment, closure and recultivation	EUR 61 million	EUR 110 million
Monitoring equipment, leachate/gas collection and treatment	EUR 74 million	EUR 123 million

OTHER RELEVANT ASPECTS

During the search and selection of the appropriate location, sufficient spatial resources shall be considered as reserve which – in the case of an advanced state of technology – at a later date can be used to set up the corresponding recycling facilities close to material deposits.

MISCELLANEOUS

MARKET INFORMATION

REFERENCE FACILITIES *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	A vast number of German landfills were closed after 2005 based on the legal termination of landfilling untreated waste. Some examples of landfills are listed that are currently filled with pre-treated waste: - RAVON, landfill "Kunnersdorf": www.ravon.de - Abfallwirtschaftsgesellschaft des Kreises Warendorf mbH www.awg-waf.de - Landfill "Pohlsche Heide": www.pohlsche-heide.de - Central Landfill "Cröbern" www.wev-sachsen.de

RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	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 *Laying 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 *Laying 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.bmf-haase.de - LAMBDA Gesellschaft für Gastechnik mbH — www.lambda.de - Green Gas Germany GmbH — www.greengas.net

REMARKS AND REFERENCE DOCUMENTS

A **list of companies** dealing with the construction of facilities for the storage and safe deposition of hazardous waste 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.bu-umwelt.de

LANDFILL FOR HAZARDOUS WASTE

APPLICATION OBJECTIVE:	- Environmentally safe depositing and permanent secure storage of hazardous waste materials

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

Glass		Light-weight packages	X[6]	Biowaste	X[7]
Paper / paperboard		Mixed household waste		Bulky waste	X
Lamps		Textiles		Electrical and electronic waste	
Scrap metal		Waste wood		C&D waste	
Waste oil		Old paint & lacquer	X[8]	Waste tires	
Hazardous waste	X				
Branch specific waste	X	Industrial effluents and sludge, contaminated materials			
Other waste material	X	dangerous matter, contaminated ashes, slags and residues from other treatment processes			

SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION:

Pre-treatment of the input material:

Loose waste can be solidified or filled into big bags (see fact sheet on "Big Bag"), barrels or other suitable containers if transportation, stability or other features require that for subterrestrial deposits; in case that overground hazardous waste landfills are being used, moisturization of dusty waste if necessary for dust-free emplacement or its transfer in big bags.

Aftercare requirements:

First of all, aftercare comprises safeguarding of the area, regular inspections and monitoring of the wells and other control facilities. These measures must principally be undertaken as long as a potential danger still exists.

Protective needs:

Protection against the leak of hazardous substances into water, soil or air, measures to prevent unauthorized access and use of the facility.

Financing options;

Financing can be supported by a landfill tax, fees and charges.

RESTRICTIONS OR INFLUENCE OF EXTERNALITIES ON THE APPLICATION:

Infrastructural conditions:

Facilities for hazardous waste deposition and/or storage

- do have high spatial needs with specific geological and hydrogeological requirements
- must be erected/located in sufficient distance to dwelling areas
- need to be accessible via roads or railway

Climatic conditions:

- no limitations regarding the erection and operations of facilities for hazardous waste deposition due to climatic influences

[6] not properly emptied or yet filled
[7] potentially infectious or contaminated
[8] encapsulated

TECHNICAL DETAILS

GENERAL OVERVIEW

ABSTRACT

A landfill for hazardous waste is a specially engineered and protected site for the safe storage of hazardous and potentially hazardous material that cannot be treated in order to lose its danger potential or possible risk for the environment. Landfills for hazardous waste are characterized by the dangerousness of the deposited material and a constructional design which includes particular structural and/or material components to minimize the chance of release of hazardous substances into the environment. They can be set up as temporary storage places or permanent deposits.

BASIC REQUIREMENTS

Requirements of location:

Suitable geological and hydrological conditions, and especially

- not in Karst areas or areas with a cleft basis
- not within water protection areas and catchments for potable water production
- not in flood-prone zones
- not in geologically faulted areas, areas with tectonic activities or areas containing mine workings
- The underground should have a low permeability (permeability index kf ≤ $1*10^{-9}$ m/s) and a thickness of ≥ 5 meters.

Additionally ensured are:

Base liner system (combined sealing and ground drainage)

Safety distance to dwelling areas

EXPECTED RESULTS

Eliminating public health and environmental hazards and minimizing nuisances that go out from hazardous or potentially hazardous material thru a long lasting, controlled deposition without contaminating surface or groundwater resources

SPECIFIC ADVANTAGES

- safe deposition of hazardous and potentially hazardous material
- prevention of harmful emissions by the way of special protection measures such as base liner, surface sealing and collection systems for effluents and gases
- long lasting safety through aftercare and special safety measures
- economically advantageous as opposed to other, more expensive treatment options

SPECIFIC DISADVANTAGES

- requires intensive and long lasting control and aftercare

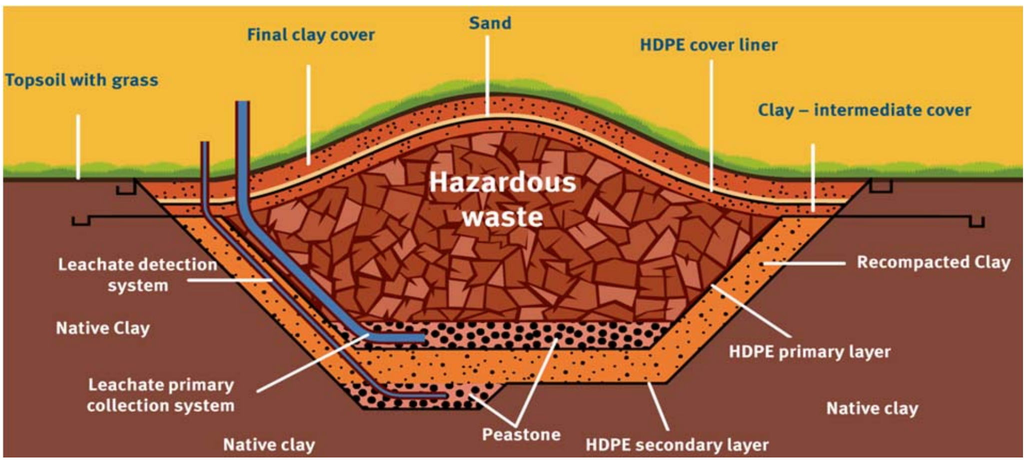
APPLICATION DETAILS

TECHNICAL SCHEME

<u>General technical design and components of a landfill for hazardous waste (aboveground)</u>

Facilities for the overground deposition and/or storage of hazardous waste are of following (general) design:

Figure 6: General design of a landfill for hazardous waste (aboveground)

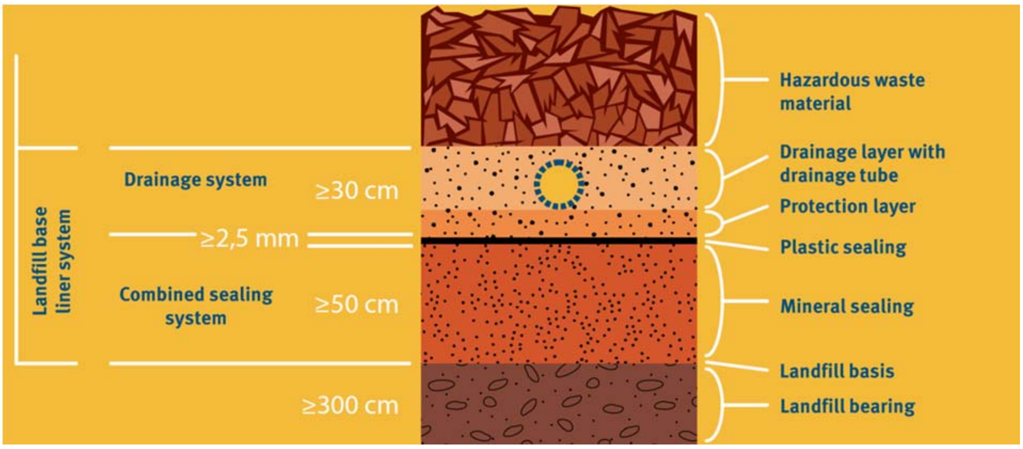


TECHNICAL SCHEME – CONTINUATION

Construction of the combined base sealing

Figure shows the basic elements of a combined landfill base liner system that is used as a barrier to prevent a discharge of leachate into groundwater and soil during the filling process and the after-closure phase.

Figure 7: Cross section of a base sealing (according to German Landfill Ordinance)



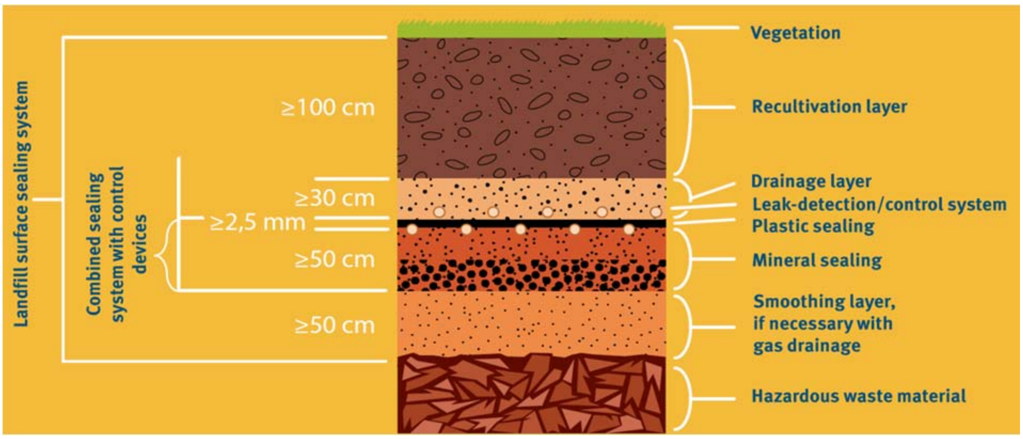
The compaction ratio on top of the landfill bearing should have a density of Proctor of > 95 %, the base liner sealing is erected on the top of the landfill basis and should comprise the following components:

- 50 cm mineral sealing (kf-value ≤ $5*10^{-10}$ m/s)
- ≥ 2.5 mm thick plastic sealing
- 30 cm drainage layer (including a protecting layer from sand or similar material) that consists of gravel or other crushed stone material with a permeability index not lower than kf-value ≤$1*10^{-3}$ m/s
- Drainage tubes that can be controlled and flushed have to be installed within the drainage layer (see fact sheet “Landfill for non-hazardous waste“)

Construction of the surface sealing

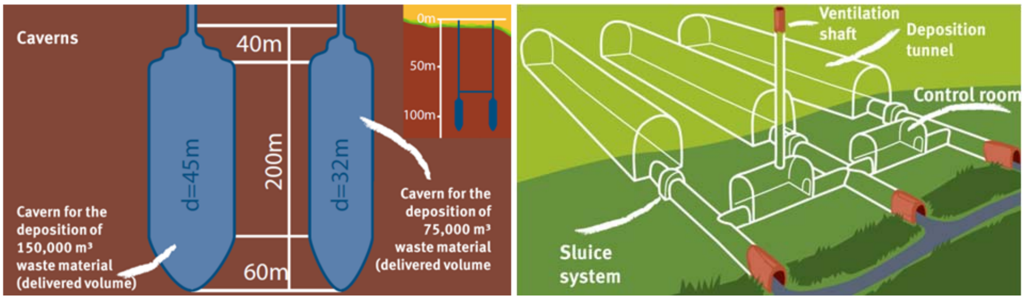
Figure shows the possible construction of a surface sealing that is used to protect the landfill body towards infiltration and weather effects (e.g. wind and water erosion) and to prevent an uncontrolled discharge of emissions out of the landfill body.

Figure 8: Cross section of a surface sealing (according to German Landfill Ordinance)



Once the deposition of waste material is completed in a certain section of the landfill or in the overall, a surface sealing need to be erected in the following way:

- 0.5 m thick smoothing layer, if necessary integrating a gas drainage (made from gravel)
- 0.5 m thick mineral layer (or similar sealing) with a permeability index k ≤ $5*10^{-10}$ m/s
- ≥ 2.5 mm thick plastic sealing and leak – detection and control system
- 0.3m thick drainage layer with a permeability index not below k ≥ $1*10^{-3}$ m/s
- 1 m thick recultivating layer from arable soil

TECHNICAL SCHEME – CONTINUATION	Constructional design – caverns, tunnels (subterrestrial deposition) Figure 5Figure illustrates possibilities for the subterrestrial deposition of hazardous wastes in caverns and tunnels. Caverns (mostly salt caverns) are technically made cavities (e.g. old salt mines), that can be used to store solid waste materials. Subterrestrial deposits are especially suited to store waste materials which contain still a potential risk for the environment (especially water and air) even if they are deposited under controlled conditions overground and whose treatment would otherwise be too costly. Figure 9: left: cavern / right: tunnel  Deposit sites on the overground are divided into three principal sections: - Gate area with space for incoming trucks, weighing platform, registration office and lab facilities for sample taking and storage of control samples - Working area with installations to open, transfer the content, empty and clean the transport containers - Storage area with space for the intermediate storing of waste to be deposited, treated or incinerated in separate ways
SCALE OF APPLICATION	The location of the deposit/landfill should be chosen to allow active operations for at least 10 years, better 15–20 years, in order to ensure the amortization of the investment for the erection and closure of the site (Access roads, drainage system, fencing, weighing platform, security and aftercare measures). Size of the area and of the installations must be determined depending on the local circumstances, size of the collection area resp. the collected quantity of wastes and manner of their deposition (over-/underground).
INTEROPERABILITY	A hazardous waste landfill is intended for the safe and long lasting deposition of waste materials that could be hazardous or potentially hazardous to the environment. Such facility can be combined with any suitable installation for the pre-treatment of the materials to be deposited.
OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION	
ENERGY BALANCE	Input: - energy, e.g. fuel for landfill equipment, electricity Output: - possibly electric energy by the utilization of collected landfill gas and also thermal energy in the case of a cogeneration system
CO_2-RELEVANCE	Expectable emissions of landfill gases (methane, CO_2, H_2S) result in a negative balance. Landfilling of untreated municipal solid waste is being considered as large contributor to the greenhouse effect, especially if effective gas collection systems are not in place.
HUMAN RESOURCES NEEDED	The personnel requirements depend on the facility design which in this field is very specific for each case. The estimated personnel requirement for an exemplary size of 110,000m³ annual receipt is about 5–6 specialized staff

AIDS AND ADDITIVES NEEDED	- Cover and sealing materials as specified above
SPATIAL NEEDS	The spatial needs depend on the planned capacity of the facility. A deposit area of approx. 200,000 m² is needed to deposit an annual volume of 110,000 m³ of waste materials over a filling period of 20 years. Further space is required for: - Fresh water supply - Power supply - Connection to road, optional also railroad or waterway network
AFTERCARE REQUIREMENTS	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.

OPERATIONAL BENCHMARKS: COST DIMENSIONS

INVESTMENT COSTS	Investment costs of a landfill are highly dependent on the volume, the planned duration of the filling process and current market conditions. As an orientation for investment costs can be cited the values for the following components and examples: - Base sealing system: to over EUR 35 million (e.g. landfill “Flotzgrün”) - Complete sealing incl. surface: to over EUR 48 million (e.g. landfill “Nord“, “Weißer Weg”)
OPERATIONAL COSTS	The total annual operating costs for an average example are estimated with (status 2008): - Running costs: approx. EUR 400,000 - Repair and maintenance: approx. EUR 1.2 million - Personnel + administration: approx. EUR 250,000
POSSIBLE PROCEEDS	- from tipping fees, possible landfill taxes and generated energy from landfill emissions that is feed to electricity grid
MASS SPECIFIC OVERALL COSTS	The following overall estimates can be used as indicative figures of the total costs (status 2008):

Annual receipt of material for deposition [m³/a]	50,000	250,000
Estimated investment [in million EUR]:		
Landfill allocation survey, underground expertise, permitting	2.6	8
Construction planning, supervision and quality assurance	77	133
Operating equipment, closure and recultivation	61	110
Monitoring equipment, leachate/gas collection and treatment	74	123

MISCELLANEOUS

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 safe deposition of hazardous waste. In Germany, some examples are:

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 deposits:
- K+S Entsorgung GmbH — www.ks-entsorgung.com
- GSES GmbH — www.gses.de
- Grube Teutschenthal Sicherungs GmbH & Co. KG — www.grube-teutschenthal.de

RECOGNIZED PRODUCER AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	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 Producers of leak-detection and control systems - PROGEO Monitoring GmbH www.progeo.com - SENSOR Dichtungs - Kontroll - Systeme GmbH www.sensor-dks.com Laying 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 Laying 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.bmf-haase.de - LAMBDA Gesellschaft für Gastechnik mbH www.lambda.de - Green Gas Germany GmbH www.greengas.net

REMARKS AND REFERENCE DOCUMENTS

A **list of companies** dealing with the construction of facilities for the storage and safe deposition of hazardous waste 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.bu-umwelt.de

Handling of specific waste streams

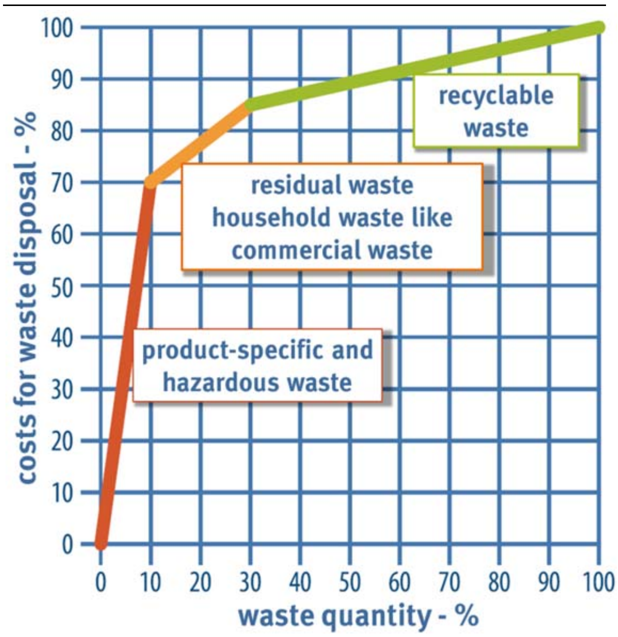
An important part of a sustainable waste management is to monitor and promote waste stream management in the different sectors of waste generation.

Further to the day-by-day waste produced in households, public institutions and small commercial outlets there are significant waste amounts that accumulate at the above and also at more industry-like sources in the form of worn out materials and products. To facilitate the recycling and/or respond to the particular characteristics, a periodic accrual and specific constraints with regard to an environmentally safe handling a separate collection and disposal of these wastes is usually required. Generally the following streams must be considered:

- *Waste with household waste like characteristics*: This waste can be collected and disposed of like and together with household waste.
- *Waste of hazardous nature or with potentially harmful content*: This is waste material which requires a stricter control regime and to which special provisions apply (e.g. Basel Convention for shipments of such material) because of the potential risks for nature and environment. The classification into hazardous and non-hazardous waste is based on the system for the classification and labelling of dangerous substances and preparations, which ensures the application of similar principles over their whole life cycle. The properties which render waste hazardous are usually laid down in regulatory documents and/or specific lists (such as the EuropeanWaste Catalogue). To evaluate the hazard potentials of chemical waste and ensure the safe handling of such material, the work done in the framework of the 'International Program on Chemical Safety' and the EU's policy on chemicals REACH must also be taken into consideration.
  A waste stream to which must be looked in a similar way as to hazardous waste is infectious or medical waste as well as sewage sludge from waste water treatment. Hazardous and medical waste in general is waste material that contains critical amounts of dangerous substances and can therefore not be utilized without proper precaution. It must be collected separately from other wastes and has to be disposed of in such a manner that no harm is caused to the surroundings. A disposal together with household waste should not take place under any circumstances. The management of sewage sludge should be aimed at the best possible use of nutrients, precious material components and energy content while it must also give respect to special precaution and appropriate treatment due to the broad range of critical substances that such sludge contains.
- *Waste of (production) specific nature:* These are wastes produced from the manufacturing industry or product-specific waste streams generated by industrial or business processes. Emerging as waste streams with rather uniform compositions, their recycling opportunities are usually good provided that utmost attention and care is given to keep the materials separated from other wastes. Special regulations and appropriate schemes for the pricing of raw commodities vis-a-vis recycled goods shall be helping in the avoidance, minimization and best possible utilization of these wastes.

Avoiding, reducing and -whenever possible- utilizing the waste from industrial/commercial activities is a basic command of proper waste management and increasingly important from the ecological and economical point of view.

Figure 1: General cost proportions for the disposal of different waste types generated in the course of commercial/industrial activities



Under the influence of dwindling resources and soaring price levels for materials, energy and environmental services waste has become a relevant cost factor and the impacts of dealing appropriately with the specific waste streams gets quickly reflected in an enterprises' balance sheet (see also Figure 1).

Environmental policy is increasingly driven by the need to influence manufacturing practices in an effort to decrease the environmental impact of products during their manufacture, use and end-of-life. Sustainable industrial waste management requires the adoption of cleaner production with the use of low waste technologies and a plant-internal as well as a cross-sectorial material flow management. Basically, this comprises all measures which can render the production of a product with less input on material and energy, improve the utilization of production residues and secondary raw materials, achieve closed material loops and avoid or substitute for particularly hazardous substances. It also includes the change of the product itself to achieve the goals. Examples of appropriate measures to realize such a policy are for instance:

- Making recovery, reprocessing and reuse (recycling) a part of the production process or company's operations (e.g. reprocessing of cooling agents, lubes or diluted acid, etc.),
- Organizing the recycling between different industrial branches (e.g. waste oil reprocessing),
- Adopting raw material-saving technologies (e.g. re-treading of waste tyres).

For the utilization and disposal of industrial/commercial waste different models are possible. One option, often labelled as self-disposal or on-site utilization, requires the enterprises to operate their own waste treatment facilities or run processes where the generated waste can be reintegrated or recycled in accordance with the accepted environmental standards. Such solutions are most adoptable for industrial branches with a particularly high generation of specific wastes and well applicable in branches like the steel, wood and paper industry. A large proportion of the rejects from paper making and the manufacturing of paper applications can for example be either reintroduced in paper production or used in the power generation of the plant.

The second option is the external disposal where the generated wastes are collected from a waste disposal company and forwarded for treatment and/or final disposal to external facilities (see factsheets 'Collection' and 'Treatment']. A problem of particular concern are quantities of hazardous waste, which, aside from a few options for thermal disposal (see for example factsheet 'Grate combustion') need to be disposed of at special landfills (see factsheets 'Landfill for hazardous waste'], mainly because of yet insufficient treatment options.

Effective waste stream management has therefore to put its focus especially on those material streams which have a high environmental relevance, either due to the potential risks they contain, their expected growth rates or because of the high recycling potentials. Such streams can be regarded as priority waste streams and to make them subject of special regulations and laws can be useful. It must be the aim then that particular attention will be paid to measures which ensure an increased utilization and the reduction of risks and any unfavourable practices in handling these wastes, respectively.

Households, commerce and industrial activities can be jointly the sources of waste streams with high priority. Good management practices, technical options for treatment and recycling, and other waste preventing and reducing measures are being described on the example of a selection of such priority streams. One of the reasons for choosing these particular waste streams is also set by the specific regulations and directives which already have been imposed on the level of the European Community for some of them.

Note: Detailed descriptions of the technology and equipment referenced in the text are provided with the following information sheets

Table 1: Overview on separately provided fact sheets related to the management of specific waste streams

Factsheets for waste streams
Construction and demolition waste
Waste oil
End-of-life vehicles
Waste tyres
Old batteries and accumulators
Waste of electrical and electronic equipment
Fluorescent, discharge and other lamps
Medical waste
Old paints and lacquers
Old carpets (textiles)
Sewage sludge r from municipal waste water treatment

Umwelt Bundesamt

CONSTRUCTION AND DEMOLITION WASTE (C&D WASTE)

RELEVANCE OF WASTE STREAM:	- Construction and demolition waste has the highest share on total waste, in general. Hence, waste avoidance, recovery and recycling play an important role considering treatment processes of C&D waste.

COMPOSITION/ MAIN MATERIAL COMPONENTS

Although the processes involved are diametrically opposed, the waste materials from construction activities, and from demolition projects, are similar in nature and generally considered as a whole. It is therefore relatively seldom that differences are made in the collection and treatment of these materials, even though the waste from construction activities oftentimes is cleaner and less a mixture when incurred.

Wastes created during construction or demolition, for example of a building or roadway, includes a wide range of materials. These will vary not only according to the type of construction but also according to the location as there are national and regional differences in construction methods and materials used.

Typically the wastes created from clearing a new site in preparation for development and also during construction are likely to be predominantly soil, clay and stone, together with smaller amounts of damaged or substandard building materials.

Waste materials generated during the demolition of a building may include mixtures of soil, sand, stone, concrete, bricks and tiles, treated and untreated wood, metals, asphalt, roofing shingles, dry wall, glass, plastics, paperboard, and textiles. There may also be cables and electrical appliances, foams, insulating materials and plumbing fittings.

Construction and demolition wastes are both bulky and heavy.

NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM

Wastes from construction and demolition activities generally constitute the waste stream with the highest mass relevance and are significantly present in the municipal solid waste too. The amounts in a given area may fluctuate widely from year to year as construction and demolition activities vary over time. That's why the principles of the waste hierarchy with avoidance being the top priority and preparation for reuse and recycling as the next following objectives do have a very high importance.

Waste avoidance in the construction sector
Waste prevention in the construction sector is largely connected to the planning and organisation of the construction process. Construction design and material selection are two principal factors influencing the arising of C&D waste. Only the material introduced in construction which produces a processing rest or leftover, or whose disassembling, take out and/or separation is eventually impossible later on will become a waste, finally.
Adopting a segmented construction and using preferably materials, for which reuse options already exist, help to cut down the overall quantity and attain a high re-utilisation rate of the C&D waste arising.

Adopting a low-waste policy for a construction project includes the re-use of construction aids such as wooden shuttering for concrete forms, and materials recovered on-site. The necessary requirements are considerable on planning, additional space and storage capacities. Care given to specifying the right quantities of materials and their delivery just in time or protective storage until use is a further approach to waste reduction.

The approach of selective De-construction and the operation of 'closed' sites are two essential elements for a low waste strategy with regard to C&D waste.

The separate collection at the moment of their generation has the highest priority to allow for a comprehensive recycling of the different C&D wastes. For the decisions to be made on the overall management and recycling alternatives for C&D waste various factors must be taken into account. Among others, these are:

Factors in favour of reclaiming construction and demolition materials:
- reduced demand on primary resources
- reduced landfill demand
- reuse on-site reduces transports and, hence, costs and environmental burdens
- produced secondary resources can improve economic balance

whereby decisions on the actual handling need to make consideration of:
- financing of additional labour costs and technical effort for a separation of fractions have to be assured
- consistency of supply and material quality
- need for more complex management of projects
- where materials are transported to a centralized site for reprocessing, there may be additional noise, atmospheric and transport

APPROPRIATE COLLECTION STRATEGIES AND SCHEMES

Once in a mix, the recovery of useful materials from C&D waste has certain limitations, especially if contaminated components, such as oil infested soils, impregnated wood or tar are parts of it. That was the reason why mixed C&D wastes were predominantly given to landfills in the past. Under the current EU legislative framework (i.e. Directive 99/31/EC) it becomes more and more necessary that non-inert and organic parts (e.g. wood, plastic) are separated from the C&D waste before a deposition is allowed. Moreover, separated fractions such as plastic and metals can achieve high sales prices in dependency on the market situation.

De-construction
The utilisation of materials from C&D waste can be optimized and processing needs minimized by applying a selective dismantling. This approach is one very important measure to achieve a significant reduction of the treatment intensity for the waste generated during demolition projects and paves the way for intense material reuse and high quality recycling in that it prevents the commingling of different materials and so also the contact of contaminated components with the rest of the material.

Table 1: Process flow for a selective dismantling/de-construction of buildings

Process step		Materials	Proceedings
Step 1:	Deconstruction and removal of contaminated material and impurities	e.g. parts made from asbestos, PCB, PCP / Lindane, tar, and thermal insulation with HBCDD, or impurities such as gypsum as components in screed and panels	Separate collection, treatment and save disposal
Step 2:	Non-destructive salvage and disassembly of directly reusable parts, Emptying of supply lines and tanks	e.g. fittings, lamps, insulations, features of architectural value such as stairs, handrails, pillars	Storage, repair, refurbishment, reuse
Step 3:	Deconstruction and removal of parts which can be reused after refurbishment	e.g. windows, roofing, flooring,	Refurbishment, storage, reuse
Step 4:	Removal and separate collection of all recyclable material remaining	Glass, metals, wood	Separation, reprocessing, recycling
Step 5:	Removal and separate collection of all non-recyclable materials	e.g. PUR foam, tar board, treated wood, gypsum plasterboard	Segregation and disposal
Step 6:	Demolition of the remaining construction incl. underground construction	Brickwork, concrete construction, steelworks, concrete footing	Separation, reprocessing, storage, recycling/reuse

Contaminated materials and impurities (e.g. gypsum), reusable materials (e.g. architectural features from old buildings) and materials suitable for a separate recycling (doors, windows, fireplaces, beams, tiles, copper pipes) must be removed from buildings before the demolition process starts. Following that, whole or part of bricks can be cleaned and re-used once the demolition has been completed. In some cases, it may slow down the construction/demolition process and increase costs, planning efforts and demands on labour force but large cost savings can be possible from saved disposal, transportation and material reuse.

Ensuring the utilisation of the components and different materials recovered at construction/demolition sites is making it indispensable that their collection, storage and transports will always be performed in a separated manner. This requires the use of appropriate container systems (see the factsheets on “Roll-off container” and “Skip container”), and their provision in sufficient number and on the right moment.

APPROPRIATE RECYCLING TECHNOLOGIES

Various possibilities exist for secondary use of materials from C&D sites. Materials may be used for the production of concrete for building construction if an adequate quality is ensured according to presented standards and norms. Other application areas are landscaping, sub-base for roadways or hard standing for driveways and car parks. Landfill operators use inert materials from construction sites, such as soil and clay, for a site engineering to a certain extent. These materials are used to construct site roads and to build the embankment walls of landfill 'cells', as well as for drainage and for cover and final capping (see factsheets on “Disposal”).

Table 2: Options for the use of different fractions of C&D waste

Material		Options of secondary use
Mixed C&D waste		Landfill after pre-treatment and separation of hazardous materials
Separated fractions of C&D waste	Stone/Gravel	Aggregate for manufacturing of new structural components, Filler material, Raw material for a new road‘s sub-base
	Concrete	Aggregate for manufacturing of new structural components, Raw material for a new road‘s sub-base
	Wood	Raw material for fibre and particle board production, Substitute fuel, Mulch or compost production
	Metals	Re-use in metal production
	Other materials	Glass: glass recycling Plastics: recycling where appropriate, substitute fuel Gypsum panels: production of new gypsum panels /gypsum fibre panels
	Asphalt	Raw material for roadbed construction, new asphalt roofing or road repair asphalt

One of the limiting factors on the re-use and recycling of construction and demolition wastes is the need for predictable and consistent performance from materials such as soil. Exemplarily, soils may be contaminated by previous site uses, and could contain heavy metals, oil, tars etc. Designers, architects and builders can rely on European standards and norms if using recycled construction materials to ensure a basic safety of work conditions and construction stability. For instance, European norms EN 206-1 and EN 12620 describe the adequate production and application of concrete with recycled mineral aggregates. Reliability of recycled construction materials can also be ensured by quality assurance systems such as the German Institute for Quality Assurance and Certification (RAL). They ensure that qualified information is provided about origin, age, composition and potential contaminations of recycled construction materials.

Tenders that describe materials to be used for construction shall be formulated in that way, that – considering presented norms and standards – recycled construction materials are not excluded. Recommendations for tenders are provided by the German Competence Center of Sustainable Procurement (Kompetenzstelle für Nachhaltige Beschaffung des Bundes (KNB)).

APPROPRIATE TREATMENT AND RECOVERY STRATEGIES

The intended utilisation of recovered C&D waste material may require additional equipment, to process the material and remove any contaminants. Processing of C&D waste can be done on site or in centralized plants.

On-site processing

On-site processing is most effective in increasing the utilisation of waste materials from construction and demolition. It applies especially to such materials for which a use exists on the same or a nearby site. When specifying materials for applications such as the sub-base of a new road or certain constructions from concrete, there may be an opportunity to use crushed, graded secondary materials directly after processing on-site. Using such recovered materials as aggregate, sand and gravel can reduce the utilisation of primary resources and, hence, lower environmental burdens.

A particular scheme is to operate 'closed' sites, where the planning conditions require all wastes created on the site to be used within the same site, and not transported off site to disposal facilities or even for re-use. This will only be completely possible when, for example in case of a demolition scheme, the constituent parts of the building to be demolished are known and present no hazard, as well as being potentially useful. If the building being demolished contained harmful materials, such as asbestos or lead pipes, the proper management and disposal of that waste would be crucial for protection of health.

On-site processing requires the allocation of space for mobile crushers and screens as well as space to store sorted graded products in containers, or possibly for long-term stockpiling until the construction project reaches a stage where the materials may be used. Such space may not always be available. On-site processing is likely to increase both noise and dust nuisance on the site although there would be a corresponding reduction in transport movements and their associated nuisance.

Figure 1: Mobile screening equipment for C&D waste (Picture sources: Jochen Zellner, Landkreis Neustadt/Aisch-Bad Windsheim , www.abfallbild.de)

Centralized processing

A fixed processing site at a centralized location may take in unsorted loads of construction and demolition wastes from sites within a certain radius. Fixed processing facilities take in larger tonnages from a variety of sources and are thus more likely to be able to meet the demands of consistency of supply and quality control required by construction contracts.

The equipment on a fixed site is likely to be more sophisticated than the mobile equipment used in on-site processing. It would be capable of consistently producing graded materials to exact specifications, making the chance of its re-use much greater.

Material delivered to the site is first screened to remove hazardous and bulky materials such as metals parts and other coarse adhesions. Afterwards the screened material is crushed, followed by magnetic separation of metal materials. Sometimes air currents are passed over the material to remove light contaminants such as paper and plastic. Multiple screen sizes produce a variety of material grades.

Material use

Preparing a site for a development such as a new road, typically soil, stones and subsoil (clay) form the greatest proportion (an average of 45%) of the materials obtained in the construction and demolition, depending on the site. The demolition of buildings mainly produce mineral materials and, in smaller quantities, wood and other fractions such as metals, glass and plastics. These materials can be suitable for the following recovery processes:

- **Soil and subsoil** can be readily screened from other wastes using a sieve (for contaminated soils a stationary soil washing plant is necessary) and all materials can in principle be used on site (filling and profiling of the construction site). If the site is the upgrading or repair of an existing roadway, the waste material may include bitumen or asphalt. These materials have to be separated if they disturb the chose application.
- **Reclaimed asphalt** can be reprocessed at the construction site. Using reclaimed materials avoids disposal fees, and reduces the expense of producing and buying paving materials. Some of the reclaimed asphalt can be mixed with new asphalt before being applied to the road surface or as road repair asphalt material. However, recycled asphalt is more often used as a road base or for shoulders on roads or as landfill cover. For use as an aggregate in new roadbed construction or cover layers the asphalt is grinded.
- **Crushed concrete** is primarily used as an aggregate for road base material. The application of certified aggregates from crushed concrete as additions to concrete (i.e. building construction) offers a promisingly and high-quality alternative to concrete made out of primary resources. Crushed concrete can also be used for many other purposes, such as foundations or the concrete layer used below the cold and hot mixes on highways.
- **Wood waste** both treated and untreated is generated in large amounts during the demolition of wooden-framed buildings. Other wood waste arises in the form of doors and window frames, and other fittings. Wood waste from land clearing and untreated wood can be reused. It can be chipped for the use in particle and fibre board production or ground for use as a mulch product or in compost generation (see factsheet on "Composting"). A larger portion of the wood from construction and demolition activities may however be contaminated by paint or varnish, and in this case should be used in thermal processes only (see the factsheets on incineration techniques).
- All **other materials** contained in C&D waste in significant amount, such as glass, plastics, metal, paperboard, etc. do have similar properties as if they were found in the household and/or commercial waste. Hence the same treatment and recycling options as being described for these waste streams are in principle applying (see factsheets on "Treatment"). However, plastics as well as paper and board in the C&D waste often do not reach the quality and amount that makes their recycling economically feasible. That's why their use as substitute fuel in co-incineration processes is a common option (see factsheet on "Industrial Co-Incineration").
- Insulation materials made out of polystyrene (EPS) require special caution and attention for existing legal requirements because of the load with persistent organic pollutants (POP), especially with the highly hazardous substance hexabromocyclododecane (HBCDD).

IMPLICATIONS TO OTHER SECTORS

Aside from the ecological and economic benefits also significant employment effects can be attained from the reclamation of materials from C&D waste. A considerable amount of manual labour is especially required in the process of selective dismantling for removal operations and the de-construction, cleaning, refurbishment and sale of the reclaimed materials.

REFERENCES AND PROVIDER FIRMS

(Important note: The list of firms does not constitute a complete compilation of companies active in the specified fields.)

Installations for the processing of C&D wastes are widespread in Germany. Numerous companies also operate mobile equipment to reclaim and recycle C&D waste. Meanwhile this has allowed to have more than 90 % of C&D waste material recycled in the country. Many producers and provider firms are with their equipment and services on the market, for example:

Screens

- EuRec Technology GmbH, Merkers www.eurec-technology.com
- Backers Maschinenbau GmbH, Twist www.backers.de
- Sutco Recycling Technik, Bergisch Gladbach www.sutco.de

	- Sandvik Mining and Construction Crushing Technology GmbH Bergisch Gladbach www.miningandconstruction.sandvik.com/de *Crusher* - EuRec Technology GmbH, Merkers www.eurec-technology.com - Sandvik Mining and Construction Crushing Technology GmbH Bergisch Gladbach www.miningandconstruction.sandvik.com/de - HAZEMAG & EPR GmbH, Dülmen www.hazemag.de *Wind sifter* - Integra Ingenieurbetriebsgesellschaft, Saerbeck www.integra-ibg.de

END-OF-LIFE VEHICLES (ELV)

RELEVANCE OF WASTE STREAM

- End-of-life vehicles constitute a waste stream with
  - high amounts of recyclable materials that can lead to high reuse (reuse of spare parts) and recycling quotas
  - also high environmental risks originating from processed hazardous substances (i.e. oils, petrol) and materials that make safety measures necessary.
- EU directive 2000/53/EC about End-of-life vehicles stipulates legally binding requirements on the collection and treatment of ELV and obliges producers to carry out their producer's responsibility.

COMPOSITION/ MAIN MATERIAL COMPONENTS

Vehicles consist of various construction parts, which are produced with diverse materials and substances. An average passenger car consists of following components and operating materials.

Table 3: Orientation values for material composition and liquids/lubricants contained in ELV

Material composition		Operating materials in ELV	
Material	Amount	Operating materials	Amount
Steel	400 kg	Car fuel	5–10 Litre
Plastics	125 kg	Coolant	7 Litre
Combustion engine	100 kg	Engine oil	4 Litre
Insulating material/cushion	50 kg	Refrigerant	1–4 Litre
Other rubber components	35 kg	Transmission oil	2 Litre
Electrical engines	10 kg	Shock absorber oil	1 Litre
PUR-foam	10 kg	Lubricant	1 Litre
Safety glass	6 kg	Brake fluid	0,7 Litre
Composite glass	4 kg	Differential oil	0,5 Litre
Cables and wiring	4 kg	Power steering oil	Not specified
Tyres	5 pieces		

EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

The regulative framework for the management, recycling, treatment and safe disposal of end-of-life vehicles in Europe is provided with Directive 2000/53/EC of September 18, 2000 on End-of-life vehicles. It is supported by Commission Decision 2005/293/EG laying down detailed rules on the monitoring of the reuse/recovery and reuse/recycling targets of end-of-life vehicles. Member states are obliged to report collected and treated amounts every three years to the EU according to Commission Decision 2001/753/EG. Additionally, the Commission Decision 2003/138/EG requires a labelling for components and materials for vehicles.

NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM

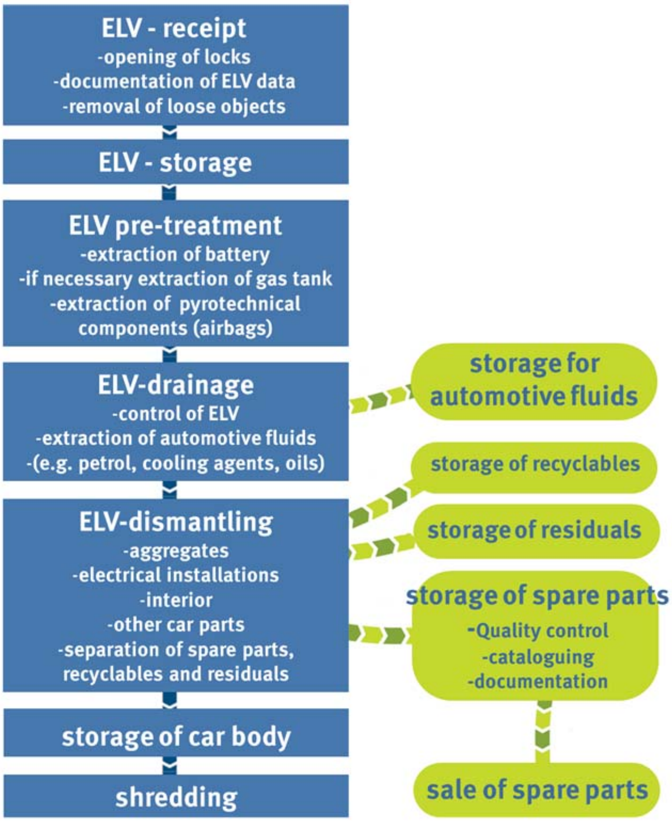
For this waste stream it is obligatory to ensure a maximum recycling through a selective collection and other appropriate measures such as the removal of all environmental relevant parts and liquids.

According to Directive 2000/53/EC, reuse and recovery shall be enhanced and specific targets shall be met. Target quota for the reuse and utilisation of car components, as fixed in the EU directive, are strong drivers for ELV recycling. As of 2015, reused and recovered materials shall achieve a minimum of 95 % of the average weight of a vehicle and recycled and recovered materials shall amount to 85 % of the average weight of an ELV.

Further hereto, minimum technical requirements for the treatment of end-of-life vehicles are formulated. These comprise in particular:

	<u>Operations for the de-pollution of end-of-life vehicles</u> - removal of batteries and liquefied gas tanks, - removal or neutralisation of potential explosive components, (e.g. air bags), - removal, separate collection and adequate storage of fuel, motor oil, transmission oil, gearbox oil, hydraulic oil, cooling liquids, antifreeze, brake fluids, air-conditioning system fluids and any other fluid contained in the end-of-life vehicle, unless they are necessary for the re-use of the parts concerned, - removal, as far as feasible, of all components identified as containing mercury. *<u>Operations in order to promote recycling</u>* - removal of catalysts, - removal of metal components containing copper, aluminium and magnesium, if these metals are not segregated in the shredding process, - removal of tyres and large plastic components (bumpers, dashboard, fluid containers, etc.), if these materials are not segregated in the shredding process in such a way that they can be effectively recycled as materials, - removal of glass. An essential contribution to achieve waste prevention targets is being made by repair/refurbishment and dismantling activities which help to extend the life span of vehicles and/or to obtain spare parts and other car components for reuse. The promotion of such activities is highly recommended whereas exports and the sale of outdated vehicles with low safety standards and bad environmental performance to third world countries shall not get the support and recognition as a recycling measure.
APPROPRIATE COLLECTION STRATEGIES AND SCHEMES	End-of-life vehicles should be returned at accredited collection points or directly at dismantling facilities by end users. An accreditation of accepting collection points and dismantling facilities ensures an environmentally compatible dismantling, an adequate treatment and appropriate documentation of the whereabouts of ELV. In contrast to dismantling facilities, accredited collection points only accept ELV delivered by end users and monitor the further way of treatment. These collection points must assure that accepted ELV are not piled up, not stored sidewards or stored upside down (on the roof). It prevents the leakage of hazardous substances such as car fuel and oils and impedes the activation of pyrotechnic components (i.e. airbags). Moreover, a damage of potentially reusable spare parts should be prevented (i.e. window glass). Producers of cars are obliged to take back and ensure an adequate treatment of ELV in some countries such as Germany. Producers shall take back the ELV, transfer it to an accredited dismantling facility and record the transfer and recovery, whereby they have the choice to instruct accredited collection points with their duties. If ELV are illegally disposed and no car owner/originator is traceable, municipalities mostly are responsible to take care of the collection and transfer of the ELV to accredited collection points and/or dismantling facilities.
APPROPRIATE TREATMENT AND RECOVERY SCHEMES	At first, ELV are dismantled into spare parts and components to provide best conditions for a reuse on the one hand and a subsequent recycling of separated components and fractions on the other hand. The dismantling process is characterised by the following basic procedure: 1. Acceptance of ELV, control of ELV and issuing a certificate of destruction to end user 2. Interim storage at suitable location and in appropriate position 3. Emptying of systems (removal of batteries, airbags, fuels, lubricants, refrigerants, oils) 4. Removal of reusable components (engines, gear box, generator, etc.) 5. Removal of recyclable components (plastics, glass, catalyst, etc.) 6. Comminution of the remaining car body in a shredder, recovery of the Fe-metals and non-ferrous metals for recycling and proper disposal of the residual material

Figure 2: Procedure of a dismantling process of a ELV



After the dismantling facility accepts the ELV, the battery, pyrotechnic components and, if installed, the gas tank is dismantled. Special requirements should be met while removing passenger restraint systems (airbags, belt tensioners) that work on the basis of pyro-technics. A special training of employees is necessary about the handling with and removal of these pyrotechnic components.

In a next step, all automotive fluids are removed. This includes car fuel, refrigerant (from air-conditioning), engine oil, transmission oil, lubricants, shock absorber oil, etc. All fluids are removed from the ELV and collected and temporarily stored in appropriate containers. After, they are subject to an adequate disposal in an environmentally friendly manner (see fact-sheet on "Waste Oil"). Especially refrigerants from air conditioning systems such as R134a (1, 1, 1, 2-Tetrafluorethan), which was mainly used until 2011, should only be removed with a special A/C service unit. It prevents emissions of the volatile refrigerant into the air (GWP of R134a = 1430).

After removing all fluids, the dismantling of all reusable spare parts (e.g. generator) and recyclable components (e.g. glass, plastics) takes place. Not less than following components should be removed out of the ELV.

- Latent heat accumulator
- Shock absorber (if oil in shock absorber is not removed)
- Parts containing asbestos
- Parts containing mercury (as far as possible)
- Materials not belonging to ELV (household waste)
- Catalysts
- Counterbalancing weights
- Aluminium rims
- Windscreens, rear and side windows, glass roof
- Tyres
- Large plastic parts
- Parts of copper, aluminium and magnesium

The level of detail of the dismantling process is dependent on age and condition (e.g. car damaged in accident) of the ELV and the corresponding profitability.

The shredding of the remaining vehicle body follows the previous steps. The generated fractions (e.g. iron, non-ferrous metals, shredder fluff and heavy fraction shredder scrap) are subject to further recycling processes. Materials that cannot be recovered in an economic and environmental efficient manner should be adequately treated, whereby the energetic recovery plays a priority role (see also the factsheets on incineration technologies). The landfilling of removed parts and components is prohibited due to the landfill ban of untreated waste materials. Moreover, it is no suitable option in terms of a sustainable resource and environmental protection policy.

Dismantling and recovery plants of ELV should fulfil special environmental requirements and, hence, should be subject to licensing procedures, as an inadequate storage and treatment follows in a contamination of soil and water.

Additionally, dismantling facilities should have the duty to monitor/record the amounts of ELV that enter the facility and the amounts of fractions that leave the facility. The documentation should include reused, recovered, recycled and disposed components to ensure a proper traceability of treated amounts.

APPROPRIATE RECYCLING TECHNOLOGIES

The separation and marketing of spare parts plays an important role during the dismantling process of ELV. The sale of spare parts accounts for a significant share on total revenues to finance the recycling process. Private persons as well as businesses are potential customers for these spare parts.

Plastics constitute a significant and increasing share on the total manufactured materials. Large plastic parts such as fittings should be removed and transferred to a high-quality recycling, whereby the economic feasibility is dependent on the market situation and the demand for recycled plastic flakes.

The shredding process of the remaining vehicle body uses several technical installations (e.g. zerdirators, mills, shredder and condirators). The shredded material is then separated into following fractions using different separation steps (e.g. metal separation, float-sink-plant, wind sifter):

- Ferrous metals (shredder scrap product)
- Non-ferrous metals
- Shredder fluff
- Heavy fraction shredder scrap

Ferrous metals and non-ferrous metals can be returned to the production process, whereby the repeated use substitutes primary resources.

Heavy fraction shredder scrap and shredder fluff can be further treated/ further separated in post-shredder plants into different fractions. Although fewer amounts of recyclables are contained in shredder fluff and heavy fraction shredder scrap, revenues can be expected if specific market prices are high. Factors that additionally enable a further mechanic treatment are:

- trend of a miniaturisation of electronic construction parts (e.g. fine data wires, small electric motors)
- higher amounts of recyclables in the shredder fluff because of a decreasing own weight and, hence, a higher flight capability of small recyclables.

Shredder fluff and heavy fraction shredder scrap are characterized by a high calorific value (e.g. plastics, rubber). Especially shredder fluff is used to produce substitute fuels, which offers the possibility to use these fractions for an energetic recovery (see factsheet on "Industrial co-combustion").

Old car tyres can be subject to divers recovery and recycling possibilities (see factsheet on "Tyres")

REFERENCES AND PROVIDER FIRMS *(Important note: The list of firms does not constitute a complete compilation of companies active in the specified fields.)*	Germany in 2015 has had 51 shredder plants and 1,300 ELV dismantling facilities in operation. Operators of plants with post–shredder technology are for example: – TSR Recycling www.tsr.eu – Scholz Recycling GmbH www.scholz-recycling.de – SRW metalfloat GmbH Espenhain and Nürnberg www.srw-recycling.de – ISR Itzehoer Schrott und Recycling GmbH & Co. KG www.isr-itzehoe.de

ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

Information and data about all German collection points, all kind of dismantling facilities and shredder plants are collected by a central authority ("Gemeinsame Stelle Altfahrzeuge" - GESA) and transferred to the public and to enforcement authorities. Gemeinsame Stelle Altfahrzeuge www.altfahrzeugstelle.de

Post-shredder technologies and corresponding researches are especially supported and financed by the automotive industry to improve recovery processes of recyclables out of the material streams heavy fraction shredder scrap and shredder fluff.

Umwelt Bundesamt

WASTE TYRES

RELEVANCE OF WASTE STREAM:

- Waste tyres are bulky and cause a risk for the environment as hazardous substances are contained or other environmental pollution is created when set on fire. They shall therefore be separately collected and treated adequately, also to exploit the high utilisation potential.

COMPOSITION/ MAIN MATERIAL COMPONENTS

Tyres are made up from the tyre carcass as the basic body and the tread. The tyre carcass consists of rubberized fabric from twisted fibre or filament of polyester rayon and nylon, the belt and a bead which is made out of wire material and of particular strength on truck tyres. Given the different types of tyres and the fact that producers keep their receipts secret, no specific details are available about the composition of tyres. For coarse orientation the following data can be used:

Table 4: Material composition of waste tyres

Materials		according to BUWAL[1] in mass-%	according to LfU[2] in mass- %			
			Motor car	Light truck	truck	average
Hydrocarbon-polymers	Natural rubber	47,0	21	19	31	24
	Synthetic rubber		24	23	14	21
Soot and active filler substances		21,5	28	26[1]	21[1]	26[1]
Steel		16,5	12	18	24	16
Fabrics		5,5	4	4	1	3
Zinc oxide		1,0	11	10	9	10
Sulphur		1,0				
Miscellaneous		7,5				

Table 5: Chemical composition of waste tyres

Element/substance	BUWAL[1]	Vest[3]	Element/ substance	BUWAL[1]	Vest[3]
Carbon	Ca. 70 %	70–75 %	Oxygen	4 %	3,5– 5%
Iron	16 %	13–15 %	Nitrogen	0,5 %	
Hydrogen	7 %	6–7 %	Stearic acid	0,3 %	
Zinc oxide	1 %	1,2–2,0%	Halogens	0,1 %	
Sulphur	1 %	1,3–1,7%	Copper compounds	200 mg/kg	
			Cadmium	10 mg/kg	
			Chromium	90 mg7kg	
			Nickel	80 mg/kg	
			Lead	50 mg/kg	

As a rule of thumb, the scrap tyre generation in industrialized countries is approx. one passenger car tyre equivalent (20 lbs.) per person and year.

[1] Bundesamt für Umwelt, Wald und Landschaft: Vollzugshilfe für die Lagerung, Behandlung und Verwertung von Altreifen (Altpneus) –Merkblatt Altreifen, zugänglich über BiCon AG: Altreifen Entsorgung – Was ist ökologisch sinnvoll? http://www.bicon-ag.com/gutachten-uvp/VCS_Altreifen_BiCon_2003.pdf , last access 26.08.2015

[2] Landesanstalt für Umweltschutz Baden-Württemberg: a.a.O., S. 8.Entsorgung von Altreifen in Baden-Württemberg, 03/2002, http://www.lubw.baden-wuerttemberg.de/servlet/is/11081/entsorgung_altreifen.pdf?command=downloadContent&filename=entsorgung_altreifen.pdf , last access 26.08.2015

[3] Vest, H.: Recycling of Used Car Tyres, Technical Information W13e, www.gate-international.org/documents/techbriefs/webdocs/pdfs/w13e_2000.pdf, last access 26.08.2015

EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS	There is no specific Directive for this type of waste in the European Union. Tyres that are collected separately from end-of-life vehicle are covered by the Waste framework directive. The Directive 2000/53/EC on the end-of-life-vehicles does refer to tyres on the account that they are part of collected end-of-life vehicles and as such have to be included into the materials reuse and recycling targets stipulated. Further to this, the Landfill Directive 1999/31/EC places restrictions on the disposal of tyres at landfills. If old tyres are subject to a retreading, legal guidelines of the UN/ECE (United Nations/Economic Commission Europe) apply regarding requirements on the retreading process: - Tyres of passenger cars: UN/ECE Guideline No. 108 - Truck tyres: UN/ECE Guideline No. 109
NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM	Waste tyres are generally considered items which require particular attention as discards. This implies their collection and treatment and other specific requirements indicated for this type of waste by different regulations. The EU Landfill Directive lists tyres as a separate waste stream and specifically bans the landfilling of whole tyres and shredded tyres. Next to recycling and recovery of waste tyres, options for their utilisation exist, e.g. the utilisation as safety barriers. The disposal of waste tyres in landfills or their deposition is no suitable option. Aside from legal provisions, which normally should rule out these methods, there is a very high danger of fires with great environmental damages (air pollution) resulting from it. Moreover, the material recovery and the energy value would remain unused.
APPROPRIATE COLLECTION STRATEGIES AND SCHEMES	Waste tyres should preferably be collected at the source of their generation; usually these are car repair shops, retailer, wholesaler and dealer of tyres and used cars, towing companies, fuel stations and companies with large car fleets. Basis for this should be (voluntary) agreements for the taking back of these products. To a certain extent collection will also be necessary thru special collection schemes for bulky items and public bring sites/recycling stations. The used tyres have then to be taken over from recycling firms and companies certified for their further management from whom they should be sorted into the following three main groups: - Grooved tyres: tyres which are still in usable state, i.e. the tread have a minimum depth of 1.6 mm and no other damages have occurred so that the tyre can be reused without further treatment. - Carcass: tyres which are not older than 6 years and whose carcass are yet without damages, especially on the side wall. These tyres can be used for retreading. - Scrap tyres: tyres which have serious damages and cannot be treated for reuse on cars.
APPROPRIATE RECYCLING TECHNOLOGIES	Reuse Only grooved tyres can be directly reused. Due to their lower optical quality these tyres are often exported to low income areas and thus less frequently used within the region/country where they have been generated. Other possibilities for the utilisation of used tyres are: - in agriculture: weights for silage cover sheets - in harbours and docks: dock bumpers and ship fenders - in landscaping: as erosion protection for dam, walls and slopes In all these uses, the long life span and elasticity of tyres are availed of. Retreading: Retreading is only possible for tyres where the tyre carcass is still intact. Requirements on the retreading process are stipulated in UN/ECE Guidelines 108 and 109. Special test and measuring procedures as described in both guidelines make sure that retreading is done with fully intact tyres only and requirements on the retreading process are met.

For retreating the old tread is stripped off and a new tread applied on the carcass. The methods to be used for this are

- hot retreading and
- cold retreading

APPROPRIATE RECYCLING TECHNOLOGIES –CONTINUATION–

Retreading of one tyre for passenger cars takes about 2–3 kg rubber material for the new profile, for a truck tyre 16–20 kg are needed respectively. The energy demand is about 30 % that for the production of a virgin tyre.

Aside from the options of reuse and retreading there is also the possibility to material recycle waste tyres to generate different rubber granule and powder for further applications. The necessary processing steps are:

<u>Granulation</u>
Before the shredding the tyres have to be “debeaded“. This is especially important for truck tyres which have a particularly strong bead (up to 25 mm thick). The debeader machine used for this has been specifically designed to remove hydraulically the steel beads and side walls from both sides of a truck tyre. Further destruction of the tyre by shredding is considerably easier having debeaded the tyre.

<u>Comminution</u>
In the next step, the tyre carcass is shredded to a grain size of about 50–150 mm. Slow speed two-spool shredders are used for this. To get the desired grain size, the chopped tyre particles are passed thru a screen and the oversized parts returned to the shredder aggregate. The screening is done by means of different screens such as drum screen or shaking screen. For the subsequent milling the following two methods are common:

- *Ambient milling*

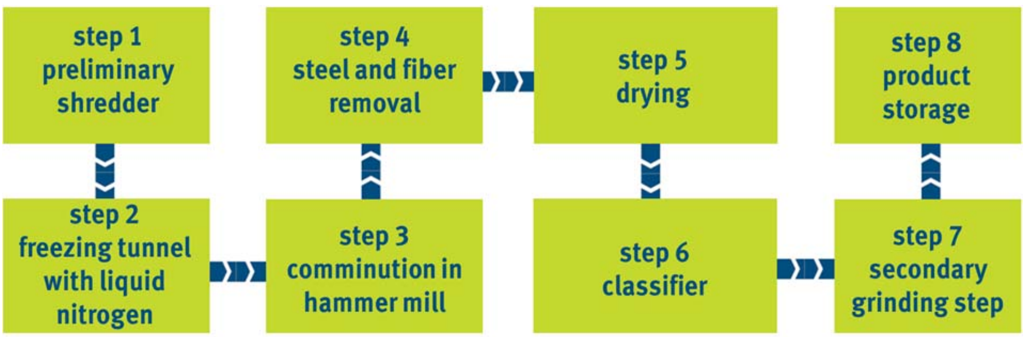
This milling method is called an ambient process because the further comminution is done in an atmosphere of ambient temperature. Only the milling aggregates are cooled in order to reduce the heat generated from the friction. A grain size of the rubber material up to 800 µm can be produced with this method.

Figure 3: Example of process arrangement for an ambient scrap tyre recycling

- *Cryogenic milling*

In this milling method, the chopped rubber material is cooled down with liquid nitrogen to a temperature of minus 100°C. The finished particles have a smooth surface so that the mechanical connection in mixture with other materials is somewhat lower than that of the particles obtained from ambient milling.

Figure 4: Example of process arrangement for a cryogenic scrap tyre recycling



	In both processes mills are being used that have been specially developed for the production of rubber granule. The so obtained granule and powders can among others also be used for the production of new tyres. Safety reasons do not allow the use of such material beyond a certain limit in tyre production. Larger amounts can be used for products without special physical and chemical demands, for example floor coverings, basis layer for carpets, sport ground flooring, motorway sleepers. Devulcanisation/Depolymerisation As a further step after milling, the particles can also be devulcanised. The most advanced method is that of mechanical devulcanisation. In this process, the rubber material undergoes intensive mechanical treatment in order to cut off the sulphur compounds. A technology for depolymerisation is the FORMEX-process. Within this process procedures are applied which prevent the generation of harmful compounds. The end product, called FORMEX CARBON BLACK® can be reused in rubber production. In this process scrap tyres are first shredded and the chips are then feed into a special reactor. The arrangement of the reactor prevents oxygen to be present during the process. The depolymerisation takes place in a bath of liquid tin at a temperature below 500°C. The low temperature guarantees that the rubber particles can stay long enough in the reaction zone. The gases and oil generated in the result of this reaction are stored in tanks. Steel particles are taken out by magnetic separation. Fibres get caught in a tumbling screen. The mix of carbon black is forwarded into a mill which reduces the particle grain size below 40 µm. 99 % of the products generated in this process can be utilized. Use of the granule Rubber granule aside from being returned for tyre production can also be used in gardening, landscaping and for road construction. The use of rubber granule in mixture with asphalt in roadside construction (rubber modified asphalt – RMA) delivers a road surface which is noise absorbing, more resistant to wear and has a better grip.
APPROPRIATE TREATMENT AND RECOVERY SCHEMES	Thermal utilisation Waste tyres have a heating value of 26 to 32 MJ per Mg. This makes them especially suitable as substitute fuel. As such they can be used in cement kilns, power plants and paper mills (see also fact sheet on "Industrial co-combustion"). As of now the thermal utilisation is the most used option for the disposal of waste tyres in Europe as well as in the rest of the world. It is principally possible to use waste tyre for all three types of firing in a cement kiln (calcinator, secondary and primary heating). Large scale applications have only been successful for the secondary heating, however. That's why waste tyres are so far used for this process. Here they don't have to be shredded and supply a raw material aside from their thermal value. The steel from the tyre complement to the concentration of iron from the limestone and oxidizes zinc and sulphur which gets then fixed in the cement matrix. Waste tyres can also be used in coal-fed power plants but the need to have them shredded first makes the process too costly.
REFERENCES AND PROVIDER FIRMS *(Important note: The list of firms does not constitute a complete compilation of companies active in the specified fields.)*	In Germany, numerous facilities for the processing, recycling and retreading of tyres are in operation. Many of the described applications as well as the use of rubber granule and powders in various production sectors are commonplace. *Plant manufacturer:* - ANDRITZ MeWa Gechingen: www.andritz.com/index/locations *Production of rubber granules and retreading materials:* - Genan GmbH, Oranienburg www.genan.de / www.genan.eu - Kraiburg Holding GmbH & Co. KG www.kraiburg.de Providers of required equipment and technologies, among others, are: *Shredding equipment:* - HERBOLD, Meckesheim www.herbold.com - EuRec Technology GmbH, Merkers www.eurec-technology.com *FORMEX-process:* - Berliner-Oberspree Sondermaschinenbau BOS GmbH, Berlin www.bos-berlin.de

WASTE OIL

RELEVANCE OF WASTE STREAM:

- Waste oils can cause severe environmental damages when encountering soil and water, a separate collection and a further recovery of waste oils shall be applied to prevent negative impacts

MAIN COMPONENTS

The approximate composition of waste oil can be described as follows[4]:

Table 6: Approximate composition of waste oil

Components of waste oil	Percent by weight
Base oil fraction	60–70
Gas oil fraction	10–15
Additives[2]	7–15
Water	0–10 [1]
Oxidation products[3]	4–8
Lower boiling fraction	1–6
Solid foreign substances[4]	1–3
Brightstock	0–5

1 – occasionally up to 50 %
2 – including their decomposition products
3 – polar, partly aromatic compounds from oxidation processes
4 – wear particles, soot, resinous substances with diameter less than 2 mm

Important is the concentration of heavy metals because metals and their compounds must be eliminated in the case of recovery of waste oil for the use as lubricant base oil, raw material for the chemical industry or fuel confirming to given standards. During the incineration of waste oil metals and their compounds accrue as dust in the flue gas cleaning. The concentration of heavy metals in waste oils has a broad range which, among others, depends on the structure of supplying industries, car engine technology, driving habits and can alter depending on the analytical procedures applied.

EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

The Waste Framework Directive 2008/98/EU stipulate regulations to achieve the best possible utilisation under given conditions and to ensure a safe handling and disposal of waste oils.

NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM

The Waste Framework Directive stipulates: “The management of waste oils should be conducted in accordance with the priority order of the waste hierarchy, and preference should be given to options that deliver the best overall environmental outcome.” (Waste Framework Directive, (44)). Hence, regeneration processes using refinement shall be preferred to a thermal treatment. It shall be decided between the disposal ways of incineration, destruction, storage or landfilling, if a recovery process is not an option. The separate collection of waste oils remains crucial to their proper management and the prevention of damage to the environment from their improper disposal. (see more details on Waste Framework Directive).

For a safe disposal and utilisation the following shall be prohibited:

- any discharge into inland surface and ground water, territorial sea water and drainage systems;
- any deposit and/or discharge harmful to the soil and any uncontrolled discharge of residues resulting from the processing of waste oils;
- any processing causing uncontrolled air pollution

[4] Möller: Altölentsorgung durch Verwertung und Beseitigung, Band253, expert Verlag, ISBN 3-8169-2250-3, Renningen 2004

	Which is why: - any undertaking which collects waste oils must be subject to registration and national supervision, possibly including a system of permits; - any undertaking which disposes of waste oils must obtain a permit. No authorisation is to be given to the mixing of waste oils with polychlorinated biphenyls and polychlorinated terphenyls (PCBs and PCTs) or with toxic and dangerous wastes. Any oil containing PCBs or PCTs, or containing toxic or dangerous products must, without exception, have to be destroyed.
APPROPRIATE COLLECTION STRATEGIES AND SCHEMES	Take-back schemes are the most common way for the collection and recovery of waste oil. Take back for individual consumers can most efficiently be realized via sales stores, car repair or petrol stations who are also selling oil. Pick-up arrangements with recycling companies are common for commercial consumers. In some parts of Europe there have also public collection systems in form of special container installations or pickup arrangements from households been established. For the transportation of waste oil in Europe the European Agreement concerning the international carriage of Dangerous goods by Road (ADR, 2008/68/EG) has to be respected.
AVAILABLE RECYCLING TECHNOLOGIES	Waste oils can be utilized by material or thermal recovery. In the case of thermal recovery, waste oil can be used as waste derived fuel in e.g. cement kilns, furnaces or other incinerators to produce steam and electric energy (see also factsheet "Industrial co-combustion"). The incineration in fluidized bed combustions is another suitable option (see factsheet "Fluidized bed combustion"). Waste oil that is used as a fuel must undergo basic treatment to remove water and particulates before it is fit for use as fuel known as recovered fuel oil Material recovery is possible on different ways. They shall be briefly described hereafter. - Re-use: Two methods exist to reclaim clean industrial lubricants before returning them to the users: *Laundering:* This is a close-loop system especially for hydraulic and cut-ting waste oil. Solid removal (filtration), de-watering and fresh additives addition allows to return the oil to its original state again fit for use. *Reclamation:* This is a recycling process especially for hydraulic waste oil. These oils are simply centrifuged and/or filtered and then used, for instance, as mold release oil or base oil for the production of chain saw oil. - Re-refining: Re-refining produces re-refined base oil. This is a more expensive and complex process than other routes, but produces a high-quality oil. A variety of proprietary technologies, e.g.: - acid/clay-process, - distillation/chemical treatment or solvent extraction process, - propane de-asphalting process (PDA), - thin film evaporator (TFE) and hydro-treatment process, - thermal de-asphalting process (TDA), - TFE and lubricant refinery recycling process In essence, the used oils are first cleaned of their contaminants, such as dirt, water, fuel, and additives, through vacuum distillation and then hydro-treated to remove any remaining chemicals. Finally, the re-refined base oil is combined with a fresh additive to make the finished lubricant. The main process steps, generally used by all technologies are: - Dewatering and de-fuelling: Removal of water, light ends and fuel traces (naphtha, etc.) by using the gravity effect in settling tanks, clarifiers or plate separators, but centrifuges or distillation can also be used. This pre-treatment process is not compared with other oil treatment systems because it does not yield an end-product, nor does it achieve the final aim of treatment.

- De-asphalting: Removal of asphaltic residues (heavy metals, polymers, additives, other degradation compounds) by distillation and addition of acids
- Fractionating: This involves a separation of the base oils using their different boiling temperatures to produce 2 or 3 cuts (distillation fractions).
- Finishing: Final cleaning of the different cuts to achieve specific product specifications Finishing may also include the polycyclic aromatic hydrocarbons (PAH) removal in the case of a severe hydro-finishing (high temperature and high pressure) or solvent extraction (low temperature and low pressure).

Used oil can be re-refined over and over again, and is subject to the same stringent refining, compounding, and performance standards as virgin oil. However, new high quality products require highly consistent and predictable quality, which is obtained from using high pressure hydrogenation.

Regeneration creates by-product streams that, in the case of the lighter components, may be used as fuel. The heavier residual stream, containing additives and carbonaceous species, may be used as a blending component in the bitumen industry, where it is incorporated in construction products such as road surfaces.

Thermal cracking:
Thermal cracking uses heat to break down long-chain hydrocarbon molecules into shorter ones thus generating lighter liquid fuels. In this way, larger molecules of more viscous and less valuable hydrocarbons are converted to less viscous and more valuable liquid fuels.

Various technologies exist for cracking waste oils for use as lubricants, heating oil, automotive fuels or others. After removal of the water, much of the heavy metal contents are removed as sludge or via an acid treatment prior to the cracking step. The pre-treated waste oil is thermally cracked at 420°C at low pressure (without a catalyst). Depending on the intensity of the cracking, the product may either be a fuel oil or a fuel suitable for blending with diesel (diesel-extender).

The typical yield for a thermal cracking is 71 %, this results from the partial yields in the processes of 95 % dewatering, 90 % thermal cracking, 83 % distillation and 99,5 % purification/stabilisation.

The main drawback is that it is an energy intensive process requiring more sophisticated, and thus costly, equipment. The process can rarely compete directly with the direct use of waste oil as a fuel

FACTORS INFLUENCING THE APPLICATION

What will be priorities for waste oil management is strongly influenced by such factors as the local supply/scarcity of the like resources, the availability of the appropriate technologies or installations, the general price levels and financial mechanisms which could promote the utilisation of waste oil (e.g. charges on waste oil disposal, subsidies for regenerated oil use).

REFERENCES AND PROVIDER FIRMS

(Important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)

Recognized actors and service providers in the field of waste oil management and with regard to the technology requirements in Germany are for example:

- BAUFELD-OEL GmbH, München www.baufeld.de
- SÜDÖL Mineralöl-Raffinerie GmbH, Eislingen www.suedoel.de
- AVISTA OIL AG, Uetze www.avista-oil.com
- Starke & Sohn GmbH, Niebüll www.starkeundsohn.de
- PURABLUBE GmbH, Zeitz www.puraglobe.com

Further information about waste oil management and utilisation concepts, the applicable technologies and on services and provider firms can be obtained from

- Bundesverband Altöl e.V. (BVA) www.bva-altoelrecycling.de

Umwelt Bundesamt

WASTE OF OLD BATTERIES AND ACCUMULATORS

RELEVANCE OF WASTE STREAM

- Waste products that cause severe environmental damages to soil and water when improperly disposed, separate collection and material recovery shall be applied to avoid that
- EU directive 2006/66/EG about batteries and accumulators stipulates legally binding requirements on collection and treatment and obliges producers to carry out their producer's responsibility

COMPOSITION/ MAIN MATERIAL COMPONENTS

Batteries are divided into primary batteries (one-time use) and secondary batteries (repeated use through charge). Various electrochemical functionalities are available at the market. Table 1 presents currently usual types of batteries, their composition and characteristics:

Table 7: Approximate composition of waste oil

Type of battery	Applied chemical system	Main components	Capacity (mAh)	Nominal voltage	Durability
Batteries (Primary batteries)	Alkaline-Manganese (AlMn)	Manganese dioxide Iron Zinc	~ 2.800	1,5 V	1 cycle
	Zinc-carbon (ZnC)	Manganese dioxide Iron Zinc	~ 1.200	1,5 V	1 cycle
	Lithium (Li)	Iron Manganese dioxide Nickel Lithium	~ 3.000	1,5 V	1 cycle
Accumulators (Secondary batteries)	Lithium-Ion (e.g. with Li-NMC, Li- NCA, Li-LFP as cathode material)	Graphite Cobalt Nickel Manganese Lithium	~ 2.400	3,6 V	Up to 1,000 cycles
	Nickel-metal hydride battery (NiMH)	Nickel Iron Rare earth	~ 2.200	1,2 V	Up to 1,000 cycles
	LSD-nickel-metal hydride battery (LSD-NiMH)	Nickel Iron Rare earth	~ 2.000	1,2 V	Up to 1,000 cycles
	Nickel-cadmium-battery (NiCd)	Iron Cadmium Nickel	~ 600	1,2 V	Up to 1,500 cycles
	Rechargeable alkaline-manganese battery (RAM)	Zinc Manganese	~ 1.800	1,5 V	minimum 25 cycles

Batteries that contain mercury have a decreasing share on the sales market, because in 2015 a placing on the market of these batteries with more than 0.0005 per cent per weight of mercury has been prohibited. Nevertheless, batteries containing mercury are still in circulation and will be part of the waste management in the future. In Germany, about 1.5 tons per year of mercury were recovered from batteries and button cells.

Recommendations support the application of lithium-ion batteries as efficient option in the area of energy supply of batteries and accumulators.

EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

The legal framework for the safe handling and disposal of used batteries and accumulators in the countries of the EU is provided through Directive 2006/66/EG of September 6, 2006. This directive replaces a number of former directives issued on the same subject.

Being considered potentially hazardous due to heavy metal concentrations and other hazardous components they contain, old batteries and accumulators are also given special attention in the national regulations of many countries outside the EU.

NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM	Best Practice in managing this kind of waste as being determined also by the above directive means to adhere to certain standards concerning hazardous content when introducing battery products on the market and in handling them once becoming a waste <u>Production and marketing:</u> A ban on the marketing of batteries and accumulators containing more than 0.0005 mass-% of mercury or 0.002 mass-% of Cadmium provides the basis for the further penetration of these substances into the market and for a stepwise reduction of heavy metal concentrations in the municipal solid waste in Europe (Accumulators used for special systems/items such as alarm systems or emergency lighting are excluded from the cadmium restriction). <u>Handling of old batteries and accumulators:</u> Batteries and accumulators shall be collected separately from household waste and other waste streams to achieve a high recycling quota. The installation of separate take-back systems for old batteries and accumulators has proven to be a very effective collection system. In Germany, producers of batteries and accumulators are legally obliged to transfer their producer responsibility to a take-back system: This is possible through the participation in a common, non-profit and comprehensive take-back system or through the installation of an own, producer-specific take back system of one or more producers. Additionally, producers of vehicle batteries and industry batteries shall offer an acceptable take-back option to their distributors free of charge. The transfer of these duties to existing take-back systems as well as the establishment of producer specific take-back systems is possible, too. It is recommended to establish a central register that monitor, control and publishes producers that are active at the market to create transparency for all participants. Producers shall transfer information about their brand, the amounts put on the market as well as information about their realisation of their take-back obligations to the register. Additionally, producers should ensure that the transport (partially hazardous materials), the sorting of battery mixtures, the treatment and the recycling is conducted according to state of the art technologies. No costs should incur for private end users to achieve a high as possible participation quota. It also should guaranteed that private end user are sufficiently informed by producers about - the meaning of labels/symbols printed on the batteries, e.g. the meaning of toxic substances subject to labelling, which are contained in the producer's batteries - the legal obligation of end users to deliver old batteries and accumulators at official collection points to make them available to an adequate recycling - the possibility of a take-back free of charge at sale points of the producers The labelling of each battery and accumulator with the following symbol sensitize end user about the necessity of a separate collection and the importance to make old batteries and accumulators available to a secure disposal system. Figure 5: Label for separate collection of old batteries and accumulators 
APPROPRIATE COLLECTION STRATEGIES AND SCHEMES	Take-back and special collection schemes are the most common ways for the collection and recovery of used batteries and accumulators. Take back can be most efficiently realised via the stores and vendors who are selling batteries, thru public amenity sites and recycling stations of the municipalities or by pick-up arrangements between recycling companies and the (commercial) users, or thru dedicated collection campaigns (in the municipalities).

It is recommended that take back-partners make use of special containers to draw attention on and facilitate the separate collection and safe storage of the used batteries/accumulators in their premises. Moreover, the damage of batteries can be prevented at an early stage because collection containers can be exchanged and don't have to be transfilled. Damaged batteries can cause short circuits, which may lead to fires during transportation.

Figure 6: Collection container for used lithium batteries (picture source: INTECUS GmbH)

It is conceivable that public waste management systems voluntarily take part in the take-back system or even being committed to take part in the take-back system by law.

APPROPRIATE TREATMENT AND RECOVERY SCHEMES

Due to the fact that the batteries are rarely collected according to their composition, a sorting is necessary before their recycling. Before any sorting the batteries are automatically classified by size, in this way round cells are being excluded from the processing. For the further sorting the following procedures are known:

- Electromagnetic process
  First batteries are separated into magnetic (about 85%) and non-magnetic ones. The magnetic batteries are then passing a magnetic field which changes in dependence from the electro-chemical system contained in the battery. Up to six batteries can be identified and sorted per second in such processes. The achieved purity of the sorted fractions reaches 98%.
- Radiographic process
  The batteries pass a radiographic (X-ray) sensor. On the basis of the different grey shading produced on the image the electro-chemical system contained in the battery can be identified. Up to twenty batteries can be identified and sorted per second in such processes. The achieved purity of the sorted fractions goes beyond 98%.

The producers of alkaline-manganese batteries and zinc-coal batteries mark their products with a special UV-code in order to achieve a separation of batteries containing mercury and such without this element. This code can be automatically read by an UV sensor.

As an alternative for the above automated sorting processes also a manual sorting can be applied on lower quantities of spent battery products. Provided that adequate safety measures are fulfilled, this is a sufficiently reliable separation method for different types of used batteries, too. The obligatory imprints on battery content do facilitate that kind of sorting process.

Sorting and recycling operations are normally performed separately to allow for the recycling of batteries, whereby the recycling process should be subject to minimum requirements regarding efficiency and process application. In Germany an information/documentation duty of operators of recycling facilities was introduced to a central register, to control and to develop recycling procedures.

APPROPRIATE RECYCLING TECHNOLOGIES

Different metallurgic processes can be used for the various electro-chemical systems of batteries. They can be roughly distinguished into pyro- and hydro-metallurgic processes of which relevant examples shall be briefly described hereafter. The main process differences can be characterised as follows:

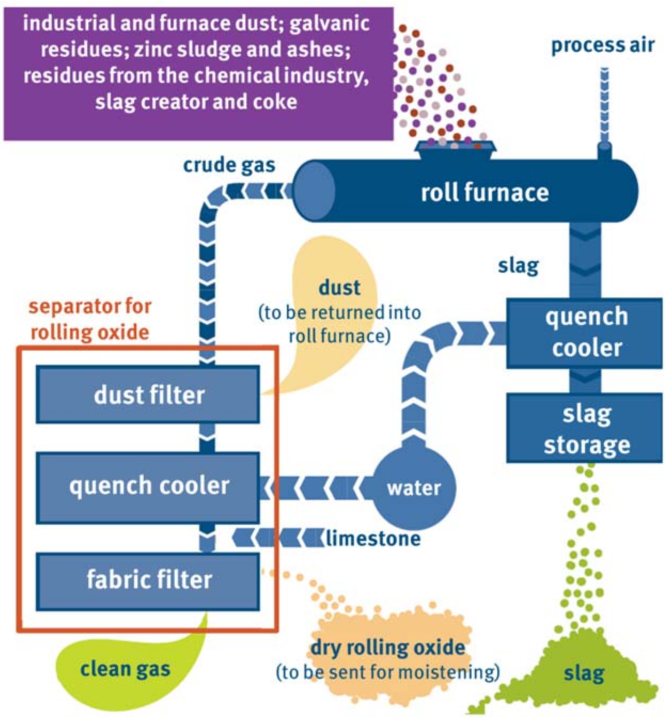
Table 8: advantages/disadvantages of pyro and hydro metallurgic processes

	Pyro metallurgic process	Hydro metallurgic process
Advantages	• High speed of reaction • High efficiency • High throughput rates • Suitable for complex compounds • Less sensitive to changing input	• Very selective reactions (high purity of output) • Well controllable for input of stable composition • Little problems with emissions
Disad-	• Less selective reaction (lower purity of output) • Process steps may have to be reiterated several times • High noise and emission potential	• Slower speed of reactions • Lower efficiency and throughput • Sensitive against changing input • Process residues may cause problems during disposal

Alkaline-Manganese and zinc-coal batteries

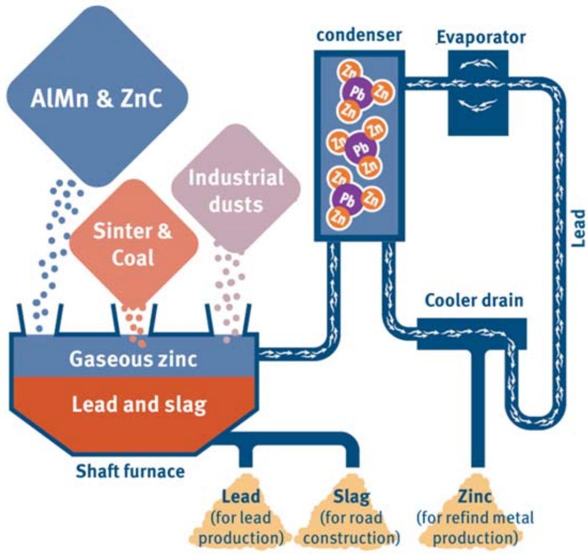
a) *Roll Furnace* – the roll furnace process is a melting technology where zinc-containing batteries are feed (together with sand and coke) into a rotary kiln. The zinc oxidises and evaporates at a temperature of 1300°C. After cooling down, the oxides are being collected and given away to a primary zinc smelting plant to produce virgin zinc from it. The produced slag can be used in road construction. The general process scheme for the utilisation of used batteries in a roll furnace is shown hereunder

Figure 7: Process scheme of a roll furnace procedure



b) *Imperial-Smelting-process* – this process generates zinc in metallic form. Also here the zinc gets evaporated and forwarded to a condenser where it is cooled down in mists from lead. The zinc sticks to the lead. Both metals get cooled and separated again. The lead is returned to the condenser while the pure zinc is being gathered and given to refining and new production.

Figure 8: Process scheme for the imperial smelting process used for battery recycling



c) *Further processes* – Further processes for the material recycling of alkali-manganese and zinc-coal batteries are available for

- Electrolytic steel furnace producing steel
- Electrolytic steel furnace producing ferromanganese
- Converter steel furnace producing ferromanganese
- Revolving hearth furnace

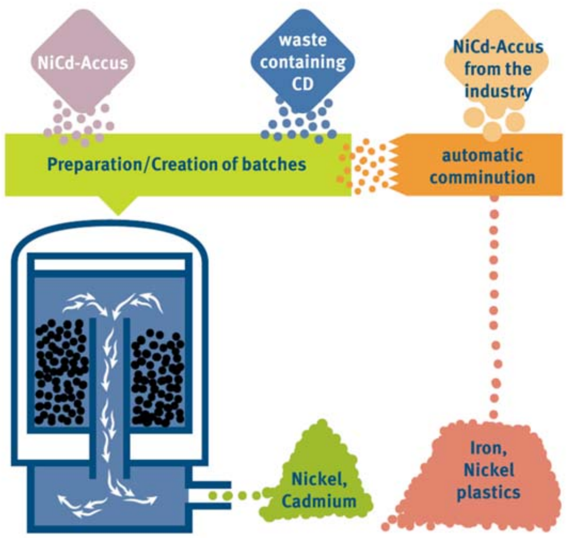
Like in the aforementioned processes the zinc is evaporated and recovered from the material mix. The processes are less common, however.

- Dismantling process: Alkaline-manganese batteries of type C and D are mechanically opened and afterwards dismantled. The products of the dismantling process are zinc oxide, iron and manganese oxide.

Nickel-Cadmium (NiCd) batteries

Used nickel-cadmium accumulators can also be thermally recycled. Here the cadmium is being extracted (distilled) under a vacuum or inert atmosphere. The remaining steel-nickel mix is given to steel production. Due to the small remaining quantity of such batteries, the already existing capacities in Europe are considered sufficient for the entire continent. One application, the Accurec process, is shown in the scheme hereafter.

Figure 9: Process scheme for the recycling of Ni-Cd batteries

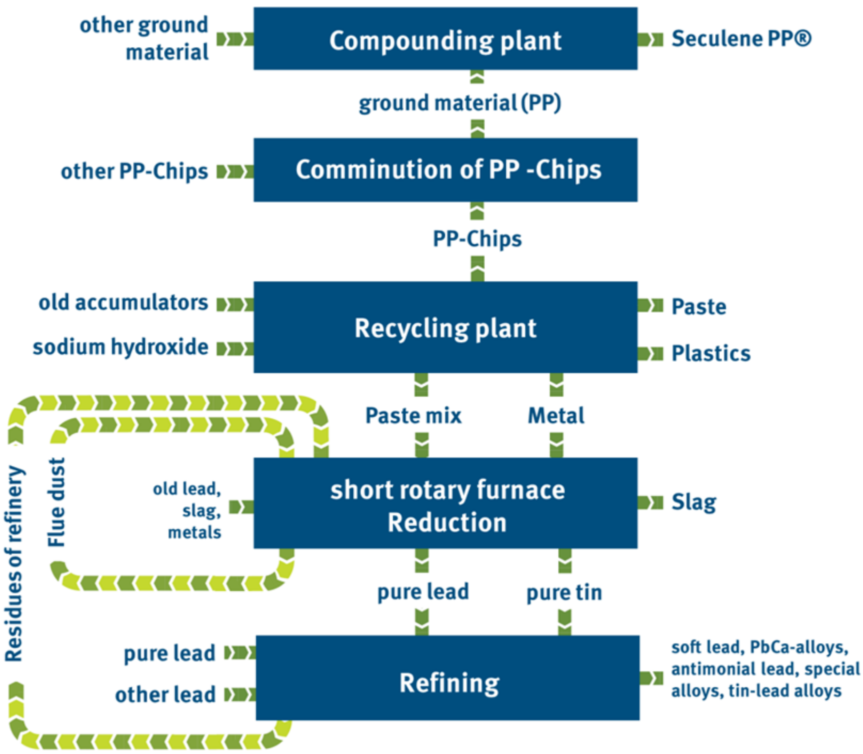


Lead accumulators

There are basically two ways of recovering lead from used accumulators. Either the batteries are treated prior to a smelting process and separated by material category (lead, plastic, acid etc.) or they are processed directly as such, after the acid has been removed from the accumulator body. After the liquid acid is drained off, the complete batteries are fed into a blast furnace without further treatment. In the furnace they are smelted in a mixture containing coke, limestone and iron. These additives promote the smelting and transformation processes in the furnace and help to recover the lead step-by-step, and to cleanse it of impurities. The result is crude or raw lead. The process is a. o. employed by the battery producer VARTA under the name (VARTA) Schachtofen-Verfahren [shaft furnace process]. Also a product of the shaft furnace process is the off-gas. It contains the gaseous components of the smelting process: in addition to carbon dioxide and carbon monoxide, dust particles with high lead content and residues from pyrolysis of the plastics. In order to clean the off-gas effectively, its organic content is first burnt off completely. Gas burners heat the off-gas from an initial 200° C to temperatures of up to 1100° C to remove even the last remnants of organic components. After cooling, the gas passes through a filter system which collects almost 100 per cent of the dust content. The collected dust contains about 65 per cent of lead, which makes it a valuable raw material. After a pre-treatment it is returned to the smelting process

The company BSB Recycling uses the Engitec-technology to recycle lead accumulators from the automotive and industry sector. As a product of the process plastic flakes, soft lead, PbCa-alloys, antimonial lead, special alloys and tin-lead alloys are recovered (Figure 6).

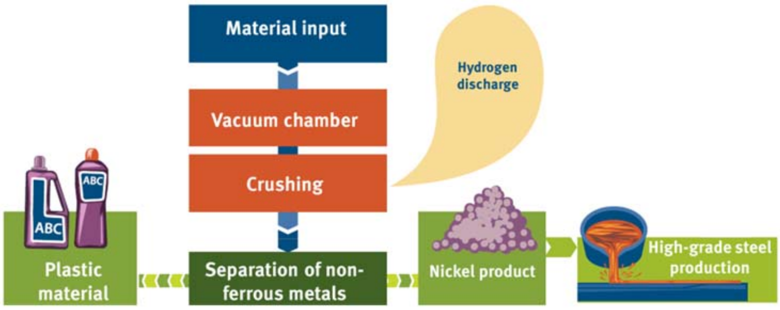
Figure 10: Process scheme of lead accumulators (modified according to BSB Recycling GmbH)



Nickel-metal hydride (NiMH) batteries

The utmost attention in the recycling of this battery type is given onto the recovery of the element nickel. One of the processes currently in use is based on a comminution under vacuum from which a premature nickel substance is obtained for further processing. Due to the possible release of hydrogen during this treatment, a protected atmosphere (vacuum) need to be created. The principle can be seen in the following scheme for the NIREC process. The obtained nickel product is highly sought from steel production for the creation of special alloys.

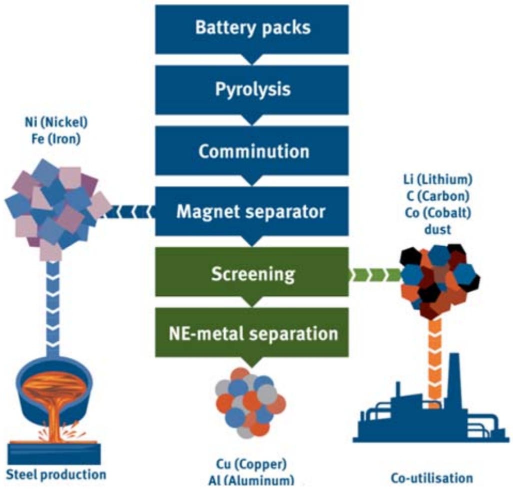
Figure 11: Scheme for the recycling of NiMH batteries based on the NIREC-process



Lithium batteries

The focal attention in the recycling of lithium batteries is on the recovery of nickel, iron and manganese. The corresponding processes are yet under development. The general principle is shown in the following figure.

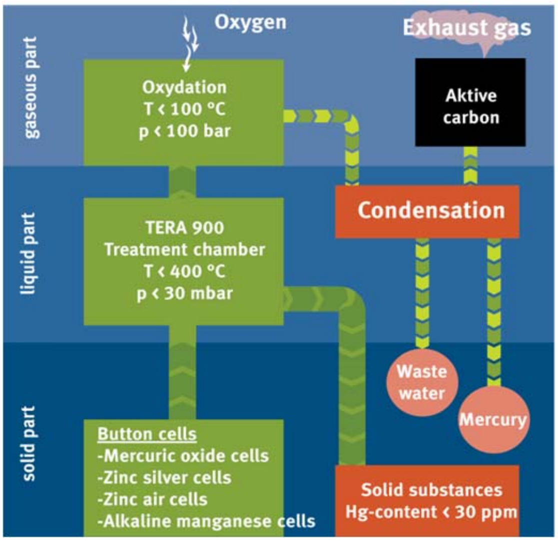
Figure 12: Scheme for the recycling of batteries containing lithium



Batteries containing mercury (round cells)

The mercury is recovered with the help of the ALD process which is based on a vacuum-thermal treatment. In special, airtight encapsulated installations the mercury will be evaporated at 350°C and 650°C and later on it condenses at lower temperatures. The pure mercury and the mercury free steel obtained in the process can be further utilised in production. The process can be characterised by the following scheme.

Figure 13: Process scheme for the recycling of mercury-containing batteries



REFERENCES AND PROVIDER FIRMS

(Important note: The list of firms does not constitute a complete compilation of companies active in the specified fields.)

In Germany the collection of old batteries and accumulators takes place in the frame of the producer's responsibility. In 2014, more than 170,000 collection points were installed and emptied by following 4 take-back systems:

- GRS Foundation (GRS Batterien - Stiftung Gemeinsames Rücknahmesystem Batterien) www.grs-batterien.de
- producer specific take-back system REBAT, www.rebat.de
- producer specific take-back system ERP Deutschland www.erp-recycling.de
- producer specific take-back system Öcorecell www.ifa-gmbh.com

The take-back systems have to ensure a minimum collection quota of 40% per year, which will increase to 45% in 2016. In 2014 about 19,142 tons of batteries and accumulators were collected in total.

Facilities doing the recycling and utilisation of used batteries and accumulators operate in Germany in larger number. Reference plants for some of the processes described above are for example:

Table 9: Reference facilities

Application	Revolving furnace	Imperial-smelting-process	Converter furnace
Location	Goslar	Duisburg	Duisburg
Input of batteries	5%	2–3 %	2–3 %
Products	zinc oxide, slag	zinc, slag	zinc dust, lead, slag, iron

Other provider firms for service concerning battery recycling or utilisation are for example:

- Recycling of AlMn and ZnC batteries as well as NiMH batteries:
  Redux GmbH, Dietzenbach www.redux-gmbh.de
- Recycling of button cells containing mercury:
  REMONDIS QR GmbH, Dorsten www.remondis-qr.de
- Recycling of NiCd batteries and batteries containing lithium:
  Accurec GmbH, Mülheim/Ruhr www.accurec.de
- Recycling of lead accumulators:
  BSB Braubach der Berzelius Metall GmbH, Braubach www.berzelius.de
  HOPPECKE Metallhütte GmbH & Co. KG, Brilon www.hoppecke.de

Umwelt Bundesamt

WASTE OF ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE)

RELEVANCE OF WASTE STREAM:

- Waste of electrical and electronic equipment (WEEE) consists of devices and components that can cause severe environmental damages based on contained hazardous substances and materials. But it also provides a huge recoverable resource potential, which demands a separate collection and treatment.
- The EU implemented the directive 2012/19/EU on waste electrical and electronic equipment that stipulates legally binding requirements on the collection and treatment and obliges producers to carry out their producer's responsibility.

COMPOSITION/ MAIN MATERIAL COMPONENTS

The generic term "waste of electrical and electronic equipment" or "scrap electronics" comprises a large spectrum of different consumer products. The waste stream is classified into 10 different categories according to the European directive 2012/19/EU, whereby the material composition highly fluctuates per type of device.

1. Large household appliances (LHA)
2. Small household appliances (SHA)
3. IT and telecommunications equipment (ITT)
4. Consumer equipment and photovoltaic panels
5. Lighting equipment
6. Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
7. Toys, leisure and sports equipment
8. Medical devices (with the exception of all implanted and infected products)
9. Monitoring and control instruments
10. Automatic dispensers

Table 1 shows orientation values for compositions of large household appliances (e.g. washing machines, cookers) small household appliances (e.g. toaster, fryers) and IT and telecommunications equipment (e.g. telephone, printer).

Table 10: Composition of categories (according to EMPA 2009)

Material	Large HH appliances	Small HH appliances	IT equipment
Iron	43	29	36
Aluminium	14	9.3	5
Copper	12	17	4
Plastics	19	37	12
Glass	0.017	0.16	0.3
Gold	6.7E-07	6.1E-07	2.4E-04
Silver	7.7E-06	7.0E-06	1.2E-03
Palladium	3.0E-07	32.4E-07	6.0E-05
Indium	0	0	5.0E-04
Lead	1.6	0.57	0.29
Cadmium	0.014	8.3E-03	0.018
Mercury	3.8E-05	1.9E-05	7.0E-05
Plastics „brominated“	0.29	0.75	18
Lead glass	0	0	19
Others	10	6.9	5.7

EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

Current legislation of the waste stream of WEEE is given by the amended Directive 2012/19/EU on waste electrical and electronic equipment and the amended Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment. Member states are obliged to report collected and treated amounts of WEEE on a biannual basis according to Commission decision 2005/369/EG.

NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM

The member states in the EU consider the waste from electrical and electronic equipment as a material fraction with a high potential value but also one carrying a considerable amount of environmentally harmful substances and posing a risk to the environment when disposed off without appropriate precaution and treatment. That is why the above mentioned directives govern the separate collection and treatment of WEEE and stipulate restrictions to the use of certain hazardous substances in electrical and electronic equipment. Accordingly, mechanisms for the take-back and treatment of WEEE should be established by producers (producer's responsibility). They are legally obliged to label their products put on the market with the symbol of figure 1. It shall inform users about the necessity to collect the equipment separately from other waste streams to provide an adequate treatment. Consumers must be given the possibility to return their used items free of charge.

If other states than EU member states do not have similar legislations, take-back systems for WEEE, however, should be established to ensure an efficient recovery of value materials and to prevent damages to the environment caused by an inadequate disposal.

Figure 14: Symbol / label for the separate collection of waste electrical and electronic equipment

In order to prevent the generation of hazardous waste, producers ensure the substitution of various heavy metals (lead, mercury, cadmium, and hexavalent chromium) and brominated flame retardants (polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE)) in electrical and electronic equipment put on the market from 1 July 2006 on. Exemptions from this regulation, concerning for example fluorescent lamps, are being specially defined in the annex of directive 2011/65/EU. Targets for collection, recovery and reuse of WEEE should be frequently controlled and adapted under consideration of technical and economic experiences and progresses. Currently recovery quotas of 55 to 80 per cent shall be achieved. Moreover, each Member state shall achieve a collection quota of WEEE of 45% calculated on the basis of the total weight of WEEE collected in a given year, expressed as a percentage of the average weight of EEE placed on the market in the three preceding years in that Member State. From 2019 the collection rate will account for 65 per cent.

APPROPRIATE COLLECTION STRATEGIES AND SCHEMES

Effective ways for the separate collection of WEEE prove to be:

- Return option of WEEE at sales stores of electrical and electronic items through a legal obligation of them (only valid if sold items have a minimum size) or via a take-back agreements of distributors on a voluntary basis
- Utilisation of collection systems or structures that base on municipal collection points (e.g. recycling centres, figure 2) and selective collections (street collection) of public waste management authorities

Figure 15: Separate collection of WEEE at a collection point in roll-off containers (pictures: INTECUS GmbH)

- Public bodies may use special containers (for example roller container partitioned into several sections) to collect WEEE as various separate fractions (e.g. refrigerators, fluorescent tubes, TV-sets, household appliances, IT and communication equipment, multimedia/entertainment products). Alternatively, collection points should take care that appropriate fractions are separated in their place and as such forwarded to subsequent recycling processes.
- Special requirements shall be stipulated on the collection of old devices containing lithium-ion batteries, as the storage and transportation cause self-ignition and fire risks

To ensure compliance with the take-back obligation that has become a mandatory scheme for electric and electronic equipment in Germany, producers and retailer have to register themselves at the stiftung elektro-altgeräte register (EAR). Producers of consumer products (B2C) have to maintain a guarantee deposit as part of their registration. www.stiftung-ear.de

APPROPRIATE TREATMENT AND RECOVERY SCHEMES

Repair and refurbishment programmes
The development of repair and refurbishment schemes should be the preferred option to deal with collected WEEE. This could consist of a multistage process adapted to the state in which the WEEE is upon collection or return. The different options could include
- the resale of tested, good looking equipment,
- a refurbishment and
- the recovery and utilisation of usable sub-assemblies and spare parts or total dismantling.

A high risk potential rests with processing and recovery techniques, which are performed without the necessary precaution and care for environmental damages and health risks. Their application can quite often be seen in the lesser developed regions of the world and entails practices such as the open burning of PVC cable insulations, dissolving of printed wiring boards in an open acid bath!

Dismantling
The dismantling of WEEE is executed with the objective to separate potentially hazardous components (e.g. polychlorinated biphenyl, condensers, mercury containing measurement and control technology) from the rest of the material and to recover valuable materials, especially reusable components and metals. Dismantling is manually done. During dismantling the following fractions are usually generated:

- Ferrous and non-ferrous metals
- Cable material
- Plastics
- Rubber
- Wood
- Monitor glass
- Metal-plastic-compounds
- Printed wiring boards
- Batteries
- Hazardous substances

Figure 16: Work station for manual dismantling for monitors (left) and separated monitor glass (right) (pictures left & right: INTECUS GmbH)

The intensity of separation depends from the available recycling options. For each fraction the respective recycling/disposal channels explained in this document can be used.

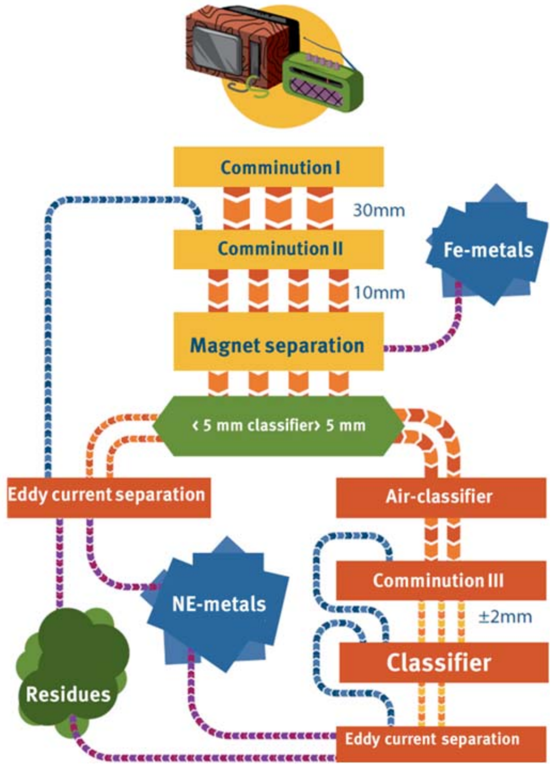
Processing of WEEE

The processing of WEEE comprises all mechanical and chemical processes that permit the further recovery of recyclable material.

- *Mechanical processes:*

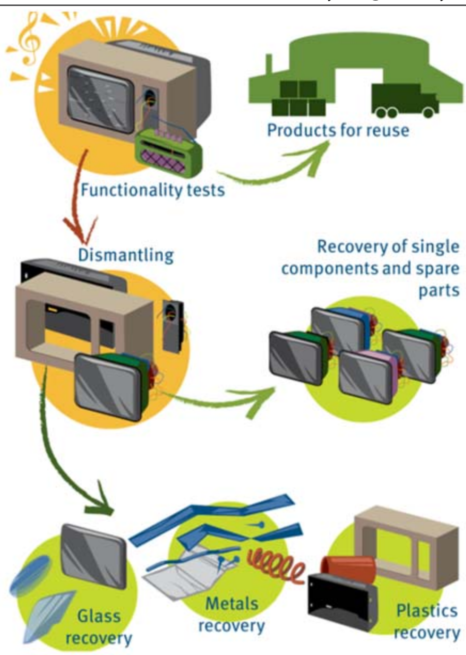
Mechanical processes for the purpose of recycling and material recovery from WEEE in the majority of cases are being applied for the separation of metal-plastic compounds. The possible flow scheme of a mechanical process is shown in the picture below.

Figure 17: Possible flow scheme for the mechanical processing of WEEE



Different recycling and reutilisation options become possible by combining various methods and treatment techniques. Integrated into a larger processing chain and one facility (e.g. a specialized recycling centre) a modern and very efficient WEEE treatment can be instituted. The example of such a combination is depicted by the following process arrangement within a dedicated disassembly and recovery facility.

Figure 18: Possible process combination in a dedicated WEEE recycling facility



Such arrangement uses various work stations for disassembly and recovery, each one specialized for a certain fraction such as monitors, personal computers (PC), large equipment or process steps such as oxy-gas cutting or plasma torch cutting.

Processing complex scrap starts with removing and sorting components or items for a subsequent processing. Shredder technologies specifically designed to process electronic complex scrap helps in material liberation and volume reduction. With a series of magnetic and other separators (e.g. eddy current separator) it is then possible to segregate the metals from non-metals and ferrous metals from non-ferrous metals.

The qualities of the material fractions obtained from such treatment can be described as follows:

Table 11: Qualities of produced material streams from mechanic processes of WEEE

Produced material streams	Fe-metals [mass-%]	non-ferrous metals [mass-%]	non-metal components [mass-%]
Ferrous metals	95–99	0.1–5	0.5–5
Non-ferrous metals		›95	0.5
Mixed plastics and dusts	0–2	1–5	›95

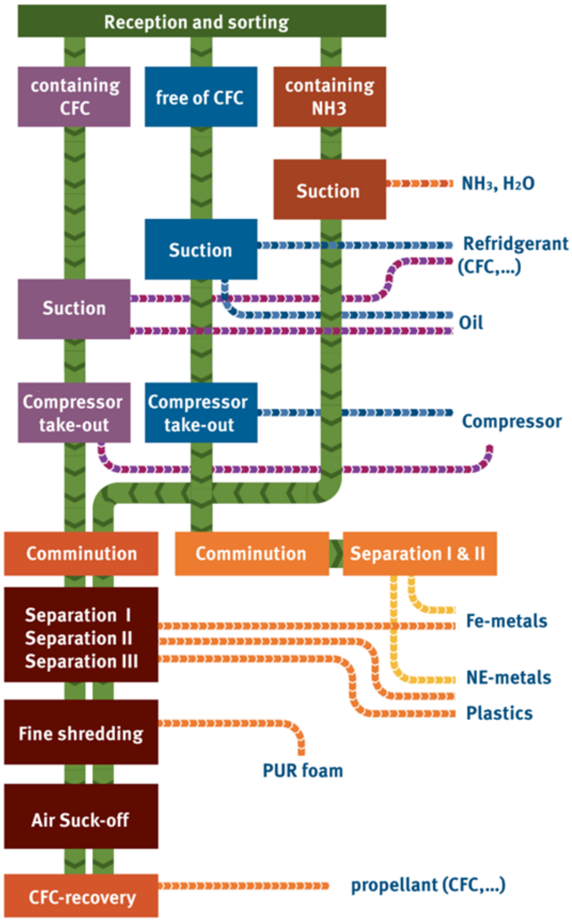
APPROPRIATE RECYCLING TECHNOLOGIES

The recycling possibilities and techniques for selected WEEE fractions will be described hereunder.

Refrigerators and freezing devices

Of utmost importance in the treatment of refrigerators and freezing devices is the isolation and recovery of the Chlorofluorocarbon (CFC) or of other volatile organic compounds (VOC) in the cooling agents contained in the newer items of this product group. The resulting process scheme can be one of the following kind:

Figure 19: Process scheme for a VOC facility *(modified according to R-plus Recycling GmbH)*

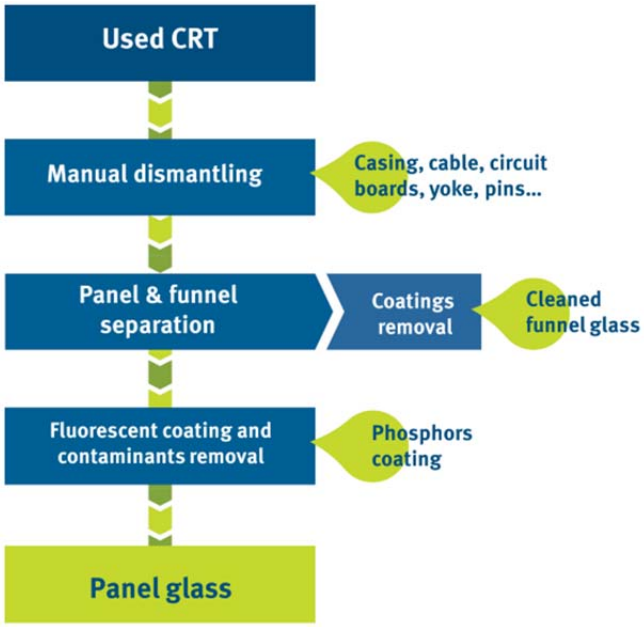


Recycling of screens and monitors

Computer monitors and televisions containing cathode ray tubes (CRT) are made of glass that includes lead oxide to protect user from stray radiation. Other heavy metal oxides, such as cadmium, are sometimes used in the phosphor coatings inside the CRTs. Because the lead may dissolve out of the glass and pollute the soil and groundwater, it is not environmentally desirable to dispose of CRTs in landfills.

The best alternative for disposing of CRT glass is by separating the different types of glass (panel from funnel), removing coatings, crushing and removing metal contaminants and then closing the loop by sending it back to glass manufacturers to make new CRTs. In order to produce cullet (clean, separated, crushed CRT glass) that can be used for closed-loop recycling, the panels and the funnels must be sorted into classifications consistent with the glass manufacturers' requirements. One challenge encountered when recycling CRTs stems from dealing with the hazardous materials. Coatings inside the panel usually contain zinc sulphides or lead and cadmium. A wet/dry vacuum with high-efficiency particulate air or special filter has to be used to remove the potentially hazardous coatings. CRT glass manufacturers require that the ferrous and nonferrous metals be removed from the glass prior to accepting it for reuse. This may be achieved with a magnetic head-pulley to remove the ferrous metals, and a vertical drop metal separator to remove the nonferrous metals from the crushed glass. The resulting product is cleaned, furnace-ready cullet that can be used for closed-loop recycling.

Figure 20: Simplified process scheme for the recycling of screens and monitors



Monitors that currently dominate the market (flat screens) work on the basis of a liquid crystal display (LCD) and of many small gas discharge lamps or light emitting diodes (LED). The recycling process of these flat screens starts with a manual dismantling of the LEDs (see factsheet "Lamps") to prevent mercury emissions caused by damaging the LEDs. Alternatively, facilities already exists that shredder flat screens while vacuuming mercury emissions. Shredded materials is then automatically sorted and separated into different fractions.

Plastics components

For an effective plastics recovery the system must include:

1. Volume Reduction (breaking large housings into small pieces) and Purification (removing contaminants).
2. Separation of plastics by type. This may include a 3-step density separation process (Redundant Hydrocyclone Process, 2nd Redundant Hydrocyclone Process, Sink-Float-System) and as the 4th step a Dual Electrostatic Separation.
3. Characterization and Identification of plastic compounds, determining the physical characteristics of the separated plastics.

	After completion of all processes six output streams may be generated: - Commingled Polyethylene & Polypropylene - Acrylonitrile Butadiene Styrene (ABS) - High Impact Polystyrene (HIPS) - Polycarbonate - Polycarbonate ABS alloys - Other plastics, such as nylons and Polyvinyl Chloride (PVC) The commingled Polyethylene & Polypropylene can be put into the market without further separation or processing. HIPS, ABS, polycarbonate and polycarbonate/ABS hold the highest value and can be used in place of raw material. The other plastics, such as nylons and PVC, as of now are generally not economical candidates for further separation and are disposed of as waste. **Printed wiring boards (PWBs) and complex scrap** Most of the metal-bearing stream in electronics demanufacturing consists of printed wiring boards (PWBs) and complex scrap. Complex scrap includes items such as hard drives, floppy drives, casings, chassis, printers, and keyboards. Different methods and equipment are required to process printed wiring boards versus complex scrap. PWBs contain the highest value metals as well as some of the most toxic metals found in electronics scrap. There are 10 to 100 times more precious metals in PWBs than in an equal weight of ore taken from a mine. Most practices for the recycling of complex scrap begin with demanufacturing works and continue with various steps leading to a comminution and subsequent segregation of components of different nature. The majority of PWBs on the other hand are currently sent directly to copper smelters for recovery of precious metals and copper. Sending whole PWBs to copper smelters is, however, inefficient because a PWB is approximately 70% by weight non-metallic materials. A significant economic improvement in metals recovery can be achieved by separating the metals from the non-metals using various processing techniques, thereby improving the purity of the PWB material before it is sent to the smelter. For this beneficiation techniques introduced by the minerals processing industry can be used. Beneficiation includes the steps of grinding, screening, separating, and concentrating to improve the physical properties of an ore so that metal can be economically recovered. Melting with differentiated treatment (refining process) can be used to recover metals of various types. One example for such process is applied at the Umicore plant in Belgium (www.preciousmetals.umicore.com). Precious metals get separated within the melting process by sending the other metals into the plumbiferous slag where they are concentrating. Copper and precious metals are then leached out while electrolysis is used to get them separated. Subsequent electro-refining achieves that precious metals of high purity are obtained. Other metals such as nickel or lead are recovered in parallel processes.
IMPLICATIONS TO OTHER SECTORS	The treatment of WEEE for the purpose of recycling and reuse does constitute a very good chance to employ a larger number of persons, in particular for operations such as repair, refurbishment and disassembly. In conjunction with the provision of training, there is especially an opportunity for disabled, less qualified and socially deprived people to find work in this sector. Specialized workshops and charity organisations can make use of this business opportunity for income generating activities of their clientele.
REFERENCES AND PROVIDER FIRMS *(Important note: The list of firms does not constitute a complete compilation of companies active in the specified fields.)*	In Germany/Europe, it exist an established network of facilities for the demanufacturing and treatment of WEEE. These facilities were set up from waste disposal firms or operate as independent undertakings. Examples in Germany are the facilities of:: - Berliner Stadtreinigungsbetriebe, Berlin www.bsr-online.de - REMONDIS Electrorecycling GmbH, Lünen www.remondis.de - ALBA Elektronics Recycling GmbH, Eppingen www.alba.info/the-recycling-company.html

- GWAB Recycling-Zentrum, Wetzlar www.gwab-recycling.de
- Stena Recycling Sweden, Standort Wangerland www.stenatechnoworld.com/de/

Further information about recycling processes of WEEE and companies active in this area can be obtained from following organisations:

- ZVEI - Zentralverband Elektrotechnik- und Elektronikindustrie, e.V. www.zvei.org
- Bundesverband der Deutschen Entsorgungs-, Wasser- und Rohstoffwirtschaft e.V. www.bde.de
- Bundesverband Sekundärrohstoffe und Entsorgung e.V. www.bvse.de

Umwelt Bundesamt

WASTE FROM FLUORESCENT, DISCHARGE AND OTHER LAMPS

RELEVANCE OF WASTE STREAM:

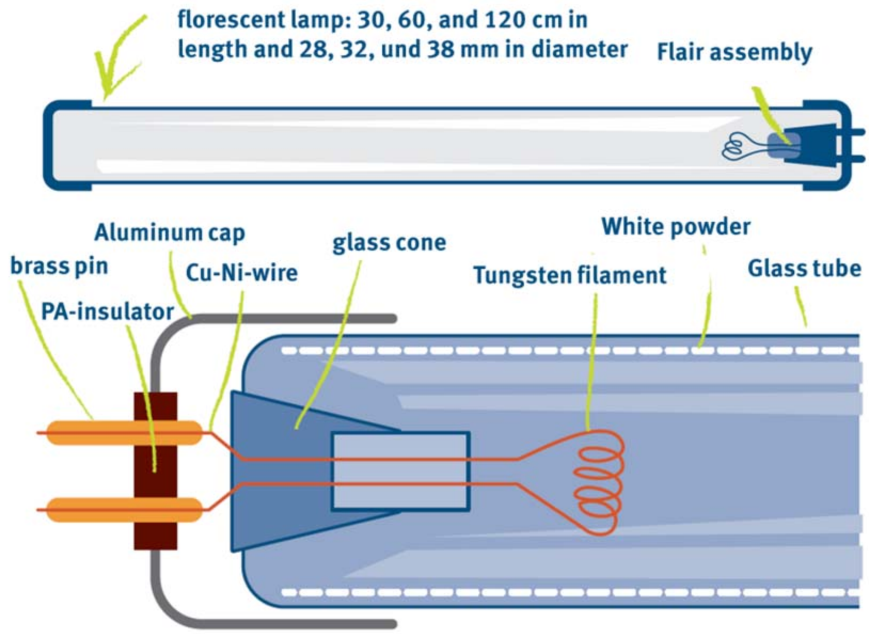
- Especially gas discharge lamps contain hazardous substances such as mercury that requires special demands on collection and treatment of this waste stream

COMPOSITION/ MAIN MATERIAL COMPONENTS

Aside from their glass coat and metal components made from steel and aluminum, fluorescent and other discharge lamps contain between 0.003–1.5 g of mercury, depending on type and manufacturer.

Concentrations of mercury in	fluorescent lamps:	0.003–0.015 g
	high pressure sodium lamp:	0.03 g
	energy saving lamps:	0.0025 g
	high voltage/discharge lamps:	1,5 g

Figure 21: The engineering structure and composition of a fluorescent lamp



Incandescent and metal halide lamps do not contain mercury and are thus not considered hazardous waste. Energy saving lamps is sold without electronic ballast or as self-ballasted lamps.

EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

Being part of the waste of electrical and electronic equipment (WEEE) this waste is covered by Directive 2012/19/EU of 04 July 2012 on waste electrical and electronic equipment and Directive 2011/65/EU of 08 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS).

NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM

Due to their possible content on mercury, fluorescent and discharge lamps have to be considered a potentially hazardous waste to which special treatment and controlled disposal procedures shall apply. This means first of all the protection of the environment including other material from a contamination with this substance during use, collection and disposal.

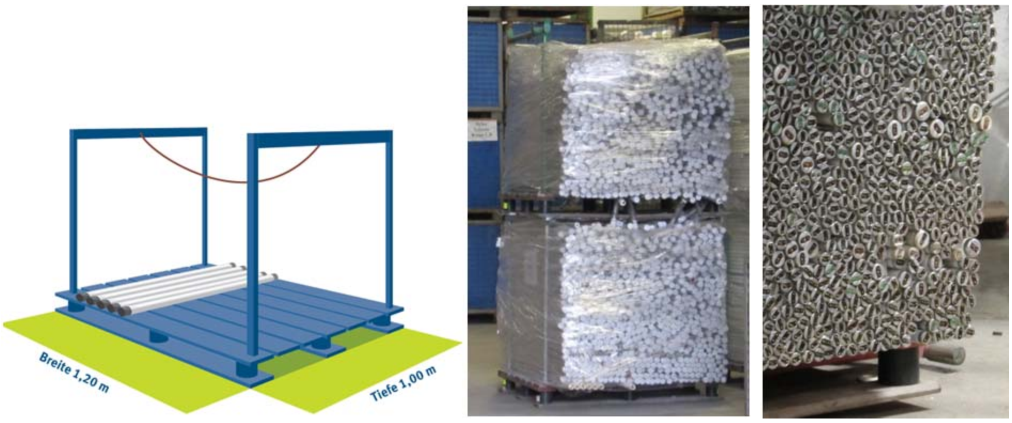
Disposing of fluorescent and other discharge lamps together with other waste materials or via the common waste collection shall therefore be strictly forbidden. This does not apply to ordinary bulbs which can be disposed of with the household waste and treated together with it.

APPROPRIATE COLLECTION STRATEGIES AND SCHEMES

Fluorescent and other discharge lamps make up a proportion well above 50 % of the market. The most common types are of tubular shape with a total length of 120–150 cm. These products should not be disposed of together with other wastes or in the ordinary waste collection systems. Collection should preferably be done in dedicated collection schemes for WEEE or hazardous waste in pick-up arrangements or thru public recycling stations where people can bring them.

In occasions where such wastes are generated in larger amounts (factories, offices, schools, reconstruction and demolition sites), a separate collection in special receptacles should be organized. Most appropriate are lattice box pallets or special stake cars as shown below.

Figure 22: Suitable options for the collection of fluorescent lamps at places with a huge generation of this waste (picture sources: Intecus GmbH)



For smaller lamps, such as energy saving lamps 200-litre lid casks with clamping rings or small lattice box pallets are the best choice

For the transport of these wastes special receptacles such as metal or plastic casks of various sizes should be used. Metallic mercury must be transported in steel bottles.

In the frame of mandatory producer responsibility/take-back schemes, an area-wide collection and pickup of fluorescent and discharge lamps can be organized. An appropriate arrangement for this is the formation of (a) collective organization(s) of the lamp manufacturers/retailers that can take care for the returned lamps in a cost efficient and environmentally benign manner through an established network of take-back points, recycling centers or a direct pickup from large consumers. The organization may also run its own recycling facilities or contract this service to other companies.

APPROPRIATE TREATMENT AND RECOVERY SCHEMES

The aim of any treatment process for discharge lamps is, firstly to reliably separate, remove and eventually dispose of the hazardous components without to cause any nuisance or damage to the environment. Secondly, marketable materials such as glass and metal should be recovered for recirculation into the production process and material flow.
To ensure that both be done in an environmentally benign way, tubular fluorescent lamps are commonly processed by the so called Kapp-Trenn® (clip-and-sort)-process. For this process, a pre-sorting of the lamps by length is advisable.

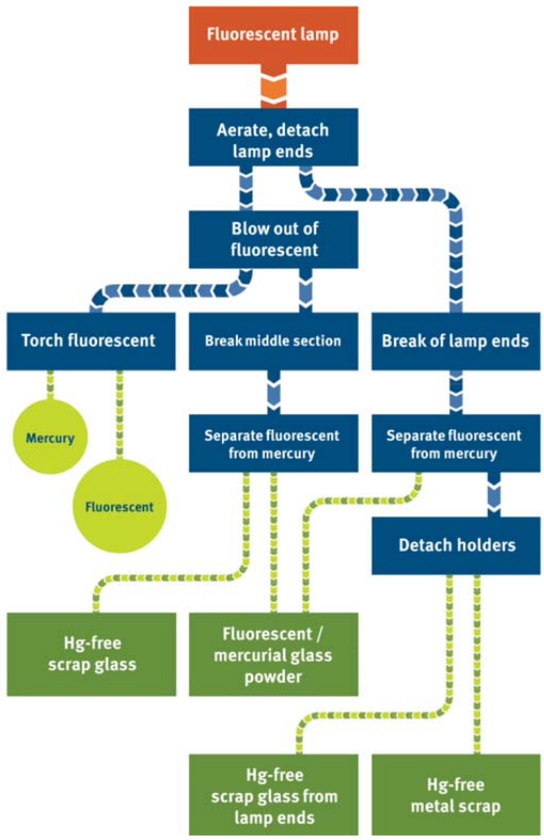
The main product which is recycling glass of a special quality can be used right away for the production of new fluorescent or other discharge lamps.
The separated metal components (aluminum, steel) are as well returned as raw materials for production. Glasses which contain lead can be directly used to obtain recycled lead. Also mercury can be recovered for industrial uses.
Contaminated substances and materials (usually less than 10 %, and not more than 3 % in the above process) after proper preparation (e.g. container) can be safely deposited in subterrestrial mines (see also fact sheet "landfill for hazardous waste").

APPROPRIATE RECYCLING TECHNOLOGIES

Provider and operator of a specially developed Kapp-Trenn®-process is the company LAREC® in Germany. With this special "de-manufacturing" technology based on the selective dismantling of the lamps, clean material fractions for the direct recirculation into production processes can be obtained. The Kapp-Trenn-process of LAREC® is automated and can handle up to 6.000 lamps per hour.

The idea of the Kapp-Trenn®/clip-and-sort-method is to separate the end of the lamps from the less mercury-contaminated intermediate glass section by, e.g. heating up the ends with a torch and then breaking them off with a cold air blast. The open tube is cleared of its mercurial fluorescents by blowing. After comminution the glass from the tube can be recycled right away by glass manufacturers. If sufficiently pure, the scrap aluminum from the lamp caps serve as feedstock for aluminum smelting. Mercury is recovered thermally and can be recycled as well. Ideally all recycling processes should be combined with the processing and recovery operations or implemented nearby. Fluorescents, arising in mixture with a small proportion of glass powder, shall be disposed of as hazardous waste or can be sent back to producers to recover rare earth elements out of the powder.

Figure 23: Process scheme of the Kapp-Trenn®-process offered by LAREC® GmbH



Mobile arrangements for the clip-and-sort-method supplement in parallel the recycling of fluorescent and discharge lamps in stationary plants. One example for this is the concept offered by the German company Herborn.

The used lamps which have been collected in boxes are forwarded to a mobile recycling unit that undertakes a dry form of the clip-and-sort process (method herborn). The metal caps are separated from the glass tube, the glass is crushed and the fluorescent powder with concentrations on mercury is sucked off from this system. The contaminated air is led through different types of filter devices including a filter using activated carbon. The system is operated under a negative pressure in order to prevent any potential discharge of contaminated air to the outside. Other components of the lamp are forwarded to a thermal processing. The metal caps are cleaned from any foreign matter in a separate treatment step.

REFERENCES AND PROVIDER FIRMS *(Important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Providers of technology and services in relation to the recycling of used lamps in Germany are for example: - LIGHTCYCLE Retourlogistik und Service GmbH, München www.lightcycle.de - LAREC® Lampen-Recycling GmbH, Brand-Erbisdorf www.larec.de - HERBORN GmbH, Ginsheim-Gustavsburg www.system-herborn.de

Umwelt Bundesamt

HEALTH CARE AND HOSPITAL WASTE (MEDICAL WASTE)

RELEVANCE OF WASTE STREAM

- Healthcare and hospital waste contains various materials including also infectious components. Infectious components account for approx. 3 percent of the total medical waste originating from hospitals and other healthcare facilities. Healthcare and hospital waste is defined as hazardous based on its risk of infection. Hence, it shall be subject to a special treatment.

COMPOSITION/ MAIN MATERIAL COMPONENTS

Healthcare and hospital waste is classified according to the European waste catalogue. Definitions of single waste streams from health care and hospital waste are laid down in the guideline for disposal of wastes from healthcare facilities (Mitteilung 18) established by German Bund/Länder-Arbeitsgemeinschaft Abfall (LAGA, Federal/State Waste Committee) (www.laga-online.de/servlet/is/23874/). A similar differentiation exists also from the WHO.

Medical waste, depending on the type, composition, properties and arising quantities, can be classified into different main categories. The European classification is derived from the origin of the waste, mainly. All wastes that are considered hazardous and/or potentially harmful wastes in accordance with the EWC are marked with a star symbol (*).

Table 12: Healthcare and hospital waste classified according to the European waste catalogue (EWC)

Specification	Waste index according to EWC
sharps (except 18 01 03)	18 01 01
body parts and organs including blood bags and blood preserves (except 18 01 03)	18 01 02
wastes whose collection and disposal is subject to special requirements in order to prevent infection	18 01 03*
wastes whose collection and disposal is not subject to special requirements in order to prevent infection (for example dressings, plaster casts, linen, disposable clothing, diapers)	18 01 04
chemicals consisting of or containing dangerous substances	18 01 06*
chemicals other than those mentioned in 18 01 06	18 01 07
cytotoxic and cytostatic medicines	18 01 08*
medicines other than those mentioned in 18 01 08	18 01 09
amalgam waste from dental care	18 01 10*

Beside these wastes which depict “very typical” fractions of medical waste there are also other kinds and amounts of waste generated in hospitals. Generation intensity and quantities of these other wastes vary heavily and are strongly linked to the specific features of the health care facility (size, type, specialization) where they arise.

Typically waste from health care activities and medical treatment in hospitals make up around 30% of the overall waste generation while about 60% are household-like waste. Another 10 % can be categorized as potentially harmful wastes of which about 3 % are infectious in nature and 7 % waste with hazardous components.

EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

The proper management and safe disposal of medical waste within Europe is regulated by a broader set of ordinances covering different sectors such as the general waste management law and regulations concerning infection prevention, labour protection, the chemical law and law on dangerous sub-stances.

The framework for the legal stipulations governing the different components comprising medical waste is provided through the Council Decision 2001/119/EG of 22 January 2001 on establishing a list of wastes pursuant to Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Council Directive 91/689/EEC on hazardous waste.

NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM	To achieve the primary goal of waste avoidance and minimization in hospitals, all options leading to a multiple use and reuse of medical equipment and auxiliary means, a low-waste material acquisition and purchasing pol-icy and an efficient storage and stock keeping shall be examined and when-ever possible adopted. For the collection, storage, transportation and further disposal/utilization of these waste special requirements concerning hygiene and personal safety need to be observed, in particular to respond to the potential danger caused by the hazardous components it may contain. Reference to these requirements will be made in the descriptions given below for each specific step of managing this waste. Main concerns are the strict separation of the different waste components, especially the source separation of sharps, the separate collection of waste from cytostatic drugs, the source segregation of infectious material from any other waste, the safe storage and transportation, and the material specific treatment and disposal.

APPROPRIATE COLLECTION STRATEGIES AND SCHEMES

18 01 01 – Sharps (except 18 01 03)

- use of unbreakable, puncture proof one-way receptacles/container for collection
- these must be lockable and leak-proof after filling
- recycling that requires an opening of the collection container is not allowed, even though a disinfection was conducted

Figure 24: Example of a collection container for used, potentially infectious one-way items(e.g. syringe) (Picture source: sudok1/Fotolia.com)

18 01 02 – body parts and organs including blood bags and blood preserves

- source separation and collection in durable receptacles which can be locked up
- any transfer to another container or sorting are forbidden
- storage must be undertaken in a way that no gases can form (storage temperature ‹15°C for a storage over 1 week in the maximum; period can be extended at a storage tempera-ture ‹8°C)
- Frozen materials can be stored for up to 6 months

18 01 03* – wastes whose collection and disposal is subject to special requirements in order to prevent infection

- Collection must be undertaken directly at the point of their generation, the receptacles used must be un-breakable, moisture resistant and leak-proof (e.g. certified container for dangerous substances) and the material is to be handed to central collection points with-out any transfers or sorting taking place. The containers need to carry the mark for “biohazards”.

Figure 25: Labelling symbol „Biohazard“

- Requirements on collection containers have to be met according to TRBA 250
- storage must be undertaken in a way that no gases can form in the containers

18 01 04 – Wastes whose collection and disposal is not subject to special requirements in order to prevent infection

- Collection must be undertaken directly at the point of their generation, the receptacles used must be un-breakable, moisture resistant and leak-proof and the material is to be handed to central collection points without any transfers or sorting taking place.

18 01 06* – Chemicals consisting of or containing dangerous substances

- A separate collection for each individual component is to be preferred
- Where large amounts of these wastes accrue, specially ruled waste streams can be generated and separately handled (e.g. acids)

18 01 07 – Chemicals other than those mentioned in 18 01 06

- Certain chemical wastes which accrue in larger a-mounts can be handled as separate waste streams and a disposal organized for them which corresponds to their specific properties
- Collection and storage must be done in containers which are appropriate for transport purposes as well.
- Storage places need to have an adequate ventilation

18 01 08* – Cytotoxic and cytostatic medicines

- All kinds of waste generated in conjunction with the preparation and application of carcinogenic, gen-modifying and/or reproduction damaging medicines must be included in this group. Further amounts of waste from cytostatica and virostatica for separate treatment are to be expected
- unbreakable, puncture proof one-way receptacles/container with a certification must be used for collection
- the material is to be handed to central collection points without any transfers, sorting or pre-treatment taking place

18 01 09 – Medicines other than those mentioned in 18 01 08

- A separate collection is to be performed
- unauthorized persons shall not have access in order to avoid any kind of misuse during the collection

18 01 10* – Amalgam waste from dental care

- A separate collection and treatment in regular intervals are to be performed

APPROPRIATE RECYCLING TECHNOLOGIES	Health care facilities which generate wastes with household waste like composition and properties shall avail of treatment/recycling options known from the household and commercial waste sector. Prominent examples are the recycling of diverse plastic fractions, such as infusions bottles, unused drain tubes and syringe. Contaminated hospital wastes, which have undergone a thorough disinfection process in treatment plants according to DIN 58949 and/or combined shredding and disinfection, may also be handled as recyclable fractions. A Sorting as well as recycling of non-hazardous waste from healthcare facilities and hospitals is only eligible, if specific requirements on the work safety are met. Single chemical wastes can be recycled, too. Amalgam waste can for example be subject of material recycling processes too where attention is being paid on its separation during dental operations.
APPROPRIATE TREATMENT AND RECOVERY SCHEMES	***18 01 01 – Sharps (except 18 01 03)*** - The waste shall not become subject of sorting operations, a material recycling requiring the collection containers to be opened is therefore forbidden - The applied technical processes shall make sure that there won't be any dangers/risks associated with the treatment of this waste - A joint disposal with wastes of category 18 01 04 is possible, provided that certain safety measures are applied - An incineration of the waste is to be preferred ***18 01 02 – body parts and organs including blood bags and blood preserves*** - The waste must be incinerated in the approved facilities without any prior compression or comminution and while still in the containers used for collection - single containers filled with blood or liquid blood products can be emptied using appropriate drains, if requirements of local waste water regulations are met - A recovery of single blood components is allowed by the pharmaceutical industry ***18 01 03* – wastes whose collection and disposal is subject to special requirements in order to prevent infection*** - The waste must be incinerated in the approved facilities without any prior compression or comminution and while still in the containers used for collection - The utilisation of this waste shall be prohibited - The Waste can be subject to a disinfection and a joint disposal with waste of waste code 18 01 04, if foreseen treatment plants meet the requirements (structural and functionally) of DIN 58949 and if the effectiveness of foreseen treatment plants is proofed (see "Disinfectants and disinfection procedures tested and recognized by Robert-Koch-Institute / DGHM") ***18 01 04 – Wastes whose collection and disposal is not subject to special requirements in order to prevent infection*** - Waste of this kind must be separated from other ordinary wastes and forwarded to the appropriate treatment installations - A sorting or material recycling shall not be allowed for hygienic reasons - Receptacles containing human liquids may be emptied into proper sewer systems by taking account of the hygienic and infection-preventing aspects in this act. ***18 01 06* – Chemicals consisting of or containing dangerous substances*** - The hazardous material is to be forwarded for treatment to an approved installation such as a waste incinerator or chemical-physical waste treatment facility. - The specific waste code of the chemicals concerned shall be made available to the disposal operator ***18 01 07 –- Chemicals other than those mentioned in 18 01 06*** - Disposal routes approved for the specific composition of the waste shall be used ***18 01 08* – Cytotoxic and cytostatic medicines*** - This waste has to be de-activated at temperatures of 1000°C and hence need to be forwarded to specialized incineration facilities.

18 01 09 – Medicines other than those mentioned in 18 01 08

- A joint disposal with wastes of other categories (e.g. 18 01 04) is possible, provided that unauthorized persons do not get access to the material
- Combustion in an approved incinerator shall be the preferred option

18 01 10* – Amalgam waste from dental care

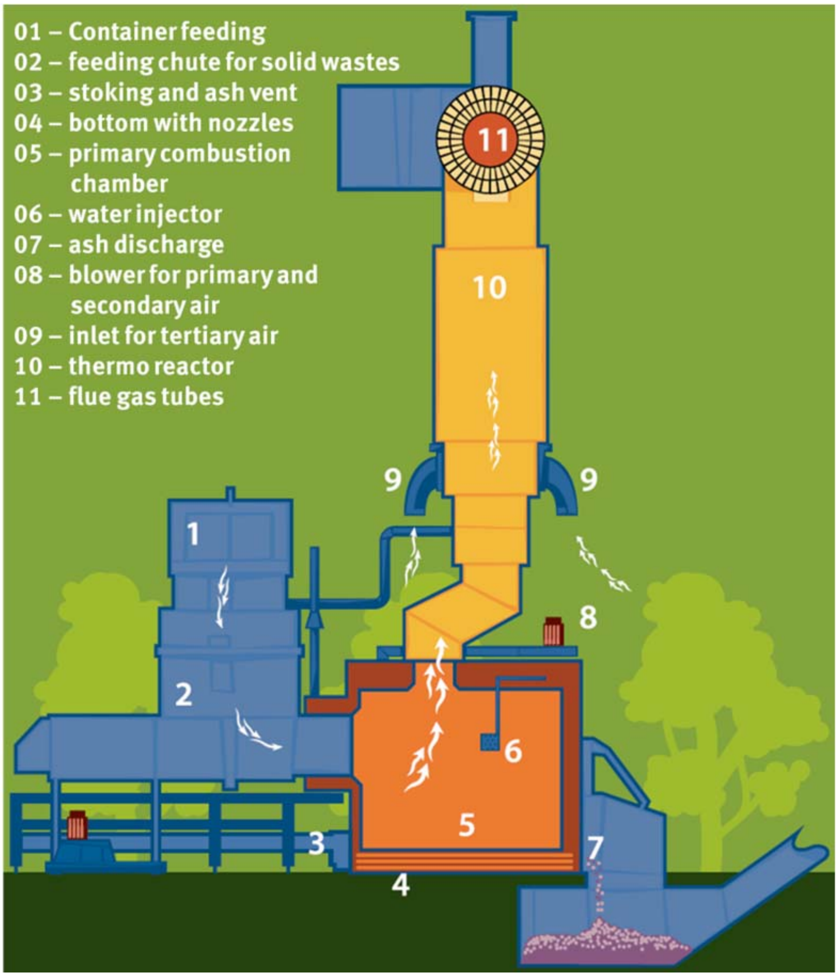
- There exists the possibility for a material recycling by the manufacturer or distributor of the amalgam or any third company specialized in this sector, however, a disinfection need to be undertaken beforehand.

Following hereafter an incineration facility which can be run by hospitals shall be briefly described. In this installation the incineration is performed as a two-step process:

Primary combustion chamber: In the primary combustion chamber the waste is set alight by means of a pilot burner and subsequently combusted at temperatures of 400 °C to 800 °C and with a lack of oxygen. The smoulder coke produced that way is incinerated under optimal oxygen supply hereafter.

Thermo reactor: The combustible gases generated in the primary combustion chamber are mixed with air in surplus concentrations and the mixture is then incinerated at temperatures of about 1.000 °C. Through this step is ensured that all organic compounds are completely burned out and oxidized. The flue gas can be directed through additional combustion chambers, which may have been set up to thermally treat the household waste fraction for example. Before being released to the atmosphere, they have to pass through a five-stage flue gas cleaning [see also fact sheet "Flue gas cleaning").

Figure 26: Constructional scheme of an incineration facility for medical waste (modified according to AVA Augsburg)



REFERENCES AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Many places in Germany operate facilities for the dedicated treatment and disposal of medical waste. Some prominent examples are: for municipal waste incinerators operating special installations for a thermal treatment of infectious wastes: - Abfallverwertung Augsburg GmbH, Augsburg www.ava-augsburg.de - Abfallheizkraftwerk der MVA Bielefeld-Herford GmbH, Bielefeld-Heepen www.mva-bielefeld.de German manufacturers of special devices needed to safely manage medical wastes are for example: for certified collection and transport containers: - Firma Brosch, Winterbach www.brosch-pe.de - Firma Infa Lentjes, www.infa-lentjes.de Incineration plants for medical wastes: - IFZW, Zwickau www.ifzw.de - Michaelis, Veitshöchheim www.michaelis-umwelttechnik.de - Ruppmann Verbrennungsanlagen Stuttgart www.ruppmann.de Major principles, approaches and techniques for managing healthcare and hospital waste contain also the publications provided, inter alia, by - World Health Organization (WHO): "Safe management of wastes from health-care activities" 2nd edition (2014) "WHO core principles for achieving safe and sustainable management of health-care waste" (2007) - United Nations Environment Programme (UNEP) "Compendium of Technologies for Treatment/Destruction of Healthcare Waste" (2012)

Umwelt Bundesamt

WASTE OF OLD PAINT AND LACQUERS

RELEVANCE OF WASTE STREAM	- Collection and treatment of waste paints and lacquers have to meet special requirements to prevent negative effects of contained hazardous substances
COMPOSITION/ MAIN MATERIAL COMPONENTS	The chemical composition of paint and lacquers is very much differing depending on the producer and the applications they are made for. The principal components of such products however can be described as: - Binding agents - Colour pigments (partly containing lead, cadmium, chrome, nickel and zinc chromate) - Solvents and thinners (turpentine, petrol, alcohol) - Fillers - Additives like preservatives, etc. The share of solvents can be up to 80% in nitro lacquer paints and up to 10% in emulsion lacquer paints. Paint for indoor applications (glue paint/ lime paint/emulsion paint), usually do not contain concentrations of solvents.
EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS	There is no specific legislation such as a directive in place for waste of old paint and lacquers in Europe, however, all stipulations specifically made on hazardous wastes in the European framework legislation have to be applied on those components which contain substances counted under the category of hazardous waste or being listed as such in the European waste catalogue. Aside from this, compliance with the general waste legislation is to be achieved, with the prevention of this waste and the protection of human health and the environment from any negative effects being the priorities.
NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM	Preventing environmental and health hazards and the generation of such waste in general are primary demands. Large contributions towards this end can be made through a careful planning of usage areas and dosage, an intelligent and environmentally conscious purchase policy and proper storage. Aside from that there often exist alternatives in form of solvent and heavy metal free suspensions for many applications. Paint and lacquers that do contain solvents must be considered environ-mental hazardous substances and have to be treated as such once they are becoming waste. In order to avoid contaminations or a pollution of other waste streams and material components it is especially necessary to perform a source separation and the collection of old paint and lacquer separately from other wastes.
APPROPRIATE COLLECTION STRATEGIES AND SCHEMES	Larger amounts of paint and lacquers (and sludge of it) should be collected thru an appropriate technical and logistic system by the varnishing industry itself and returned to those places where they are used. Where such is not possible, the material must be collected in appropriate containers and forwarded to a thermal utilisation. Public recycling stations that accept small amounts such as households generate them or special bring schemes, i.e. centrally located container devices where people can drop off such wastes should be installed for the public. Alternatively an announced door-to-door collection in regular intervals can be offered. Used paint and lacquers that are given into such kind of collection systems cannot be used for material recovery, however. This has to be attributed to the large variety of such products and their different compositions. A separation according to the type or composition of the substance would not be economically feasible. The only option here is the thermal utilisation of this waste. It is important though that old paint and lacquers are stored in leak-proof, unbreakable containers which can be closed with a cover upon their collection. Drums made out of solvent-resistant plastics and metal containers proved to be most suitable here.

APPROPRIATE TREATMENT AND RECOVERY SCHEMES	Generally speaking, thermal utilisation (in incinerators) is the standard way of disposal for used paint and lacquers. The waste is treated like a hazardous material and incinerated at temperatures of 1200 – 1400°C. Fluidized bed combustion (see fact sheet „Fluidized bed combustion") is the most prominent method used for this. Due to the high calorific value, this waste material can also be used in special co-incineration processes at industrial plants (see fact sheet "Industrial co-incineration"). In a pre-treated (e.g. immobilization) and/or encapsulated form, the waste can also be forwarded to special hazardous waste landfills for its safe final disposal (see fact sheet "hazardous waste landfills"). Using the energetic content of this waste in thermal processes and for energy generation should, wherever possible, be the preferred strategy, however.
APPROPRIATE RECYCLING TECHNOLOGIES	Used paint and lacquers can be recycled and utilized only if they are collected in large amounts and without any intermixture or pollution. This is possible in large varnishing companies only. For this special varnishing cabins and precipitation basins need to be installed, and exhaust systems equipped with washer devices. From the so collected sludge the lacquer can be recovered. Suitable absorbing and adsorbing processes can be employed to also recover the solvents from the exhaust air. A direct reuse of used paint and lacquers in the varnishing industry can be achieved by catching the overspray, i.e. lacquer that has not been absorbed by the target material. This is possible because of the known composition of the suspension and only before the material has been drying up. After restoration of the original mixing ratio with the help of solvents the over-spray can be used for a second time instantly. Further recycling possibilities are available for certain printing dyes, however their application is profitable for larger quantities (from 100 t and up) only. The recovered product is marked by a somewhat lower quality and can be used to a limited extent only.
REFERENCES AND PROVIDER FIRMS *(Important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Recognized companies and service providers in the sector of paint and lacquer recycling in Germany and especially knowledgeable on best practices and the technology required are for example: - Chemische Werke Kluthe GmbH, Heidelberg www.kluthe.de - Hunsrück-Sondertransport-GmbH, Hoppstädten-Weiersbach www.hstg.de - Sonderabfallagentur Baden-Württemberg GmbH, Fellbach www.saa.de - AVG Abfall-Verwertungs-Gesellschaft mbH, Hamburg www.avg-hamburg.de

WASTE CARPETS (AND SIMILAR TEXTILE ITEMS)

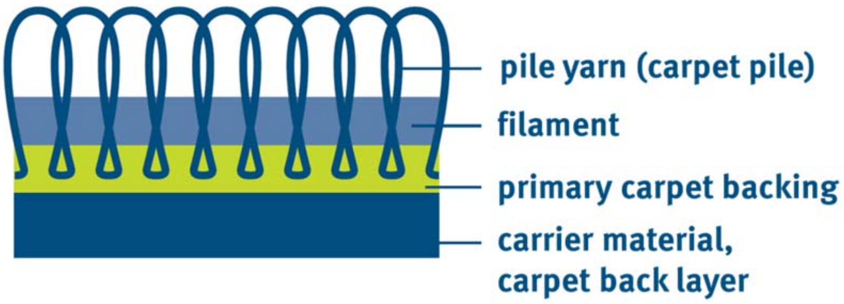
RELEVANCE OF WASTE STREAM

- old carpets produce a waste stream of high volume, a separate collection is necessary to prevent an overload of the general collection system and negative effects to treatment plants (i.e. smouldering fire, blockades)

COMPOSITION/ MAIN MATERIAL COMPONENTS

Carpets can be made from many single or blended natural and synthetic fibres. For the seam or filament chemical fibres such as polyamide (PA), polypropylene (PP), polyethylene (PE), polyethylenterephthalate (PET) or polyacrylnitril (PAN) but also herbal fibres such as cotton, sisal, jute, coconut or animal hair like wool and silk can be used, depending on the manufacturing method and style. Nylon is the most popular synthetic fibre used in carpet production and is petroleum-based. Polypropylene is used for the carpet yarn and polyester or "PET" in both spun and filament constructions. The latter is typically used in mid- to low-priced carpeting. For the carpet backing styrene-butadiene-rubber (XSBR) is often used for the primary layer and networked, foamed styren-butadien-styren (SBS) or XSBR, irregular atactic polypropylene (aPP) or acrylate-rubber (ACM) for the back layer. Carpet tiles are often made with amorphous polyalphaolefines (APO), bitumen, ethylene-vinylacetate (EVA) or polyvinylchloride (PVC) at their back layer. An herbal fibre regularly used for knotted carpets is jute.

Figure 27: Scheme of a carpet construction



EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

There is no specific legislation such as a directive in place for this type of waste in Europe; however, the stipulations made by Directive 1999/31/EC on the landfilling of waste do also apply here, excluding this waste from landfill disposal and demanding other forms of treatment and utilization.

NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM

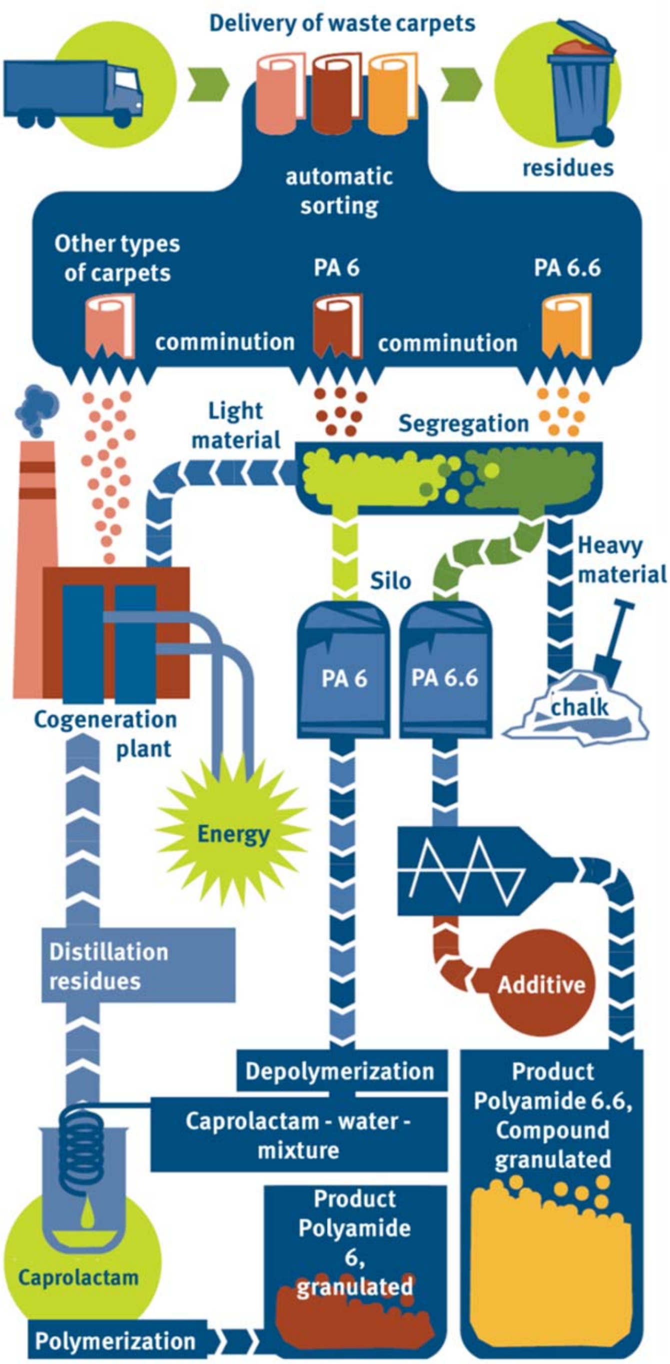
Being large-sized items of waste, waste carpets need to be collected together with bulky waste as part of a separate collection scheme for house-holds or through the commercial outlets and points of generation. Afterwards waste carpets should be subject to recycling and/or energetic utilization as carpets in general have a high calorific content and components suitable for material recycling. As of the moment, energetic utilization is still the priority option available.

APPROPRIATE COLLECTION STRATEGIES AND SCHEMES

To ensure high recovery rates and a good amount of old carpets being used in thermal processes, it is highly recommended to establish extensive take back schemes (for example via mandatory producer responsibility), for example in such a way as Germany has done this to some extent already. In such system, the old carpets can be taken from households either to public recycling points (take back centres) from where they are picked up from a commercial recyclers, or the latter companies provide shops, retailers and households with special containers or bigbags (see fact sheet "Big Bag") which are then picked up by them once they are filled up. Where such schemes are absent, old floor coverings are to be given to the bulky waste collection or disposed of together with waste from C&D sites. The material can then be recovered by sorting plants, as it is the case in Germany, too.

APPROPRIATE TREATMENT AND RECOVERY SCHEMES	Until now, old floor coverings are mainly sent together with other waste materials to waste combustion facilities for energy recovery. Chopped into small pieces they can however also be used for thermal processes in cement kilns or for power generation in industrial incinerators (see fact sheet "Industrial co-incineration"). An alternative to the energetic utilisation is the recycling of carpets made out of polyamide, polypropylene or wool.
APPROPRIATE RECYCLING TECHNOLOGIES	For the recycling of waste carpets made from polyamide (PA) a technical process was developed in Germany. Plants of similar type are nowadays operated in the U.S.A. These plants also receive significant quantities of old carpets from Carpet Recycling Europe GmbH (CRE) after their collection in Europe. Old carpets or processed carpet components from PA can be material or chemically recycled and processed to new polyamide this way. The process scheme that was adopted for this purpose in Germany worked as follows:

Figure 28: Process scheme of the polyamide recycling line of Polyamid 2000



	After receipt, the unsorted and untreated carpets are automatically sorted with the help of spectroscopic analysis of the shag material into the fractions PA 6, PA 6.6, and others. Carpets that do not contain polyamide will be shredded and used in a thermal power station to generate process energy. Next to this the polyamide carpets get chopped and forwarded to multi-stage centrifuges where their disintegration takes place into polyamide fibres, chalk and other fibrous substances (carrier material). The chalk is used as raw material; the other fibrous substances are used in the thermal processes, too. PA 6-fibres are prepared for further utilisation and undergo a chemical treatment (refining) at the next stage. The polyamide 6-fibre is first split in a chemical depolymerisation process to Caprolactam. What follow is a multistage cleansing and eventually the polymerization to virgin polyamide 6 which can be used like original polyamide for the production of textile fibres. Due to yet existing technological limits and for economic reasons proceedings in the PA 6.6-line are different. Instead of the novo synthesis a physical treatment process is applied to the polyamide 6.6-fibres after the mechanical processing. In this process the granule is melted with the help of an extruder, physically cleaned and mixed with additives in a compounder to obtain a marketable, compounded polyamide 6.6. This product is different from the product generated in the novo synthesis in that it has a limited usability but is also less expensive in its generation. It has not been possible to produce textile fibres from this product but it can replace original polyamide compounds in the growing field of "Engineering Plastics". <u>Carpets made from wool</u> A technology has been developed to produce a biological insulation material from carpets made from wool. With that process the insulating material can be produced from 100% recycled material. First wool and polypropylene fibres are ripped off from the collected carpet material. Next to this a mixing of the recovered fibres to obtain the desired material ratio (e.g. 80/20) is taking place. The mixture is used to produce a non-solidified dolphin pile. The hardening of this dolphin pile is achieved in a thermal treatment step where polypropylene fibres meld together with the wool (Thermobonding). The hardened dolphin pile can be equipped with flame retardant substances such as boric salts for better fire protection. By using polypropylene, chemical hardeners and insecticides for the protection of the material won't be necessary. The new insulating material can be produced at fewer costs than insulating products from virgin wool. <u>Carpets made from polypropylene</u> Different processes for the material recycling of carpets made from poly-propylene have been developed and tested in the frame of the RECAM-project, however no large scale applications are known in Germany until today. <u>Other carpet materials / sorting residues</u> Fibre mixtures and carpet materials for which no economical use has been existing in the past are becoming increasingly used as fuel substitutes. Sorting and processing can be done decentralized from specialized firms. Used in cement kilns and calcinators, it is not just a substitution of fossil fuel with fibres and rubber components that takes place but also the chalk will be used (see fact sheet "<u>Industrial co-incineration</u>"). It is for this reason that the process is considered a combination of energetic and material recovery.
REFERENCES AND PROVIDER FIRMS *(important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)*	Reference facilities for carpet recycling in Germany are for example: - Recotex GmbH, Würzburg <u>www.recotex.de</u> - Pallmann Maschinenfabrik GmbH & Co. KG <u>www.pallmann.eu</u> Information concerning all recycling phases for carpet backings, beginning from the collection of used carpets until the production of new carpet backings are provided from the European research project RECAM (Recycling of Carpet Material) <u>www.cordis.europa.eu/result/rcn/80438_en.html</u> Further information about the carpet recycling sector and links to technology and service providers in Germany can be obtained from: - Fachverband Textilrecycling <u>www.bvse.de/fachverband-textilrecyling.html</u>

SLUDGE FROM MUNICIPAL WASTE WATER TREATMENT

RELEVANCE OF WASTE STREAM:

- Solid remains from municipal waste water treatment contain organic carbon and nutrients from which plants and the soil can benefit as well as other substances worth to recover. Other inorganic and organic components are potential contaminants to soil and ground water or have pathogenic effect on human health which is why particular precaution or treatment must be adopted when the material is further utilized. Forms of combined treatment with municipal solid waste can be used to realize protection goals and benefits in an efficient and optimized manner.
- This waste stream is governed by specific requirements during its disposal within the EU.

COMPOSITION/ MAIN MATERIAL COMPONENTS

Sludge generated in the course of the treatment of municipal waste water is differentiated as follows:

- *Primary sludge* – is the sludge generated in the mechanical cleaning stage as a result of physical processes, i.e. sedimentation. It represents the vast majority of the total sludge volume produced by waste water treatment plants (WWTPs). Primary sludge contains approximately 2.5–3.0 % solids, the rest is water.
- *Return sludge* – is sludge that results from biological treatment. It comes along with the excess sludge but depicts the proportion of biomass that settles in the sedimentation stage (intermediate and secondary clarifiers), from where it is subtracted and returned to the activation basin where it is eventually consumed completely.
- *Excess sludge (secondary sludge)* – is the portion of sludge from biological treatment for which there is no need of returning it to the biological process. The excess sludge from the biological stage contains only about 0.5–1.0 % solids, thus requiring an up-concentration with the help of primary sludge for further processing.

Primary and excess sludge together make up the sludge volume for which subsequent treatment is needed. Also known as tertiary sludge this is the sludge amount municipal sewage treatment plants release once phosphate precipitation (removing phosphorous with the help of iron or aluminium salt, or lime) is completed and/or need to take care of. The sludge still contains a whole series of harmful substances that complicate proper management, such as heavy metals, pathogens and endocrine disrupters. But it also contains a number of nutrients such as phosphorus, nitrogen and potassium.

Sewage sludge can be regarded as a multi-substance mixture. Because of the inhomogeneity and tremendous differences in the concentrations of its components, it is difficult to determine or define a standard composition for sewage sludge (Table 13a+b+c)

Table 13a: Orientation values on the selected properties of municipal sewage sludge

Main properties	Unit of measure	Orientation value range (based on reference values from various sources)
pH-value		7.7
Loss on ignition	%	45–80
Net calorific value	MJ/kg dry solids (DS)	10–12

Table 13b: Orientation values on material properties of municipal sewage sludge

Substances in sewage sludge of particular interest for the nutritional value	Orientation value range in g/kg dry solids (based on reference values from various sources)
Phosphorus (P)	2–55
Magnesium (Mg)	9–9.5
Calcium (Ca)	70
Potassium (K)	2–3
Cobalt (Co)	6–7
Molybdenum (Mo)	3.5–4

Most of the organic substances in sewage sludge comprise a bacterial mass that is mainly composed of carbon, hydrogen, oxygen, nitrogen and sulphur. There are also organic pollutants, the most harmful being polychlorinated dibenzodioxins/furans (PCDD/F), halogen compounds and organic tin compounds.

Tensides and polycyclic aromatic hydrocarbons (PAHs) are also found in sewage sludge. All of these various organic substances often stem from numerous household products while wood preservatives or pharmaceutical products can make up sources as well. Heavy metal concentrations in sludge from municipal waste water treatment are for the most part attributable to inputs from the surfaces of roads and other man-made urban elements.

Table 13c: Orientation values on further material properties of municipal sewage sludge

	usually present in sludge in following ranges of concentration per kg dry solids content (based on reference values from various sources)						
Substance in sewage sludge	> 300 mg	>100–300 mg	> 50–100 mg	5–50 mg	1–< 5 mg	0.1–< 1 mg	< 0.1 mg
Antimony (Sb)				x			
Arsenic (As)				x			
Lead (Pb)			x				
Cadmium (Cd)					x		
Chrome (Cr)			x				
Copper (Cu)	x						
Manganese (Mn)	x						
Nickel (Ni)				x			
Selenium (Se)					x		
Thallium (Th)						x	
Vanadium (V)				x			
Mercury					x		
Zinc (Zn)		x					
Tin (Sn)			x				
AOX	x						
PCDD/F							x
PAC						x	
DEHP				x			
Polybrominated diphenyl ethers							x
Polychlorinated biphenyls (PCB)							x
Linear alkyl benzene sulfonate (LAS)					x		

Last but not least of importance are pathogens such as bacteria, viruses, parasites and worm eggs that can be found in sewage sludge. These can endanger the health of humans and animals when entering their bodies via direct contact or food chains. The goal of sewage sludge treatment and management is to minimize harmful sludge content and its potential threats for environment and society while retaining sludge nutrients.

EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

The legal framework for the utilization of sewage sludge from municipal waste water treatment for agricultural purposes or in other ways on soil in the countries of the EU is provided in the form of the Council Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. This piece of legislation currently undergoes a process of review and debate in order to get new findings made on the harmful substances content and their impacts, as well as progress occurring on technology and in analytical fields properly considered in the future. Selected countries already adjusted their national regulations in accordance to these new insights and in some cases imposed a halt on the use of sewage sludge in agriculture and/or ordered a recovery of phosphorus to be applied on one or various process stages, i.e. from waste water, the sludge or on the treatment residues such as the ashes from mono incineration.

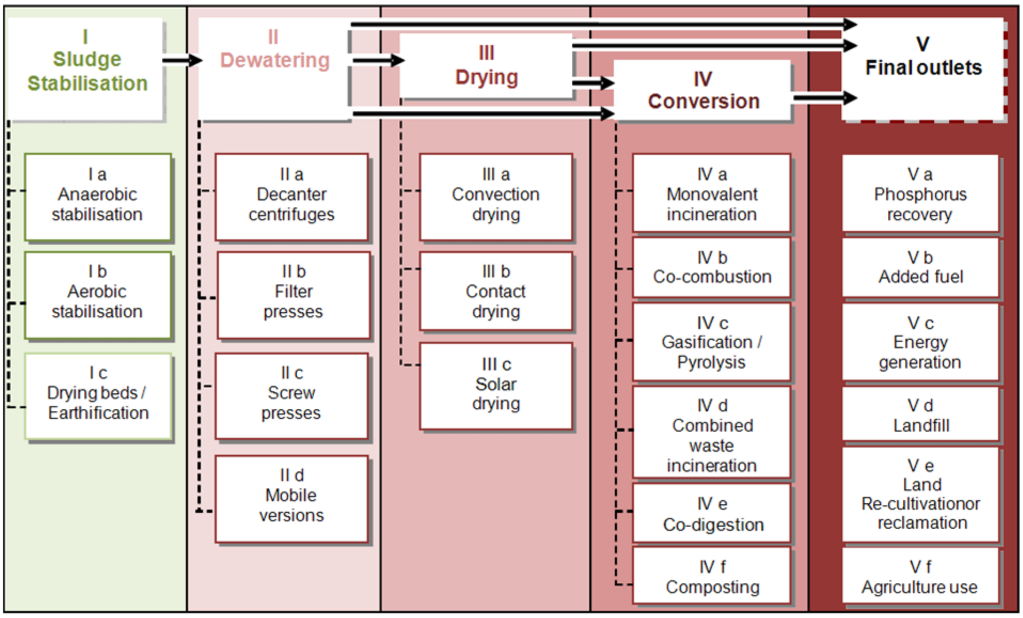
NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM

With the treatment of the sludge it has to be ensured that potentially dangerous substances are reduced to uncritical levels or diverted to routes of safe disposal while best possible utilization of its valuable content shall also become possible. The application of appropriate thickening, stabilisation and dewatering processes is crucial in order to get sewage sludge utilized or disposed of correctly and efficiently. Thickening and dewatering must be well adapted to the further processes of sewage sludge utilization. Only input material that has been suitably pre-treated with view to subsequent processes will allow the optimum treatment and utilization results to be attained.

Various stages of pre- and post-treatment must be passed before a material utilization, recovery of energy from the organic components or final depositing of the sludge can take place. In any case can and should be minimized through appropriate measures the generation of excess sludge in order to reduce the overall need and costs for sludge treatment.

The individual steps and procedures that eventually facilitate the ultimate use or disposal of sludge can be varied, generally there exist several process options and techniques which, depending on the final objectives and next process step can be used in combination but partly also replace one another. Figure gives kind of an overview on that.

Figure 29: Overview on the principal options for a sludge management process



All treatment steps have to be accompanied from specific pollution control measures, management practices and careful monitoring, including analytical measurements, so as to mitigate the risks associated with harmful constituents of the sludge and residues from its processing. Critical process control parameters and baseline data on sludge properties should be established and recorded to facilitate and support subsequent management operations and for optimizing treatment processes.

Table 14: Overview on main operations parameter's relevance for sludge disposal and use options(ISWA/EEA, 1997)

	Sedimentation	Stabilisation: aerobic	Stabilisation: anaerobic	Stabilisation: chemical	Stabilisation: thermal	Thickening	Dewatering	Drying	Transportation	Landfilling	Composting	Agriculture	Incineration
Temperature		x	x				x	x			x		x
Density						x		x	x				
Rheological prop.							x	x	x	x		x	x
Settleability	x					x	x						
Solids concentration	x	x	x	x	x	x	x	x	x	x	x	x	x
Volatile solids		x	x	x	x				x	x	x	x	x
Digestability			x										
pH		x	x	x			x				x	x	
Volatile acids			x										
Fats and oils		x	x									x	
Heavy metals			x							x	x	x	x
Nutrients		x	x								x	x	
Particle size	x					x	x						
CST						x	x						
Spec. resistance						x	x						
Compressibility							x						
Centrifugability							x						
Calorific value													x
Leachability										x			
Microbial. Prop.		x	x								x	x	

APPROPRIATE COLLECTION STRATEGIES AND SCHEMES	Sludge from municipal waste water is generated during processes at specialized waste water treatment facilities and does accumulate there. No specific mechanisms or forms of collection must therefore be established. However, amounts of faecal matter and/or sludge from waste water tanks also accumulate under certain conditions or circumstances at private properties and need to be collected from them. These quantities must be forwarded then to aforementioned specialized waste water treatment facilities for further treatment in their processes. For collection and transport specialized tank vehicles capable to undertake the suction dredging of the liquid slurry are being used.
APPROPRIATE TREATMENT AND RECOVERY SCHEMES	Sludge treatment methods include thickening, biological stabilisation, dewatering, drying and conversion techniques that lead to hygienization and/or inertisation (through incineration) of the sludge. It should be noted that every application has its specific advantages and disadvantages (including for downstream processes and further disposal), therefore no single sludge treatment process can claim to provide the "ideal" solution. It is important that local conditions and needs as well as long-term environmental and economic effects are adequately taken into consideration when selecting appropriate sludge treatment paths and technologies. **<u>Thickening:</u>** The purpose of sludge thickening is to reduce sludge volume by removing as much water as possible from the sludge. Thickeners similar to sedimentation tanks in terms of their design and processes allow sludge particles to naturally sink to and deposit on the bottom. Other thickening techniques (disc or snail-wheel design) split off water by simple sludge densification. Reducing sludge volume is critical to let storage, transportation and treatment become more efficient. Raw sludge from the thickener can be left untreated only for further processing in a fresh sludge incineration. **<u>I. Stabilisation:</u>** Sludge stabilisation can involve chemical, physical and thermal methods. Stabilised sludge with reduced concentrations of harmful components offers higher security as far as different disposal options and access to them are concerned. Objectives of the sludge stabilisation process are: - lowering reaction potential of the substrate; - reduction of sludge and solid component quantities; - improvement of the dewatering characteristics of the sludge; - creating a possibility to recover biogas, at the cost of lowering the calorific value of the stabilised sludge; - creation of a buffer and storage capacity for sludge treatment Different levels of sludge stabilisation are required to make use of utilization options for sludge. In principle, the following is recommended: - Stabilisation is not mandatory for sludge that will be used in thermal processes or that will undergo biological conversion (unless this is required due to transport, safety or odour development concerns on the part of the operators of the respective facilities). - Utilization in agriculture (in a liquid or drained state) requires fully stabilised sludge. - Utilization in a quasi-liquid state on land, especially for landscaping purposes also requires fully stabilised sludge. - Utilization after dewatering on land which can be for re-cultivation and landscaping requires the sludge to be at least semi stabilised. - Dewatering or drying and a partial to full stabilisation of the sludge (depending on the applied method) comprise the minimum treatment needed where a landfill disposal is necessary and allowed. Chemical stabilisation, for example with quicklime, leads to a rather fast but short-term result but not the sustainable effect that biological processes provide. For biological sewage sludge stabilisation a distinction is to be made between aerobic and anaerobic processes.

Table 15: Key specifics of anaerobic and aerobic sludge stabilisation methods

	Anaerobic processes	Aerobic processes
Main process features	- The active organic load and the quantity of the sludge are reduced through the biodegradation of organic material content in the absence of oxygen (anaerobic digestion). - Stabilisation method is usually executed in digesters (e.g. towers) in a mesophilic (30–38°C) or thermophilic (49–57°C) temperature range and usually takes 20-30 days. - Methane gas (biogas) is generated as a by-product and can be used to produce energy. - The coupling of the energy flows obtainable from digestion with heat generated from biogas combustion is an efficient way to realize an economical drying of sludge. It is also essential that digestion improves sewage sludge de-watering capacity. - The specific investment costs for classic egg-shaped digesters come to 600–1000 EUR/m^3 digester capacity; additional staffing requirement is 8–10 hours/month.	- Microorganisms contained in the sludge are stimulated through the supply of oxygen to convert almost all available organic matter into humus-like substances and mineral end products. - Activation basins which are ventilated in various ways (e.g. centrifugal aeration, rotary brushes, fans or other ventilation devices such as membrane diffusers) are used to stimulate the micro-organic activity. - Alternative applications of aerobic stabilisation processes are composting (see factsheet on "**Composting**") and soilification of sludge (using for example reed planted basins). - The indicative investment for a sludge earthification facility in Germany is 60 EUR/m^2 of treatment area (all installations included).

Chemical or thermal disintegration as integrated or preceding steps to anaerobic digestion help optimizing the gas yield and stabilisation result. However, anaerobic digestion of sewage sludge before sludge combustion can be counterproductive because of the reduced calorific value of the digested sludge.
Nitrification using cascade design processes is also a recommendable practice to support stabilisation and detoxification especially in conjunction with an aerobic treatment process. A possibility that must be considered as well is that of a recovery of phosphorus from the sludge (see fact sheet on "Phosphorus recovery").

II. Dewatering (Drainage):
Lowering the sludge's water content significantly is essential for further efficient utilization and in particular for an economical transportation of sludge. Dewatering is the first technical step which reduces the water load far beyond the simple thickening of the sludge. This process increases dry solids content and produces a solid filter cake by sludge filtration through fabric filter cloths in filter presses, or by using decanter centrifuges or screw presses. The increased calorific value of the sludge cake makes subsequent thermal treatment more cost effective.

Mechanical dewatering of sewage sludge results in solids concentrations usually amounting to 20 to 45 %, measured as dry residue. The success of mechanical dewatering mainly hinges on the machinery used, the nature and properties of the sludge, as well as any conditioning it may undergo. Dewatering at ratios typically higher than 10 % will first require some form of chemical conditioning through the use of flocking and flocking agent additives. They assist in the separation of the bound and entrained water from within the sludge. A distinction is made between inorganic flocking agents such as iron or aluminium salt, lime, and coal on one hand, and organic flocking agents (organic polymers) on the other. Iron and aluminium salts are often used as dewatering precipitates for phosphate removal. The dry solid content after drainage can be increased by up to 5 % and more through phosphate reducing measures. The application of salts substantially increases the non-combustible material (i.e. ash) content of dewatered sludge, however. Organic conditioning agents are therefore used where thermal sewage sludge treatment is foreseen.

The energy required to raise the dry solid content of the sludge from 5 % to 35 % in a drainage installation is approximately in the range of 3–5 $kWh_{electr.}$ per kg H_2O.

III. Drying:

There exist a number of reasons that require a further drying of the sludge following its mechanical dewatering. Principal arguments for using this technical option are:

- a further reduction of the sludge amount to be handled;
- a further increase of its calorific value;
- further stabilisation and increased hygienic safety;
- easier storage and transportation;
- elimination of the problems of handling paste-like substances respectively the possibility of a better dosing in their further utilization.

The main drawback of drying is the additional energy needed. Tremendous amounts of energy are required as residual sludge water is evaporated using thermal energy. In the process, the drying gradient is determined by the intended sludge use. Hence a critical economic evaluation should always precede the decision for drying sludge. An economical drying process can be realized where there is enough excess heat available from other processes or where solar energy can be used for drying and the dry product can be marketed as a secondary fuel.

35 % dry solids content is generally sufficient to allow for a self-sustained incineration of sewage sludge The counterpart minimum value for digested sludge is 45 to 55 % dry solids, since digestion leaves behind a lesser amount of organic material for incineration. Sewage sludge combusts spontaneously at a heat value of around 4,500 to 5,000 kJ/kg, drying increases the calorific value sewage sludge up to 13,000kJ/kg. Thus, the calorific value of dried sewage sludge is on a par with that of dry wood or lignite.

Drying of sewage sludge is carried out in separate or connected installations. Generally, the following drying methods for sewage sludge and combinations of these are known:

- contact drying (for example with the help of a thin film dryer, disk dryer, centrifugal dryer);
- convection drying (for example with the help of a belt dryer, drum dryer, fluidized bed dryer, cold air dryer);
- solar drying,

Solar drying entails heating the sludge and then drying it in a greenhouse-like construction using solar energy. This process has come into greater use in recent years. (see fact sheet on "Solar drying"). The throughput of solar sludge dryers is considerably lower than that of most other dryer technologies, and is generally lower than that of thermal methods, however. Drying sewage sludge is practically applied to the following extent:

- partial drying, up to approximately 60–80 % DS;
- complete drying, up to approximately 80–90 % DS.

Drying thickened sludge from 25 % to 90 % DS requires approx. 70–80 kWh_{therm} per kg of evaporated H_20 using contact and convection drying techniques.

Partial drying is especially an option where drying in subsequent energetic utilization process reactors (e.g. fluidized bed incinerator; see fact sheet on "Fluidized bed incinerator") can be achieved at higher efficiency than with any other drying technique. Pre-drying should only be carried out up to the point at which the sludge contributes positively to the energy balance of the following incineration process.

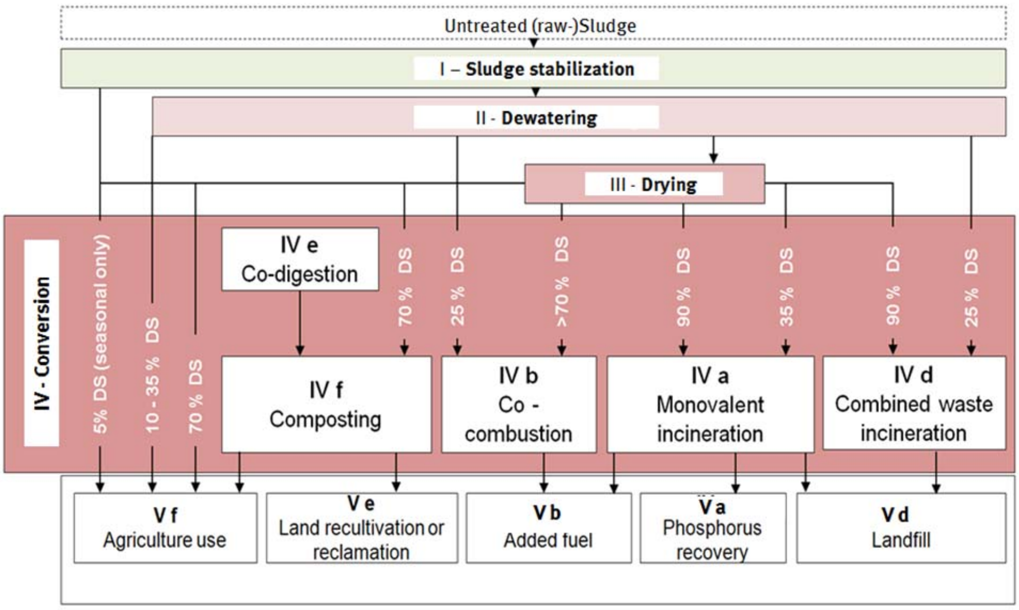
Dried sewage sludge represents free-flowing granulate which can be used as added fuel especially in power plants and cement kilns. Sewage sludge in cement plants needs to be both dewatered and fully dried. Fully dried sludge can also be used in power plants. Often such plants have coal grinding systems that allow for integrated sewage sludge drying, however. In these cases sewage sludge with a solids content ranging from 20 to 35 % dry residue is normally used for incineration purposes. Waste incineration plants are usually capable to handle dewatered, partly dried and fully dried sewage sludge. In places where mixed municipal waste of higher calorific value (9,000 kJ/kg and more) is generated and burnt, a mixture ratio of drained sewage sludge to municipal waste of in maximum 10 % weight of drained sewage sludge is typical.

APPROPRIATE RECYCLING TECHNOLOGIES

There exists quite a wide range of processes in which a material transformation of sewage sludge can be undertaken for the purpose of using its ingredients and neutralizing the potentially hazardous components it contains substantially. Many of these processes correspond to standard treatment techniques applied to different types and streams of waste materials.

Since sewage sludge loses its original properties and then comes to use in another form these practices can be referred to as processes of conversion. Sludge conversion processes may require *dewatering* and/or *drying* as a pre-treatment stage, although under certain conditions a direct application next to *stabilisation* can be possible (see figure below).

Figure 30: Role of conversion processes in sludge management and their basic requirements



To make effective use of the available conversion capacities and further ways for sludge utilization in a country, it is advisable that waste water treatment plant operators maintain separate storage space or secure access to such. A storage capacity equivalent to one year is considered optimal; in the minimum it should be good for a period of 3-6 months at least.

IV a-c. Thermal utilization:

Thermal utilization is the method which guarantees at best the destruction of potentially hazardous components and is supposed to become the most widely available disposal alternative as other options (landfill disposal, agricultural use) are successively ruled out for diverse reasons. Incineration of sewage sludge is, compared with other disposal options, one of the most costly ways of sludge utilization, though. Typical process conditions apply to sewage sludge incineration. Particularly important factors to take into account when incinerating sewage sludge are:

- the composition of the sludge as primary, secondary, bio-sludge, etc.,
- the dry residues content and therewith the calorific value (typically this varies but has major impact on the incineration process),
- the state of stabilisation (for necessary precautions during sludge storage and feeding)
- was the sludge digested or not,
- contents of conditioning agents in the sludge.

Monovalent incineration is dedicated exclusively to sewage sludge combustion with the aim to effectively destroy harmful organic compounds in the sludge and to generate energy. Such installations are usually erected at waste water treatment sites and have the advantage for the plant operator that waste water treatment and sludge disposal can be done independently from other offers and in the way that offers the highest benefit to the waste water treatment plant itself (e.g. generation of energy and heat for own plant processes).

Different process technologies showing different advantages and disadvantages are applied for the furnace system used in monovalent incineration facilities. In recent years, the stationary fluidized bed (see fact sheet on "Fluidized bed incinerator") has become a preferred technology for monovalent incineration. Monovalent sludge incineration opens up the possibility for a recovery of phosphorus (see fact sheet on "Phosphorus recovery") from the ash of the incinerated sludge.

Table 16: Comparison of the main furnace systems used for dedicated sewage sludge combustion

	Fluidized bed	Multiple-hearth	Multiple-hearth fluidized bed	Cycloid
Attributes	No moving parts and minimal wear and tear	No separate pre-drying phase needed; more complex design with moving parts and cooled hollow shafts	No separate pre-drying phase needed; moving hollow shafts; low fluidized bed volumes	No moving parts and minimal wear and tear; needs no fluidized bed materials
Operating performance	Rapid start up and shutdown thanks to short heating-up and cooling cycles; can be operated intermittently	Lengthy heating-up times; needs to be operated continuously	Medium heating – up and cooling times	Similar to fluidized bed; compatible with a broad range of fuels
Combustion	Only minimal excess air needed; complete burn-up only occurs above the fluidized bed	Burn-up difficult to control; impervious to fluctuations in load volumes and to large elements	Requires minimal excess air; burn-out readily manageable; most combustion occurs in the fluidised bed; as compared to fluidized bed furnace, impervious to sludge quality fluctuations	Solids content, long an gaseous elements, short dwell times, variable primary and secondary air intake at various levels
Waste gas ash content	High	Low	High	High
Ash discharge	Via waste gas flow and sand removal	At the bottom-most hearth	Via waste gas flow and sand removal	Cia waste gas flow; large ash particles on the bottom
Residues	Ash; fluidized bed materials	Ash	Ash; fluidized bed material	Ash; in some cases large ash particles

Lately, the ***co-combustion*** of sewage sludge in power plants and industrial furnaces has taken an increasing share of sewage sludge disposal. Sewage sludge can be co-incinerated in the kilns of cement plants, lime works as well as in coal-fired power plants (see fact sheet on "Industrial Co-combustion"). In most incinerating facilities there is no substantial problem with feeding, conveying and combustion of appropriately pre-treated sludge (see above under *Drying*). Dried sewage sludge used for cement production can replace fossil fuels and at the same time substitute part of the raw materials such as sand or iron ore through its mineral components. Cement plants and lime works hence use sewage sludge to the extent of about 15 % of their thermal power requirement as an added fuel. In addition to sewage sludge, other wastes from the waste water treatment process are often incinerated, e.g. swim scum, screenings, and extracted fats.

For most power stations a share of sludge of up to 5% of the total fuel mass is so far seen. Pulverized coal injection or fluidized bed firing systems are mainly used for co-combustion in power stations. Power stations in general accept only stabilised sewage sludge for incineration since raw sludge is associated with greater difficulties and risks in handling and storage.

Table 17: Features of the co-combustion of sludge in coal-fired power stations

	Fuel properties	Combustion mode	Sewage sludge co-incineration
Coal-fired power plants	Coal water content: 7–11% Calorific value: 27–30 MJ/kg	Pulverized-coal firing, cyclone melting chamber, circulating, fluidized bed firing	The extent to which dewatered sewage sludge can be used is limited owing to low coal grinder drying capacity
Lignite fired power plants	Lignite water content: 46–60% Calorific value: 8.5–12.5 MJ/kg	Pulverized-coal firing, circulating fluidised bed firing	Sewage sludge use is limited owing to sludge heavy-metal content

The main drawback of co-incineration/co-combustion is that it precludes recovery of the phosphorous in sewage sludge (see fact sheet on "Phosphorus recovery").

Also other methods for thermal utilization, such as pyrolysis and gasification have already more advanced in the area of sludge treatment than in other waste areas. One example from this technology segment is the PYREG®-process. That aforementioned techniques have more advanced in this sector has to do with the sludge's homogenous nature. For other waste streams where this is more seldom the case, the success both processes have on the market is rather limited with rarely any functional application at larger scale seen until to date.

IV e-f. Biological conversion:

The ***production of biogas from sewage sludge*** is well-known from the techniques mentioned in the treatment chapter above for *biological sewage sludge stabilisation*. Mixed with other biodegradable waste, sludge can also be a suitable input material in co-digestion processes. Brought in a mix with other biogenic substances such as kitchen and food waste and introduced into modern bio-digester installations (see fact sheet on "Anaerobic digestion"), it has been found that an optimal biogas yield can be obtained, significantly higher than that with digestion from each fraction individually. The output, processed to gas of natural gas quality, can be used for many purposes: to fuel vehicles, to generate electric power and heat buildings or to support sludge drying.

Figure 31: Co-digestion facility for sewage sludge during construction phase (left) and after completion (right) (Photos: INTECUS GmbH)

The ***application of sludge to land*** is only an option for sludge that has been fully stabilised, converted into an environmentally safe product, thoroughly examined and certified for this. Mostly, the countries have regulations and criteria in place which also contain limits as to the places and times of use and maximum allowable application per unit of area.

An additional option is to supply suitable sludge to composting where it is sterilized (see fact sheet on "Composting"). Sludge or residues from sludge digestion are added to other composting input only at proportions, which permit allowable pollutant levels to be kept. Certified sludge compost is a stabilised organic fertilizer with moderate nutrient content, which releases the nutrients slowly and evenly to the plant and affects positively the balance of the soil humus. In the interest of completely ruling out the transmission of infectious agents, the use of sludge as fertilizer has been banned for organic farming, in forests, in grassland, and for fruit and vegetable cultivation. The material quality, environmental quality and hygienic safety of the finished compost are to be secured by external and internal supervision, and wherever possible participation in a quality assurance scheme. Important elements of a compost quality assurance are regular lab analyses, which often make up a mandatory requirement in many countries anyway, and a reliable certification system.

The ***inclusion of sewage sludge in MBT processes*** (see fact sheet on "Mechanical-biological waste treatment") makes sense only where combinations of mechanical treatment with digestion processes are used or where the output is a stabilised material which is going to be used as waste-derived fuel in thermal processes. MBT exclusively for sludge is an uneconomical solution.

APPROPRIATE DISPOSAL STRATEGIES

Combined incineration of sewage sludge with other residual waste is usually performed as a mere disposal method where harmful content is safely destroyed, organic matter mineralized and sludge volume therefore reduced to a minimum. Ideally energy is recovered from this process. Municipal waste incinerators equipped with standard furnace technology (see fact sheet on "Grate combustion"), flue gas cleaning and emission control devices provide appropriate facilities. Where added to these incinerators, the feeding techniques often make the major difference to other incinerators and represent a significant proportion of additional investment costs. For higher amounts of sewage sludge and limited piling capacity it represents a possible solution to spread well-structured, dewatered sewage sludge continuously on the refuse in the bunker with a spreading machine. Spraying sludge through special nozzles above the waste bed (often in the gas burnout zone) may provide benefits for some waste incinerators (especially such that deal with wastes of higher calorific value) in that the water content of sludge provides an additional means of controlling temperature and the primary NO_x generation. In order to ensure a good process management and control over the emissions in mass burn waste incinerators it is general practice to limit the share sewage sludge takes in the combustion input in the maximum to approx. 10%. Flue gas cleaning must be an integrated part of any waste incineration to secure the abatement of the hazard potential of emissions resulting from the incineration process. Particular attention in the exhaust gas treatment after sewage sludge combustion must be devoted to nitrogen oxides and mercury (see fact sheet "Flue gas cleaning").

Landfill disposal of sludge is generally not a good option since the sludge introduces additional moisture and organic matter to the landfill body and hence adds to the emission potential and leachate generation. On well-constructed and secured landfills (see fact sheet "Landfill for non-hazardous wastes") operating with modern management standards it is however possible to deposit dewatered sludge as temporary solution until other management options are fully developed. The same is the case for ashes from sludge incineration.

Table 18: Indicative range of sludge management costs (based on reference values given in various sources for Germany [1]

Sewage sludge management method	Disposal costs [EUR/Mg wet sludge] (German price level of 2011/12)		Sludge type (DS = dry substance)
	Min.	Max.	
Co-incineration at coal fired power plants	80	130	Dry: greater than 85%
Cement plant co-incineration	90	100	Dry: greater than 85%
Mono-incineration	80	120	Mechanically dewatered: 20–45 % DS
Waste incineration plant co-incineration	80	100	Mechanically dewatered: 20–45 % DS
Co-incineration at coal fired power plants	75	100	Mechanically dewatered: 20–45 % DS
Co-incineration at lignite fired power plants	50	75	Mechanically dewatered: 20–45 % DS
Recultivation	30	45	Mechanically dewatered: 20–45 % DS
Farming, trans-regional	33	45	Mechanically dewatered: 20–45 % DS
Farming, regional	25	30	Mechanically dewatered: 20–45 % DS
Farming, liquid	8	12	Mechanically dewatered: 20–45 % DS

REFERENCES AND PROVIDER FIRMS

(Important note: the list of firms does not constitute a complete compilation of companies active in the specified fields)

Providers of specific technologies for sludge treatment are listed in the fact sheets referenced at the corresponding sections. To obtain detailed insights about suitable arrangements of different techniques and equipment, their operational parameter and performance in practice it is particularly worth to visit reference plants and speak with practitioners. To the recommendable ones in Germany belong:

- for stabilisation techniques: WWTPs in Blümeltal/City of Pirmasens; Rhineland-Palatinate
- for drying techniques including heat exchanger: WWTP Weissach, Baden-Wuerttemberg
- for drying using solar energy: WWTP Penzing Weil, Bavaria
- for monovalent incineration with multiple hearth furnace : WWTP Sindlingen, Hesse
- for monovalent incineration with circulating fluidized bed: WWTP Steinhäule, Bavaria
- for co-combustion of sewage sludge in cement kilns: Cemex plant Rüdersdorf, Brandenburg
- for sludge gasification: WWTPs Balingen and Mannheim, Baden-Wuerttemberg
- for sludge co-digestion: WWTP Radeberg and WWTP Dresden-Kaditz, Saxony
- for phosphor elimination and recovery: WWTP Berlin-Waßmannsdorf, Brandenburg

REFERENCE DOCUMENTS	
	- [1] Publication “Sewage sludge management in Germany”. from January 2015; currently available at: http://www.umweltbundesamt.de/en/publikationen/sewage-sludge-management-in-germany - Technical Guide on the treatment and recycling techniques for sludge from municipal waste water treatment. from May 2015; currently available at: https://www.umweltbundesamt.de/publikationen/technical-guide-on-the-treatment-recycling-0 - Guidance for decision-making on sewage sludge management - Recommended proceedings for Waste Water Treatment Plant Operators. from May 2015; currently available at: https://www.umweltbundesamt.de/publikationen/guidance-for-decision-making-on-sewage-sludge - EC: Reference Document on Best Available Techniques for the Waste Treatments Industries. version of August 2006, available at: http://eippcb.jrc.ec.europa.eu/reference/wt.html - EC: Reference Document on the Best Available Techniques for Waste Incineration. version of August 2006, available at: http://eippcb.jrc.ec.europa.eu/reference/wi.html - EC: Reference Document on Best Available Techniques in Common Waste Water and Waste Gas Treatment / Management Systems in the Chemical Sector. version of February 2003, available at: http://eippcb.jrc.ec.europa.eu/reference/cww.html • German Association for Water, Waste water and Waste – DWA www.dwa.de • Technical Committee ISO/TC 275 Sludge recovery, recycling, treatment and disposal within the International Organization for Standardization (ISO) www.iso.org