SIXTH FRAMEWORK PROGRAMME
PRIORITY [policy-oriented research priority SSP 5A]

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

FORWAST

Overall mapping of physical flows and stocks of resources to forecast waste quantities in Europe and identify life-cycle environmental stakes of waste prevention and recycling

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Title:

Description of the environmental pressures for each relevant combination of material and recycling/treatment technology

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1 INTRODUCTION

This deliverable is part of FORWAST work package five “Scenario and waste technology definitions”. The objectives of FORWAST are:

- to provide an inventory of the historically cumulated physical stock of materials in the EU-27 and to forecast the expected amounts of generated waste, per resource category, in the next 25 years.

- to assess the life-cycle wide environmental impacts that result from different scenarios of waste prevention, recycling and waste treatment.

The forecasting component is done by defining two sets of scenarios: a first set of three macroeconomic scenarios and a second set describing three different waste management policies. These scenarios are crossed, giving a total of 9 scenarios.

Deliverable 5-1 provided a general review of available macroeconomic scenarios. A detailed description of the selected scenarios for FORWAST were presented in the deliverable 5-2. Deliverable 5-3 dealt with the three waste treatment scenarios. For implementing the waste treatment activities in the model, waste treatment modules were created and are provided in an Excel file. This deliverable provides additional information on these activities as well as details about the data sources and steps carried out in order to obtain the modules. The deliverable is organised in 4 parts:

- Chapter 2 presents important intermediate and final waste treatment activities structured following MFA requirements.

- Chapter 3 is based on a document given to the partners in order to help them with the disaggregation of the intermediate waste treatment activities. It has information about the virgin and recycled activities considered in FORWAST, mostly in terms of use of primary resources and use of energy.

- Chapter 4 presents information on the final waste treatment modules created for FORWAST, including BAT processes

It must be mentioned that the “intermediate” waste treatment activities (recycling) were disaggregated by each partner using the information provided by TU Vienna. The “final” waste treatment activities were left in an aggregated state by the data miners, and were disaggregated by 2.-0 LCA using the waste treatment modules described in this document.

To recapitulate, the scenarios as defined in Deliverable 5-2 and 5-3 can be summarized as follows:

Table 1 Scenarios, as defined in Deliverable 5-2 and 5-3

EU Member States Description of Scenarios	Status quo economic development	Status quo emissions (Mt/year)		Status quo waste policy and handling practise	
	Population 2000: 379.2 Mio Investment on environmental protection Specific emission Land use change	CO_2 f SO_X NO_X CH_4	NH_3 NMVOC PM2.5	Waste generation Waste recycling rate Waste treatment rate Waste disposal rate	BAT – Emissions BAT – Energy efficiency

	Economic Development	**Low Economic Growth** Pop.: 2015:; 2035: Low investment on env. protection Higher specific emission More crop / grass, less forest / other land	**Medium Economic Growth** Pop.: 2015:; 2035 Medium investment on env. protection Medium specific emission More crop / grass, less forest / other land	**High Economic Growth** Pop.: 2015:; 2035: High investment on env. protection Lower specific emission Less crop / grass, more forest / other land
Waste policy scenarios	Unit (Mt) CO_2 in (Mt C)	CO_2 f, SO_X, NO_X, CH_4 | NH_3, NMVOC, PM2.5	CO_2 f, SO_X, NO_X, CH_4 | NH_3, NMVOC, PM2.5	CO_2 f, SO_X, NO_X, CH_4 | NH_3, NMVO C, PM2.5
Waste Prevention Scenario Decrease in waste generation (%) Same waste recycling rate (%) Same waste treatment rate (%) Same waste disposal rate (%) BAT – Emissions (%) BAT – Energy efficiency (%)		Lower per capita waste generation High population growth – medium total waste generation Low BAT standard – higher emission per unit waste recycled/treated/disposed; Lower BAT standard – lower energy efficiency Change in waste composition – impact on waste recycling/treatment/disposal	Lower per capita waste generation Low population growth – low total waste generation Medium BAT standard – medium emission per unit waste recycled/treated/disposed Medium BAT standard – medium energy efficiency per unit waste recycled/treated/disposed Change in waste composition – impact on waste recycling/treatment/disposal	Lower per capita waste generation High population growth – medium total waste generation High BAT standard – lower emission per unit waste recycled/treated/disposed High BAT standard – high energy efficiency per unit waste recycled/treated/disposed Change in waste composition – impact on waste recycling/treatment/disposal
Waste Recycling Scenario Same waste generation (%) Increase waste recycling rate (%) Decrease waste treatment rate (%) Decrease waste disposal rate (%) BAT – Emissions (%) BAT – Energy efficiency (%)		Same per capita waste generation High population growth – high total waste generation Increase in recycling rate Low BAT standard – higher emission per unit waste recycled/treated/disposed Lower BAT standard – lower energy efficiency Change in waste composition – impact on waste treatment/disposal	Same per capita waste generation Low population growth – medium total waste generation Medium BAT standard – medium emission per unit waste recycled/treated/disposed Medium BAT standard – medium energy efficiency per unit waste Change in waste composition – impact on waste treatment/disposal	Same per capita waste generation High population growth – high total waste generation High BAT standard – lower emission per unit waste recycled/treated/disposed High BAT standard – high energy efficiency per unit waste Change in waste composition – impact on waste treatment/disposal
Waste Treatment Scenario Same waste generation (%) Same waste recycling rate (%) Same waste treatment rate (%) Same waste disposal rate (%) BAT – Emissions (%) BAT – Energy efficiency (%)		Same per capita waste generation High population growth – high total waste generation Low BAT standard – higher emission per unit waste recycled/treated/disposed Lower BAT standard – lower energy efficiency	Same per capita waste generation Low population growth – medium total waste generation Medium BAT standard – medium emission per unit waste recycled/treated/disposed Medium BAT standard – medium energy efficiency per unit waste	Same per capita waste generation High population growth – high total waste generation High BAT standard – lower emission per unit waste recycled/treated/disposed High BAT standard – high energy efficiency per unit waste

Old EU Member States (EU17) Data for Scenarios	Status quo economic development	Status quo emissions (year 2000)				Status quo waste policy and handling practise	
	Population 2000: 379.2 Mio Investment on environmental protection Specific emission Land use change	CO_2 f SO_X NO_X CH_4	3136.70 6.08 10.20 17.04	NH_3 NMVOC PM2.5	2.88 9.23 1.20	Waste generation Waste recycling rate Waste treatment rate Waste disposal rate (%)	BAT – Emissions BAT – Energy efficiency

	Economic Development	Low Economic Growth Pop.: 2015: 416 Mio; 2035: 449 Mio Low investment on env. protection Higher specific emission More crop / grass, less forest / other land				Medium Economic Growth Pop.: 2015: 395.8 Mio; 2035: 400 Mio Medium investment on env. protection Medium specific emission More crop / grass, less forest / other land				High Economic Growth Pop.: 2015: 412.6 Mio; 2035: 450 Mio High investment on env. protection Lower specific emission Less crop / grass, more forest / other land			
Waste policy scenarios	2015 Unit (Mt) CO_2 in (Mt C)	CO_2 f SO_X NO_X CH_4	3405.06 4.37 11.27 19.61	NH_3 NMVOC PM2.5	3.32 9.23 1.32	CO_2 f SO_X NO_X CH_4	3307.95 2.72 6.69 16.41	NH_3 NMVOC PM2.5	2.78 5.53 0.78	CO_2 f SO_X NO_X CH_4	3192.50 4.64 10.99 18.32	NH_3 NMVOC PM2.5	2.68 9.49 0.91
	2035 Unit (Mt) CO_2 in (Mt C)	CO_2 f SO_X NO_X CH_4	3552.70 2.52 12.50 21.90	NH_3 NMVOC PM2.5	3.70 9.23 1.40	CO_2 f SO_X NO_X CH_4	3332.4 2.42 3.57 16.21	NH_3 NMVOC PM2.5	2.74 3.40 0.60	CO_2 f SO_X NO_X CH_4	3136.70 3.77 9.26 19.36	NH_3 NMVOC PM2.5	2.43 8.60 0.63

New EU Member States (EU10) Data for Scenarios	Status quo economic development	Status quo emissions (year 2000)				Status quo waste policy and handling practise	
	Population 2000: 99.3 Mio Investment on environmental protection Specific emission Land use change	CO_2 f SO_X NO_X CH_4	663.50 4.24 2.13 5.63	NH_3 NMVOC PM2.5	0.79 1.98 0.59	Waste generation Waste recycling rate Waste treatment rate Waste disposal rate	BAT – Emissions BAT – Energy efficiency

	Economic Development	Low Economic Growth Pop.: 2015: 109 Mio; 2035: 118 Mio Low investment on env. protection Higher specific emission More crop / grass, less forest / other land				Medium Economic Growth Pop.: 2015: 99 Mio; 2035: 93 Mio Medium investment on env. protection Medium specific emission More crop / grass, less forest / other land				High Economic Growth Pop.: 2015: 106.Mio; 2035: 110 Mio High investment on env. protection Lower specific emission Less crop / grass, more forest / other land			
Waste policy scenarios	2015 Unit (Mt) CO_2 in (Mt C)	CO_2 f SO_X NO_X CH_4	599.27 3.95 2.77 7.18	NH_3 NMVOC PM2.5	1.00 1.98 0.76	CO_2 f SO_X NO_X CH_4	779.30 2.06 1.60 5.91	NH_3 NMVOC PM2.5	0.83 1.44 0.50	CO_2 f SO_X NO_X CH_4	670.56 3.68 2.27 6.64	NH_3 NMVOC PM2.5	0.76 1.83 0.56
	2035 Unit (Mt) CO_2 in (Mt C)	CO_2 f SO_X NO_X CH_4	866.9 4.87 3.81 10.03	NH_3 NMVOC PM2.5	1.41 1.98 1.05	CO_2 f SO_X NO_X CH_4	880.00 0.79 0.91 6.09	NH_3 NMVOC PM2.5	0.88 0.89 0.40	CO_2 f SO_X NO_X CH_4	1059.3 3.88 2.96 8.31	NH_3 NMVOC PM2.5	0.75 1.90 0.55

2 STANDARD PROCESSES IN WASTE TREATMENT

The following section gives an overview of the most common processes of waste treatment and recycling. The aim of this chapter is to show mass flows in different treatment processes based on transfer coefficients. For illustrating the systems we used the software STAN (short for subSTance flow ANalysis). STAN is freeware that supports performing material flow analysis (MFA) according to the Austrian standard ÖNORM S 2096 (Material flow analysis - Application in waste management) under consideration of data uncertainties (Cencic & Rechberger, 2008).
Each chapter shows one STAN diagram with mass flows of goods within the relevant system. Diagrams with mass flows of selected elements (Fe, Cu, Al, Cd, Hg, and Pb) can be found in the appendix.

We took a look at the following municipal solid waste (MSW) treatment processes: incineration, mechanical biological treatment, bio-gasification, composting, and land filling. In addition we analysed the following recycling processes: recycling of paper, glass, plastics, concrete, iron, aluminium, and copper.
All substance flows are shown in ANNEX I (page 102).

2.1 MSW Incineration

Incineration involves the combustion of typically unprepared (raw or residual) MSW. Waste is generally a highly heterogeneous material, consisting essentially of organic substances, minerals, metals, and water. To allow the combustion to take place, a sufficient quantity of oxygen is required to fully oxidise the fuel. If calorific values of the waste and oxygen supply are sufficient, this leads to an exothermal reaction and self-supporting combustion, i.e. there is no need for the addition of other fuels to MSW.

Combustion temperatures exceed 850°C. The waste is mostly converted into carbon dioxide and water. Any non-combustible materials (e.g. metals, glass, stones) remain as a solid, known as Incinerator Bottom Ash (IBA) that always contains a small amount of residual carbon. The direct combustion of a waste usually releases more of the available energy compared to pyrolysis and gasification (DEFRA, 2007).

In Figure 1 the mass flow of goods – related to 1,000 kg of MSW-Input – is shown.

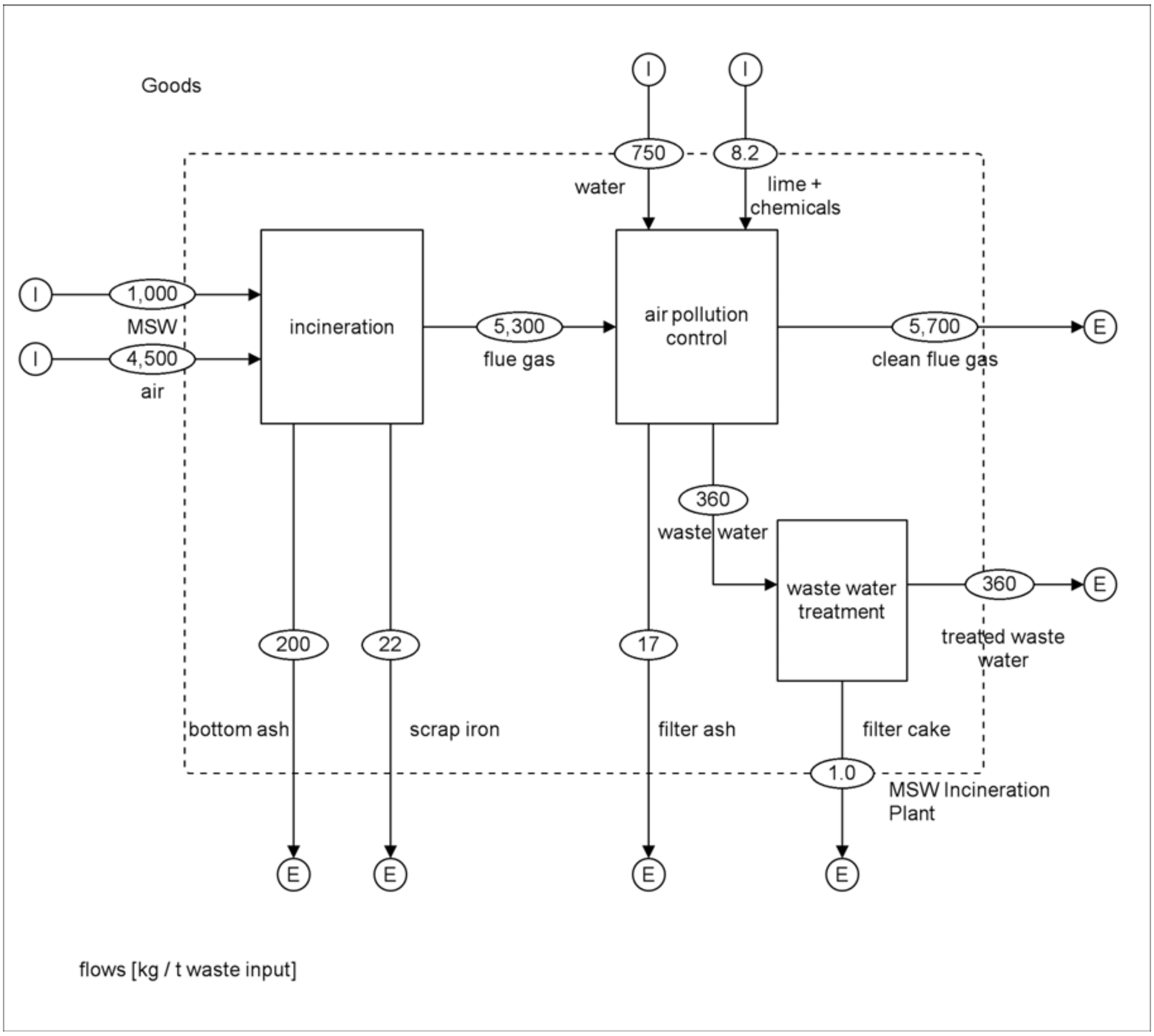


Figure 1: Mass flows at a MSW Incineration Plant.

Mass data derive from mass balance of 2006 of the Incineration Plant Spittelau in Vienna, Austria (Wien Energie, 2007), and transfer coefficients were extracted from a material flow analysis at the Incineration Plant Spittelau (Morf, 2008).

Apparently, a MSW Incineration Plant consists of three main processes: the incineration itself, the air pollution control, and the waste water treatment. Around 25% of the MSW input turns into bottom ash and around 2-3 percent leaves the plant as filter ash, and filter cake. If magnetically separated, about 2 percent is iron scrap.

2.2 MBT – Mechanical Biological Treatment

A Mechanical Biological Treatment Facility usually consists of two main processes. In the first step the MSW is mechanically pre-treated to remove inorganic materials such as plastics, metal, glass, and stones. The mechanical pre-treatment may include trommel screens (to homogenize fines), magnetic separator (to remove ferric materials), Foucault separator (to remove aluminium), ballistic separator (to remove large density materials), and shredder.

The second step is a biological treatment where organic matter is bio-degraded. Sometimes, this happens in a closed composting system during several weeks to stabilize and sanitize the material. During this period, operational parameters (temperature, oxygen, and moisture content) are monitored and controlled (Ponsá et al., 2007).

As shown in Figure 2 almost 48 percent of the MSW input is often separated with the mechanical treatment. The segregated portion mainly consists of a high heating value fraction, and scrap. The rest is preceded to biological treatment, where one half is lost due to biological degradation, and the other share is to be landfilled.

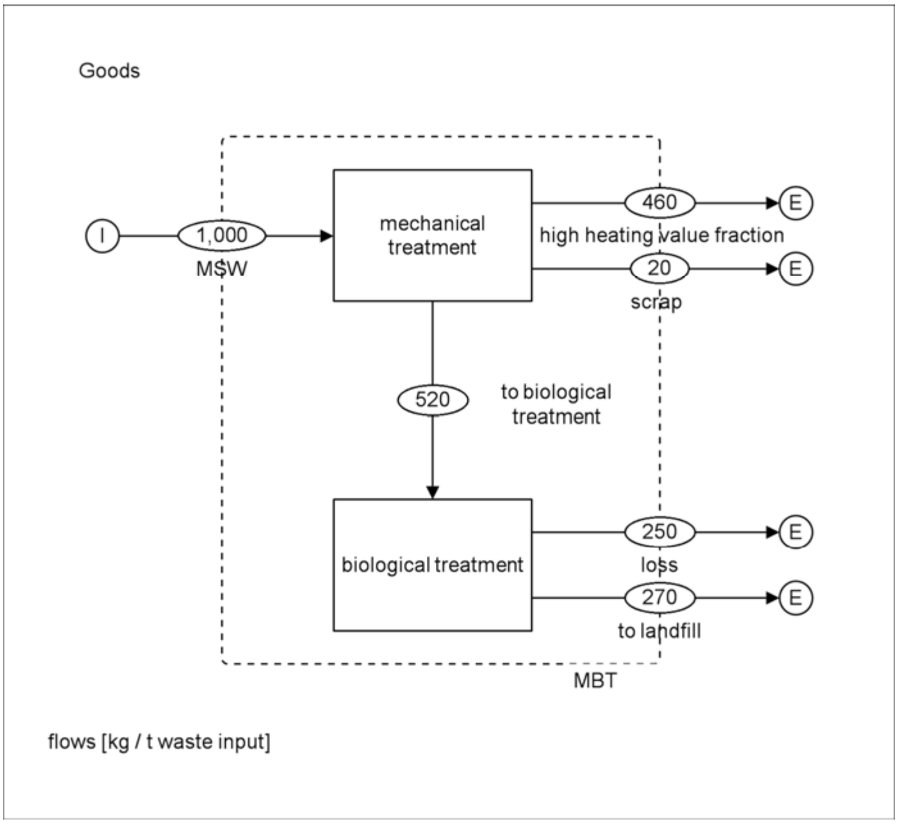


Figure 2: Mass flows at a MSW Mechanical Biological Treatment Facility.

Figure 2 is based on data from Neubauer & Öhlinger, 2006, describing the actual situation of MBT in Austria.

2.3 Bio-gasification

In an agricultural Bio-gasification Plant biogas is produced through anaerobic fermentation of organic manure, plants, and other organic waste. Usually, the emerging biogas is used for electricity generation on site. As a by-product to power generation thermal energy can be utilized as well.

The input of the exemplary agricultural Bio-gasification Plant as pointed in Figure 3 is an average of inputs as cited in Reichard, 2005. It is comprised of 21.5 percent of organic fertilizers, 1.5 percent of used grease, 21 percent of leftovers, and 56 percent of other agricultural substances (Zethner et al., 2002; Reichard, 2005).

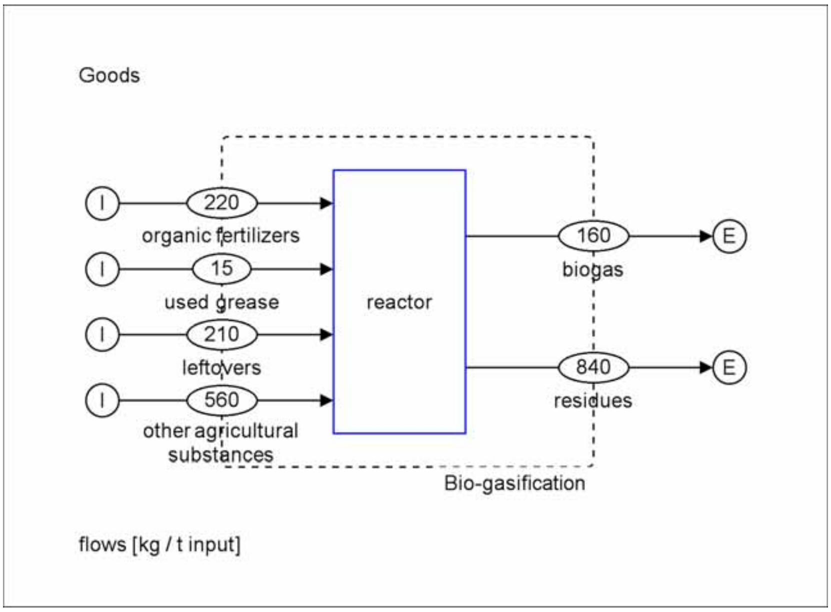


Figure 3: Mass flows at a Bio-gasification Facility.

As shown in Figure 3 around 16 mass-percent of the input were turns into biogas during fermentation.

2.4 Composting

Composting is the aerobic degradation of organic materials in a well-defined environment. The composting process takes place either in open or closed systems. During the degradation process the compost heap generates heat and has to be turned over to reduce temperature and aerate it.

Figure 4 shows the main stages of a composting facility. In the following view the collected biowaste consists of around 66 percent collected biowaste, 1 percent market waste, 5 percent biological kitchen slops, and considers almost 30 percent of private composting.

In the first step non-biological and non-biodegradable waste is separated (around 3 percent of the input). The pure biowaste is mixed with bulking material and water to optimise the process. During the composting process around two thirds of the input material turns into flue gas, the rest remains as compost.

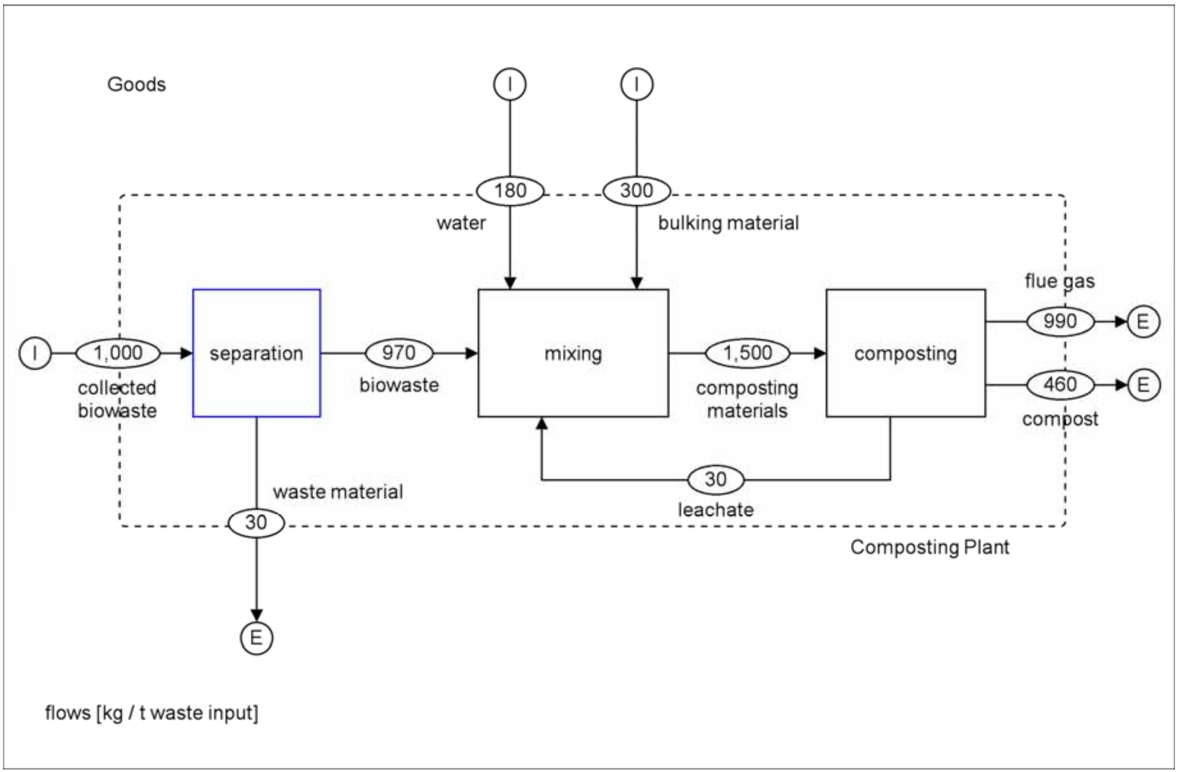


Figure 4: Mass flows at a Composting Facility.

2.5 Landfilling of MSW

In landfills carbon dioxide emerges from bio-degradable carbon under aerobic conditions, and landfill gas (methane, carbon dioxide) is generated under anaerobic conditions (bio-gasification, fermentation).

Theoretically, from 1,000 kg carbon 1.87 m³ of landfill gas can emerge, independently of aerobic or anaerobic conditions. Realistic amounts are between 150 and 300 m³ landfill gas from 1,000 kg MSW.

Nowadays, European legislation does not allow land filling without pre-treatment of MSW (e.g., incineration, MBT) anymore.

The following Figure 5 shows the mass flows at a landfill during the first 100 years after completion. It displays an input of 1,000 kg MSW and a loss of 20 percent through gaseous emissions and 0.5 percent through drain off landfill leachate. After the first 100 years it can be assumed that the "active" phase of the landfill is over (Brunner et al., 2001).

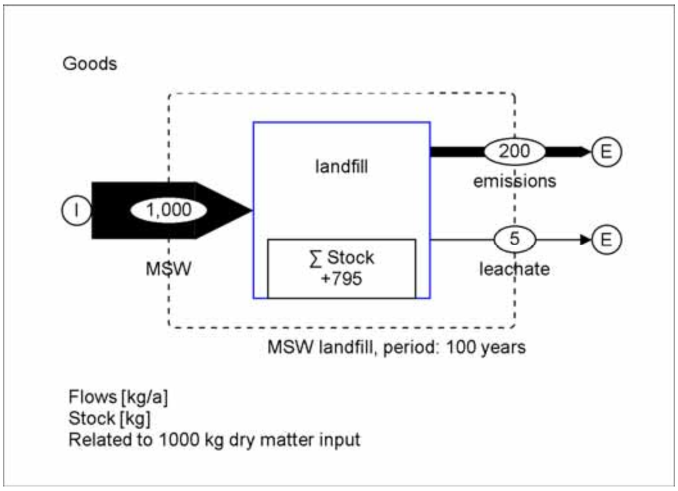


Figure 5: Mass flows at a landfill during the first 100 years after completion.

2.6 Recycling of Glass

Container glass is made from a basic soda lime formulation and is melted in a fossil fuel fired or, exceptionally, an electrically heated furnace. The molten glass is formed into the desired products. Appropriate colouring agents are added to the glass and surface coatings are applied to the finished products (European Commission, 2001).

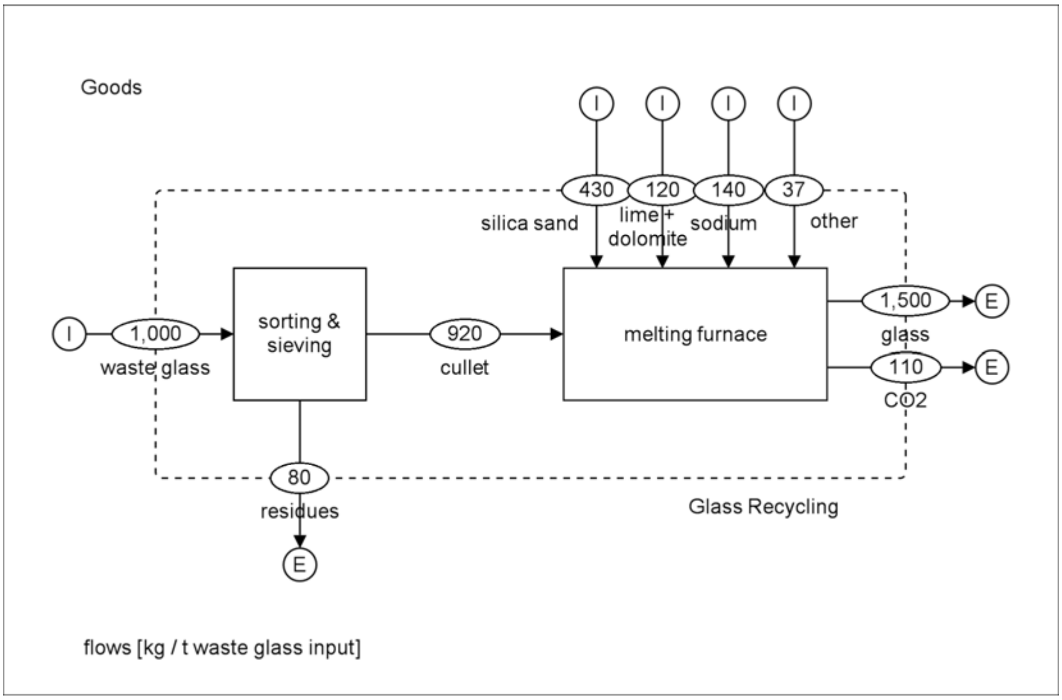


Figure 6: Mass flows of glass recycling.

In the melting furnace cullets are melted together with raw materials at a temperature of around 1,500° centigrade. For producing green glass up to 100 percent of the melted materials can consist of cullets, for white glass up to 60 percent of cullets can be used. Figure 6 bases on a calculation with an amount of 60 percent of cullets.

As shown in Figure 6 around 920 kg of cullets result from 1,000 kg collected waste glass after sorting. Together with an additional input of some 730 kg raw materials and other additives an amount of 1,500 kg new glass can be produced.

2.7 Recycling of Paper

Paper for deinking comes from the household-near collection, does also consists of paper from small enterprises such as offices. Paper from packaging, which can be found more often in households, is often not usable for deinking processes and the production of recycled paper. Paper from the printing industry is an important source for the paper recycling industry.

After elimination of further packaging papers and waste materials the recovered paper is led to the deinking process. It is used as supply to usual raw materials in paper production (Daxbeck, et al., 1999).

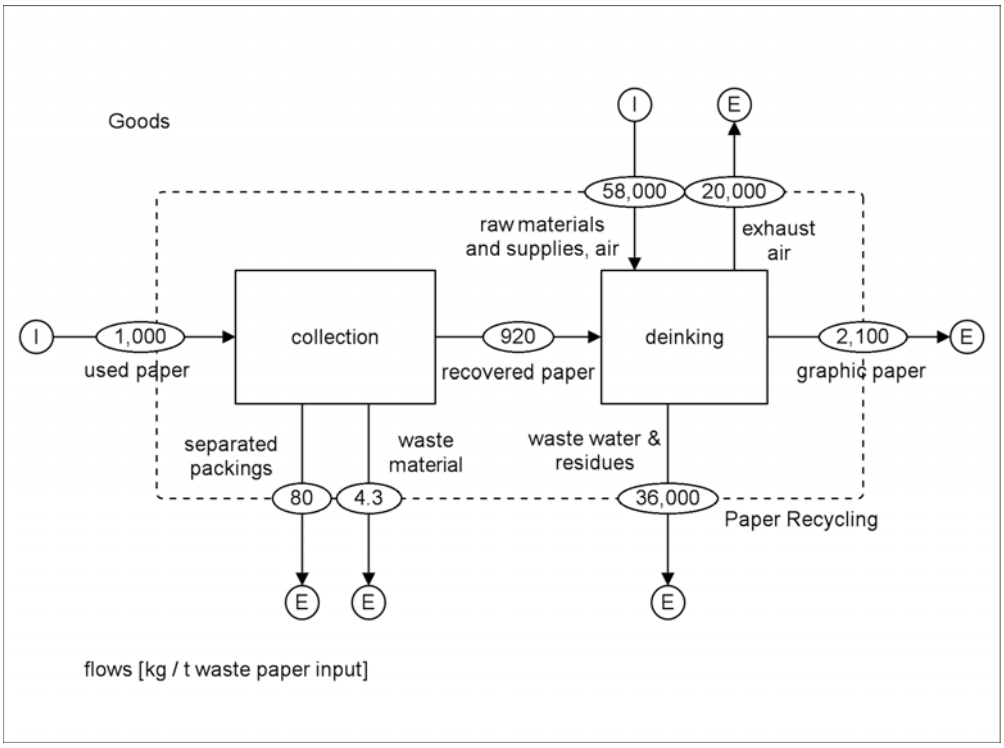


Figure 7: Mass flows of paper recycling.

2.8 Recycling of Plastics

Basic criteria for plastics recycling are sorting accuracy and pollution of plastics waste.
The aim of mono-fractional recycling is to melt and re-granulate plastics waste. Depending on the quality of the input to the recycling facility it is possible to produce the same products as before. From mono-fractional and clean plastics waste it is possible to produce secondary plastics, which has almost the same quality as primary plastics.

There are also treatments to process mixed or contaminated plastics waste. (Fehringer & Brunner, 1997)

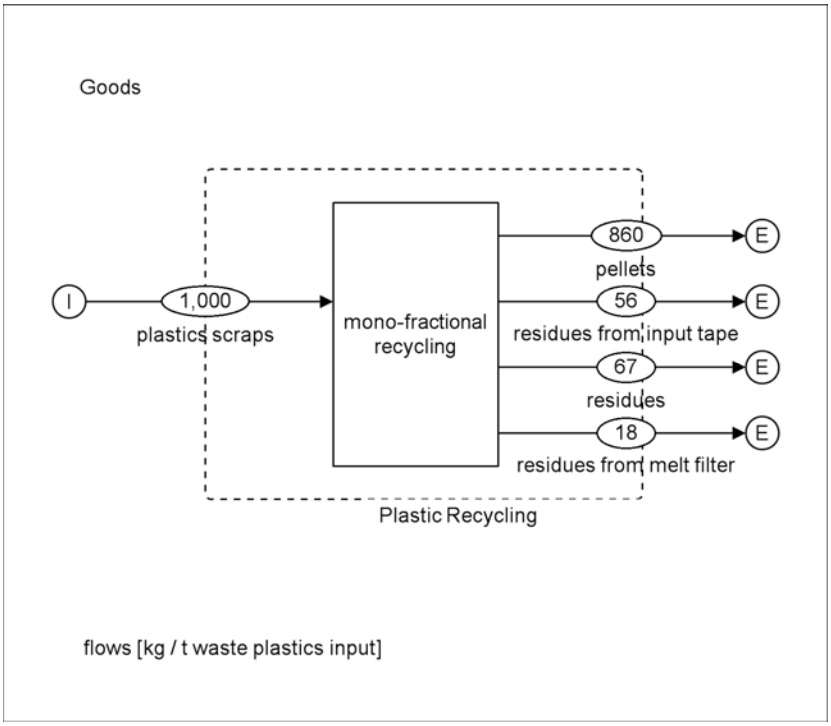


Figure 8: Mass flows of plastics recycling.

As shown in Figure 8 around 86 % of the plastics input are processed into plastics pellets. The rest are residues from different stages of the process.

2.9 Recycling of Concrete

Schachermayer et al., 1998, determined the material flow of a wet construction waste sorting plant. Incoming wastes are sorted according to the ordinance on the separation of construction waste, which reduces impurities to a minimum. In either case – dry or wet treatment techniques - a “clean” initial material is the most important prerequisite. Both processes are suitable to produce high-quality mineral fractions. Since neither wet nor dry processes are capable of directly improving the quality of the sorting products, successful recycling of construction and demolition waste requires the best possible separation of selected materials on the demolition site (selective demolition).

Their tests show that organic carbon accumulates in the light fraction, and iron in scrap iron. Heavy metals generally tended to accumulate in waste water sediment.

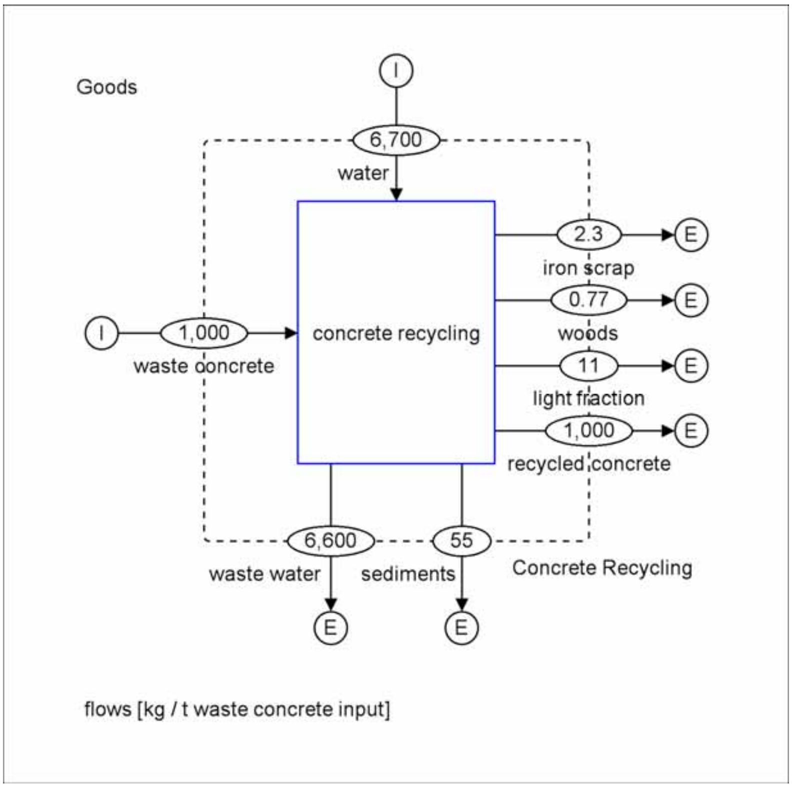


Figure 9: Mass flows of concrete recycling.

As shown in Figure 9 an amount of 1,000 kg of waste concrete is recycled by use of 6,700 kg water. The output again is around 1,000 kg of (wet) recycled concrete beside 6 % sediments, 2 % iron scrap and some light fraction and woods.

2.10 Recycling of Iron

Main inputs for steel production are pig iron, scrap and other ferrous materials, and auxiliary material. Steel can be produced with the oxygen steelmaking process and within an electric arc furnace, respectively.

At the oxygen steelmaking process unwanted associated material is burnt with the injected oxygen. At the same time the carbon content is reduced from around 4 % to under 0.5 % (Gara & Schrimpf, 1997).

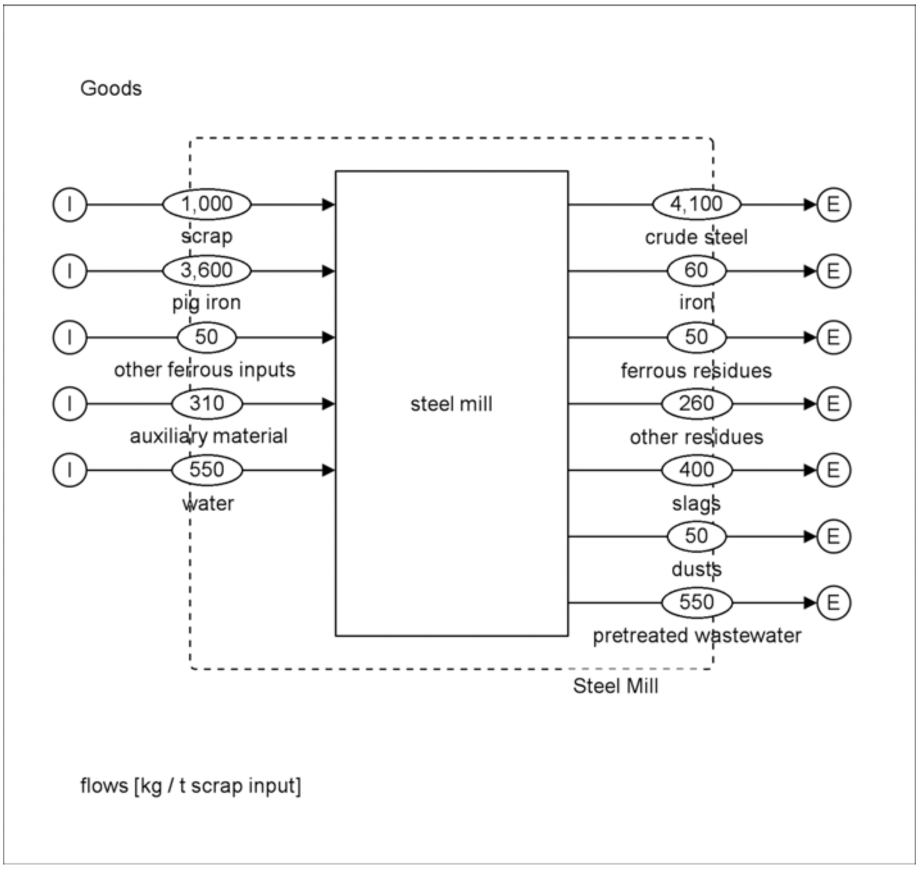


Figure 10: Mass flows of iron recycling.

Figure 10 shows a steel mill with the values standardized to 1,000 kg of scrap input. The main input into the process is 3,600 kg of pig iron. Main outputs of this process are crude steel and iron (4,200 kg), almost 1,000 kg of slags and waste water, and 360 kg of residues and dusts.

2.11 Recycling of Aluminium

Depending on the input materials and the desired product quality, a variety of smelt aggregates are used in the production of secondary aluminium. The selection of the most appropriate smelting process is determined by the metal content of the scrap (oxide content), type and content of impurity (annealing loss), geometry of the scrap, frequency of change in alloy composition, and operating conditions.

The most usual process to smelt aluminium scrap is melting under a salt cover in a drum melting furnace.

In comparison to primary production, the production of secondary aluminium permits savings on energy of up to 85%, and lower atmospheric emissions and solid residues by a factor of at least 10 (Boin et al., 2000).

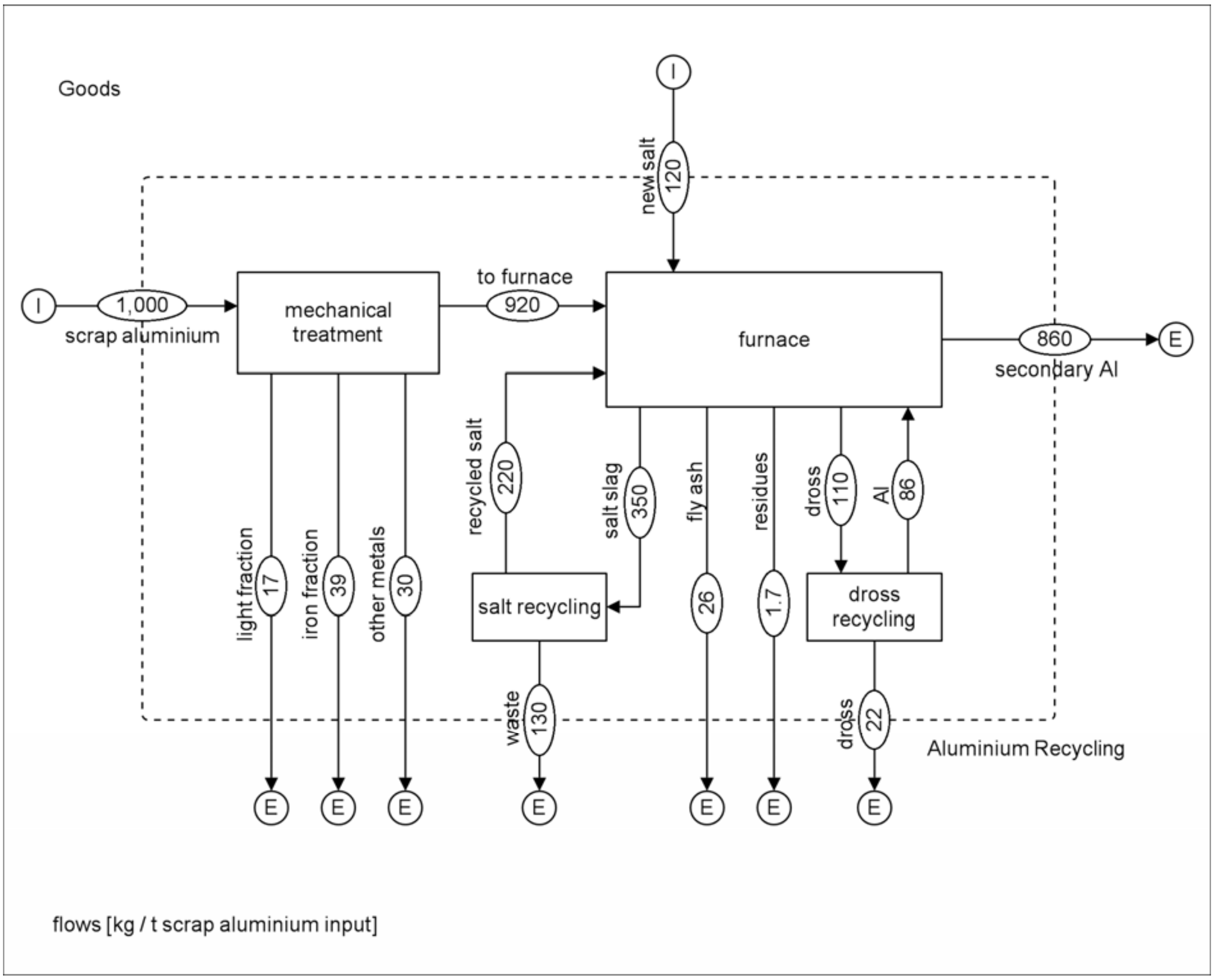


Figure 11: Mass flows of aluminium recycling.

Figure 11 shows a recycling plant for scrap aluminium without use of aluminium ore. In a first step of mechanical treatment around 8 % of the input mass is removed as waste. Salt is added to the furnace to protect the aluminium from oxidation and to fix impurities. Two recycling processes also take place to recycle salt and dross. From 1,000 kg scrap aluminium around 860 kg of secondary aluminium can be gained.

2.12 Recycling of Copper

Depending on the grade of contamination scrap copper is smelted in several steps to secondary copper of high purity (99.9 %). In the first step, so-called black copper is gained (purity 75 %). The following steps produce crude copper (95 % Cu), anode copper (99 % Cu), and finally cathode copper (99.9 % Cu; Daxbeck et al., 2006).

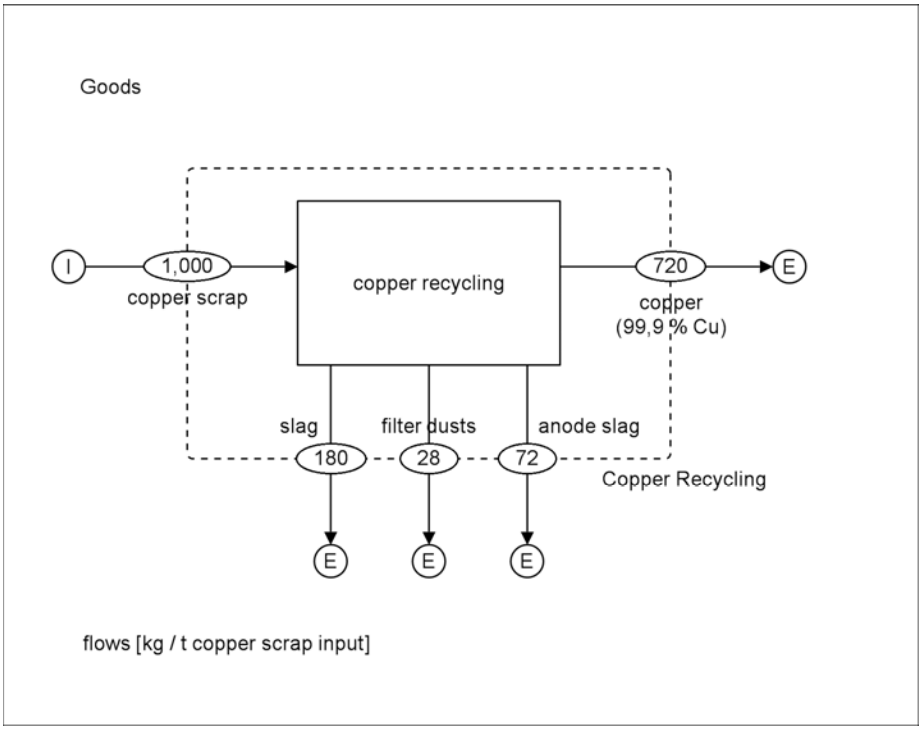


Figure 12: Mass flows of copper recycling.

Figure 12 shows that around 72 % of scrap copper input can be gained as secondary copper with the copper recycling process. Several residues derive from this process such as slag, filter dust, and anode slag. Furnace slag from the first step can be sold as a sand blasting agent after simple treatment.

3 INTERMEDIATE WASTE TREATMENT ACTIVITIES IN FORWAST

Waste treatment activities can be separated into intermediate waste treatment activities and final waste treatment activities. The columns of each of these groups of waste treatment activities is treated differently by the data miners: while for the intermediate activities the supply and use tables were disaggregated for each country by the data miners, the final waste treatment activities were left aggregated. They are later disaggregated by 2.0- LCA using country specific information and the modules presented in this document.

This chapter is based on a document provided to the data miners in order to help them in the disaggregation of the uses of the intermediate waste treatment activities. It shows the differences in fuel requirements of the virgin and recycled processes. And in most cases, it also provides some information which allows the calculation of the amount of primary materials saved thanks to recycling. The information presented here allows (in combination with the country specific information collected for disaggregating the supplies) to calculate the coefficients for the use table. These coefficients are entered in the matrix expander in the sheet “Coefficients U” into the corresponding orange cells.

These factors refer only to the use of materials directly used in the production processes. Because the FORWAST activities include all uses of the industry there will be some discrepancies. However, it is assumed that most of the inputs are related to the production processes, and therefore it is expected that these errors will be not important.

A complete description of the intermediate waste treatment activities should also include information on the supply of residuals of each activity. Since there is only very general information about that, it was decided to use in a first step the same data as for the virgin production and adjust these values in the course of model development. This is regarded as a good approximation, since the activities do not include the preceding steps, but only take the specific recycling activity into account. For example when comparing the generation of residues by the activities recycling of iron and virgin production of iron, only the processes of pig iron production and scrap recycling are considered. All mining waste produced in the mining of iron activities is considered in the mining process and is thus “added” to the virgin production of iron and not included in the production of recycled iron.

3.1 Copper recycling

The processes available in Ecoinvent were disaggregated according to deliverable 2-2 into following FORWAST categories:

- *Copper from mine*: Mining of copper ore, beneficiation of copper ore
- *Copper basic, virgin*: Copper at refinery – pre-treatment, copper at refinery - reduction
- *Recycling of copper basic*: Secondary refinery of copper.

Since the pyrometallurgical processes are more commonly used than hydrometallurgical processes, it was decided to consider the former in this document. The amount of fuel and electricity used for producing one kg of virgin and recycled copper are shown in Table 2.

Table 2: Uses for producing one kg of virgin and recycled copper.

Inputs	Unit	Uses	
		virgin	recycled
Electricity	kWh	0.49	1.10
Gas / oil	MJ	9.14	2.58
Coke - coal	MJ	0.03	6.52
Limestone / silica	kg	0.98	0.01

The amount of primary resources saved thanks to copper recycling was estimated. From Ecoinvent data it is known that for the production of 1 kg of virgin copper cathode 3.15 kg of copper concentrate are needed. For the production of 1 kg of recycled copper cathode 0.739 kg of copper scarp and 0.199 kg of copper alloy scrap are needed. Besides this, 0.14 kg of blister copper, which is produced by the copper mining industry, is further needed. This shows that copper recycling still needs inputs from the mining industry, however, much less then when virgin copper is produced. It can be seen that producing 1kg of recycled copper saves 3.01 kg of copper from the mining industry. Here again, as in the case for iron, this value needs to be transformed to copper ore, in order to get the FORWAST equivalent to material saved by the mining industry.

3.2 Iron recycling

The processes available in Ecoinvent were disaggregated following the description provided in deliverable 2-2:

- *Iron ores form mine*: mining of iron ore, sorting, beneficiation, pellet production, sinter production
- *Iron basic, virgin*: blast furnace reduction, pig iron production
- *Iron basic recycled*: iron secondary scrap
- *Iron after first processing*: electric steel furnace, basic oxygen furnace

It is assumed that the material coming out of the process „iron secondary scrap“ is then send to iron after first processing processes.

It was attempted to compare the uses of the processes „iron secondary scrap“ with the sum of the uses of the processes „blast furnace reduction“ and “pig iron”. This approach did not succeed, because Ecoinvent provided either very high or no electricity uses for the pig iron process.

Table 3: Uses for producing one kg of virgin and recycled steel.

Inputs	Unit	Uses	
		Virgin	Recycled
Electricity	kWh	0.02	0.38
Gas	MJ		0.88
Oxygen	g	62	46
Dolomite	g	2.4	50
Limestone	g	37	
Coal	g		13
Graphite electrodes	g		2.7

One alternative would have been to use the process “sinter iron” instead of pig iron, but since it is regarded to be part of the mining processes it was discarded. It is thus recommended to use data from the processes “Steel converter unalloyed and plant“ and „recycled steel“. This information is provided by Schmidt *et. al* (2005) and is shown in Table 3.

It was also attempted to obtain a figure for the amount of primary material saved due to recycling. For producing one kg of pig iron, it is necessary to have: 1.05 kg of sinter, 0.4 kg pellets and 0.15 kg of lump iron (Ecoinvent Report). These materials come from the mining industry and are not used when iron is made out of scrap iron. When considering the amount of primary iron saved by recycling 1 kg of scrap, it is seen that 1 kg of scrap saves 1.6 kg of the product coming from the iron mining industry. It must be noted however, that in FORWAST the product mined by the iron industry is iron ore, meaning that this 1.6 kg need to be transformed into ore in order to obtain the amount of ore mined that is saved.

3.3 Aluminium recycling

For the production of virgin Aluminum there are many processes described in Ecoinvent. Following process were considered: “Al hydroxide, at plant”, “Al oxide, at plant”, “Anode, Al electrolysis”, “Cathode, Al electrolysis”, “Al primary liquid, at plant” and “Al primary, at plant”. For obtaining the final values, the processes were combined using some weighting factors according to their use in the production of Al.
For Al recycling the processes “Aluminum scrap new, at plant” and “Aluminum, scrap old at plant” were available at Ecoinvent. The latter was considered and is shown in Table 4.

Other materials refers to metals (as alloying additives), non metals (Na, Cl), other minerals (lime) and chemical products nec. (acids, detergents).

The amount of Aluminum saved due to recycling was also calculated. For the production of 1 kg of virgin Aluminum 2.9376 kg of Aluminum hydroxide and 1.92 kg of Aluminum oxide are used. For the production of 1 kg Aluminum from scrap 1.2966 kg of scrap are needed.

Table 4: Uses for producing one kg of virgin and recycled aluminum

Inputs	Units	Uses	
		virgin	recycled
Electricity	kWh	15.70	0.35
Heat from oil	MJ	4.75	0.68
Heat from gas	MJ	2.02	9.32
Transport	tkm	4.53	0.73
Other materials	kg	0.13	0.11

3.4 Plastic recycling

Plastic recycling can be separated into two main groups: mechanical and chemical recycling. Chemical recycling separates the polymers into the constituting monomers. In Western Europe a range of processes is used to recover these monomers from different waste streams, using different chemicals and leading to different outputs (Joost, 2001).

Mechanical recycling shredders the plastic and melts it after that in a furnace to produce mixed plastics. Since this type of recycling is more commonly used, plastic recycling in FORWAST was modeled using only this method. In mechanical recycling the energy used is low, because the energy initially used to synthesis the polymer is conserved. It only involves reprocessing of previously processed materials and involves the use of additives to compensate for property loss during service and reprocessing (2).The specific processes encompassed in plastic recycling are: collection and sorting, cleaning, removal of unwanted materials, grinding, drying, melting, extruding and granulation (Joost, 2001).

According to the NACE Classification, the production of basic plastics considers the steamcracking process of feedstock (naphtha, gas oil, ethane or LPG) provided by the oil refining industry and the polymerisation of the products of steamcracking.

Streamcracking produces a large amount of products that have little commercial value and that are regarded therefore as fuels (Joost, 2001). This amount of fuel is substracted from the total fuel input to the industry in order to obtain the net use of fuels.

For the production of virgin plastics a weighted average for different plastic types - according to the proportion of each type of plastic produced - was calculated. The plastic types considered were: LPDE, LLDPE, LLDPE, HDPE, PP, PS, PVC, PET and two mixed categories one for other thermoplastics and the other for thermosets.

The processes involved were: the production of alkenes (steamcracking), the production of intermediates, the production of auxiliaries and the production of the polymers. Intermediate production refers to the further treatment of steamcracking products which cannot be used directly for the production of polymers (e.g. production of styrene). The production of additives was not considered due to lack of data. For the recycling of plastics, data from mechanical recycling was used.

Table 5: Uses for the production of 1 ton of virgin and recycled plastics.

Inputs	virgin production	recycled production
Electricity GJ	3.3	2.5
Steam GJ	4.8	-
Fuel use GJ	11.0	-

For estimating the savings of primary materials, some data was collected from Joost (2001). It was found that for the production of 1 t of ethylene 1.24 of feedstock coming from the oil refinery industry are needed. With respect to the material balance in the production of the polymers, it was found that 20 kg of ethylene are lost per ton of polyethylene produced. Finally, the input of auxiliary materials per ton of basic plastic produced was calculated. Auxiliary materials refers to chlorine, oxygen, nitric acid, ammonia, carbon monoxide, formaldehyde, methanol and hydrogen and in sum 0.31 t of these materials are needed for producing 1 ton of plastics.

With respect to recycled granulate it is estimated that 90% of the input plastic waste can be reprocessed as granulate and that the rest ends up as waste (Joost, 2001).

It must be mentioned that this approach does not take into account quality issues. Joost (2001) mentions that in mechanical recycling the quality of the regranulate is the main concern. Mechanical recycling of plastic waste in order to obtain a relatively high quality regranulate is only possible if the waste stream consist of one defined plastic type. This is the case with industrial plastic waste from the plastic industry (internal recycling). Also separately collected waste can be pure enough to obtain a regranulate of acceptable quality. However, even from this high quality regranulate there is a limited number of products which can be produced from this – good quality - regranulate. Regranulate from mixed plastic waste has a very low quality and can only be used for producing thick products like post and garden furniture. In this case it can be said that recycled plastics substitute mainly wood products.

3.5 Paper recycling

For paper production the Ecoinvent data was used. There is available information for sulphate and sulphite pulp production. Since 90 % of the chemical pulp produced is sulphate pulp, the first process was used.
The A non-integrated pulp mill consumes about 10 – 14 GJ of heat energy and 600 – 800 kWh of electricity per ton of produced pulp. But it also produces steam and electricity, which is the reason why a modern plant is energetically self-sufficient and has even a surplus that can be sold to other industries. The table shows an average of different values provided by Ecoinvent.

Table 6: Energy inputs and outputs when producing 1 kg of virgin sulphate pulp

Inputs		
Electricity	0.085	kWh/kg
Fossil fuels	1.64	MJ/kg
Biofuels	0.77	MJ/kg
Outputs		
Electricity	0.14	kWh/kg
Heat	0.675	MJ/kg
Biofuels	0.675	MJ/kg

For paper recycling there is a collection and sorting module and a paper recycling module in Ecoinvent. The energy used in both processes is shown in the following table. The diesel and oil inputs are found in the collection and sorting modules and include the transport of the waste paper to the plant. 99 % of the electricity and all heat are used in the recycling process.

Table 7: Inputs of energy and fuels per kg of recycled paper

Inputs of energy and fuels per kg of recycled paper		
Electricity	0.796	kWh
Heat	9.640	MJ
Diesel	0.750	g
Oil	0.428	g

Some information about the amount of raw materials saved thanks due to recycling was found. The production of 1 kg of sulphate pulp requires 1655 g of hardwood (moisture content 80%), 2217 g of softwood (moisture content 140 %) and 673 g of chips from saw mill (moisture content 70%).

Even thought the above mentioned information is enough for disaggregation of virgin and recycled pulp, it was not useful for disaggregating the use table in the countries where the pulp processes are integrated with the paper production processes. For these cases another source of information was sought. Jannick *et al.* (2007) used following values, which are recommended for disaggregation where the pulp and paper industries are together in one column in the SUTs.

Table 8: Uses for the production of 1 ton of virgin pulp, recycled pulp and paper.

		Virgin Pulp	Recycled pulp	Paper production
Heat	**MJ**	8682	182	5982
Electricity	**MJ**	4639	982	2473

3.6 Oil recycling

For recycling of waste oil there are different alternatives, for example re-refining into oil or reprocessing into fuels. It was not possible to find information about which is the most common process in Europe. Also the search for information about the involved processes, except on a narrative basis, was not successful. Rincon *et al.* (2005*)* explain that most modern recycling processes consist on the following sequence of operations:

- dehydration and light hydrocarbon removal by distillation at atmospheric pressure or light vacuum
- separation of waste oil from contaminant agents by high vacuum distillation
- finishing of the waste oil separated in the preceding step by hydrogenation.

Because of lack of further information it is suggested to use for oil recycling the same unitary values as for primary oil refining.

3.7 Wood recycling

Wood recycling in FORWAST considers the waste wood which is transformed into different types of boards. In FORWAST it was defined that wood recycling produces a material similar to the one produced by the forest products industry (FW code 7). In this way, the recycled wood replaces virgin wood. For the manufacture of the boards, it is therefore no difference if virgin or recycled wood is used as raw material.

It was not possible to gain information about the recycling process and compare it with the virgin wood production, for which there is available information at Ecoinvent. For wood recycling it is expected that the collection, crushing and sorting of wood would be necessary. These processes would have to be compared with the timber logging and chipping, which produce primary wood. It is expected that recycling processes vary depending on the origin and type of the waste wood recycled, the distance to the recycling facility, means of transport, the product produced (size of the chips) as well as the specific technology of the equipment. Since no plant specific data was found, it is suggested to use the same unitary values as for primary forest products. This would imply that the transport of wood from the forest to the chip facility is equivalent to the transport of the waste wood to the recycling facility and also that chipping of primary wood is comparable to chipping of waste wood.

3.8 Glass recycling

For glass recycling, the production and recycling of container glass were used as basis for the comparison. There are two main reasons for this: the first is that 60 % of the glass produced in the EU is container glass; the second is that cullets can be successfully used in container glass production (BAT document).

The problem encountered during literature search for this process is that glass recycling involves the use of primary raw materials besides the waste glass. Also, it was found that most virgin glass production industries reuse their own internal culets. This makes it difficult to separate clearly both processes. The proportion of cullets used depends on many factors, on average (German and Swiss data) they are: 58 5 % for white glass, 80 % for green glass and 53.1 % for brown glass (Ecoinvent). These figures consider internal and external cullets.

With respect to energy savings some information was found (CWC). Studies that show that every 10% increase in the amount of cullet used reduces melting energy by about 2, 5 % are mentioned. Preheating the cullet with the furnace exhaust allows a further reduction in the melting energy. The exact amount of energy saved depends on the proportion of cullet and the preheat temperature used. With some special preheating systems the furnace energy can be reduced by up to 12 % for cullet contents of 50 % or higher. On the other hand a higher proportion of cullets implies a larger effort in waste glass collection and sorting.

For the FORWAST project it was necessary to get information for the production glass made 100 % from virgin materials and recycled glass made 100 % of waste glass. This information was found in Schmidt *et al.* (2005).

Table 9: Use of electricity and fuel for producing 1 kg of virgin and recycled glass.

Input		Virgin glass	Recycled glass
Electricity	kWh	0.298	0.231
Natural gas	MJ	3.57	3.37
Fuel oil	MJ	4.44	3.44

With respect to the saving of raw materials thanks to recycling, the IPCC BAT report states that 1 ton of cullet replaces approximately 1.2 ton of raw materials. Schmidt *et al.* (2005) used following figures, which are recommended for the FORWAST disaggregation.

Table 10: Use of materials for producing 1 kg of virgin and recycled glass.

Input		Virgin glass	Recycled glass
Cullets	kg	-	1.01
Soda	kg	0.168	-
Limestone	kg	0.088	-
Sand	kg	0.633	-
Dolomite	kg	0.122	-
Feldspar	kg	0.032	-

3.9 Ash and slag recycling in the cement industry

The main component of Portland cement is clinker. Because the production of this clinker is the process consuming most energy in the cement industry, there was a good incentive for creating alternative cement types. The idea was to add limestone and other cement like materials (e.g. fly ash, slag, gypsum or other pozzolanic[1] materials), that do no require the large energy inputs associated with pyroprocessing (part of the clinker production).

In Europe there is a common standard for 25 types of cement; one summarised classification is shown in the table below. As mentioned before, producing alternative cement types is far less energy intensive and allows in this way for a reduction in CO2 emissions in the calcination process besides the CO2 avoided due to the reduced fuel requirements (Worrel 2004). It must be noted, however, that there are other possibilities for substituting clinker, which are not considered in the next paragraphs. One of these possibilities consist, for example, in using the pozzolanic materials directly for road bases. In this case, they would substitute cement and concrete. Another alternative is to use the clinker substitutes directly in the concrete production (mostly seen in China and in the US). In this case the production of cement is not changed, but there is still substitution of clinker in other steps not taken into account in this document (Talyor *et al*.).

1 Pozolanic materials: materials that can be added to cement to extend its volume without a significant loss of properties (Choate 2003)

Table 11: Types of cement. Source Ecoinvent, main cement types under SIA Standard 215.002

Type of cement	Proportion of clinker (% weight)	Feedstock other than clinker
Portland cement	95-100	
Portland composite cement	65-94	Limestone, granulated blast, furnace slag, silica sand (max 10%), pozzolan, flue ash or burned slate
Blast furnace slag cement	5-64	Granulated blast furnace slag
Pozzolanic cement	45-89	Pozzolan, flue ash
Composite cement	20-64	Granulated blast furnace slag and pozzoland and/or flue ash

It has been established, that fly ash can be substituted for 15-35 % of cement in concrete mixtures. Because these additions change the performance of the concrete, the type of concrete used varies according to the structure considered. For some applications fly ash content can be up to 70 %. It must be noted, however, that fly ash can contain elements (e.g. carbon), compounds (e.g. ammonia) and other constituents that might have negative effects on the performance of concrete (Choate, 2003).

Following Ecoinvent processes were considered: “Portland cement, strength class Z 52.5” for the virgin process and “Blast furnace slag cement, at plant” for the recycling process.

Table 12: Uses for the production of 1 kg of virgin and recycled cement.

Input	Unit	Slag Cement	Portland cement
Electricity	kWh	0.10497	0.10140
Natural gas	MJ	0.00313	0.00621
Coal	kg	0.01628	0.03228
Fuel oil	MJ	0.57908	0.94388
Coke	kg	0.00180	0.00357
Secondary fuels	MJ	0.56252	1.11526

For estimating the amount of raw materials saved thank to recycling, the same Ecoinvent processes used for calculating the recycling factors for fuel and electricity were used. The production of 1 kg of blast furnace slag cement requires 0.46 kg of clinker. For producing this, the amounts of used mineral raw materials (bauxite, lime, limestone, calcareous marl, sand and clay) were added, resulting in 0.76 kg. For the production of 1 kg of Portland cement 0.912 kg of clinker are needed. For producing this, in turn, 1.51 kg of mineral raw materials are needed. This shows that the recycling of 1 kg of slags and ashes saves 0.75 kg of mineral raw materials.

3.10 Concrete recycling

Concrete is produced by mixing cement with water, fine aggregate (e.g. sand) and coarse aggregate (e.g. gravel or crushed stone). Small amounts of chemicals (called admixtures) are frequently added to the concrete mix to control setting time and plasticity (Choate). A typical concrete mix is by volume about 10-15% cement, 15-20 % water and 60-75 % aggregates. A typical concrete mix is shown in Table 13.

Table 13: Typical concrete mix. Source Choate (2003)

Typical concrete mix	
Component	**Weight (%)**
Portland cement	12
Sand	34
Crushed stone	48
Water	6

Concrete recycling refers to the use of waste building materials as aggregates instead of virgin ones. These processes could be considered in different ways in the FORWAST project. It was decided to include this process as concrete recycling instead of sand, gravel and stone recycling. Because of this, the production of concrete (virgin process) was compared to the production of concrete plus the crushing of the building material.

Using Ecoinvent it was possible to calculate the energy input into these processes. For doing this, an assumption about the density of concrete was required. Since there are different types of concrete, the value representative for most concrete used in Switzerland was used: 310 kg/m3. For the recycled concrete it was assumed that 100 % of the aggregate used was recycled aggregate. As can be seen in the table, the only difference occurs on the use of electricity, which increases due to the electricity used for crushing and sorting the material.

Table 14: Uses for producing 1 kg of virgin and recycled concrete.

Inputs	Unit	Uses	
		Virgin aggregates	Recycled aggregates
Diesel	MJ	0.0732	0.0732
Electricity	kWh	0.0141	0.0202
Natural gas	MJ	0.0037	0.0037
Fuel oil	MJ	0.0529	0.0529

Although for the FORWAST recycling process a 100 % substitution of virgin aggregates was assumed, the amount of substitution is actually very variable. There are a number of studies being conducted to learn how and to which extent recycled aggregate affects the mechanical properties of concrete. Etxeberria *et al.* (2007), for example, found that that a substitution of less than 25 % of coarse aggregate by recycled aggregate scarcely affects the shear capacity of beams if some compensations in dosage are carried out (such as increasing the amount of cement or decreasing the water/cement ratio). Khatib (2004) replaced fine aggregate in concrete with 0%, 25%, 50% and 100% crushed concrete and bricks. He found that there is generally a strength reduction of 15-30 % for concrete that contained crushed concrete, but that concrete with up to 50% of crushed bricks, shows a similar strength in the long term than the control. This suggests that the proportion of aggregate that can be replaced depends on one hand, on the specific recycled aggregated that are being used and on the other hand, on the uses of the concrete produced. For some applications a reduction in strength might be acceptable, while for others only virgin aggregates might be used.

4 WASTE MANAGEMENT MODULES IN FORWAST

The waste management modules were constructed in close collaboration with the developers of the model in order to assure the compatibility of the modules with the rest of the model.

The waste treatment modules are introduced into the model once the “master tables” is available. These tables are composed of the consolidated matrices with the summed physical and monetary values (of inputs, outputs, emissions…) for all EU-27 countries. This means that there is the need to construct some average EU-27 waste modules.

All modules have the same structure. They consist of:

Monetary and physical supply and use tables (SUTs). Since the data for waste treatment inputs and outputs is available mostly in physical units, it was decided to collect the physical data and then transform them into monetary values using average EU-27 prices. Because there is no physical information on services, it was decided to take the same amount of money per unit of treated waste, than in Denmark. This monetary value was adapted to the EU-27 average price using a conversion factor which reflects the relationship between the Danish prices and the average EU-27 prices.

Data about emissions (B-matrix) and the distribution of these emissions into emissions originating directly from the waste (Gw) or coming out of products used during the waste treatment processes (Gc).

- Data about the supply of waste of these activities (Wv).
- All modules are constructed per ton of treated dry waste.

The modules were built up progressively: in a first step the waste specific inputs and outputs had to be recognised. Then the process specific, but not waste specific inputs and outputs were included. In a last step all inputs and outputs not directly related to the process (e.g. administration) were added. This means, that the results of the waste modules include all inputs and outputs into/out of the respective industries and not only those directly related to waste treatment.

According to deliverable 2-2, modules for following waste treatment activities have to be constructed: waste incineration, landfilling, composting, biogasification, manure treatment, land application of waste. Additionally, a module for waste water treatment had to be provided, since it is also included as a waste treatment activity in FORWAST.

4.1 Incineration Module

4.1.1 Introduction

Incineration is the controlled combustion of typically unprepared (raw or residual) MSW. Controlled in this manner means that heating value and oxygen supply is monitored, gaseous and liquid residuals are cleaned until they meet the requirements as set by the policy maker and the solid residuals are disposed in a controlled and safe manner.

Common incinerated waste types are (among others): MSW, hazardous wastes, sewage sludge. The property and thus type of waste to be incinerated also influences the waste incineration technology. The BAT document of the European Commission (2006) states the most established technologies for incineration as grate incinerators, rotary kilns, fluidized beds, pyrolysis and gasification systems. Depending on the process and the input material (waste quality), outputs with different qualities appears.

In Figure 13 the mass flow of goods – related to 1,000 kg of MSW-Input – is shown.

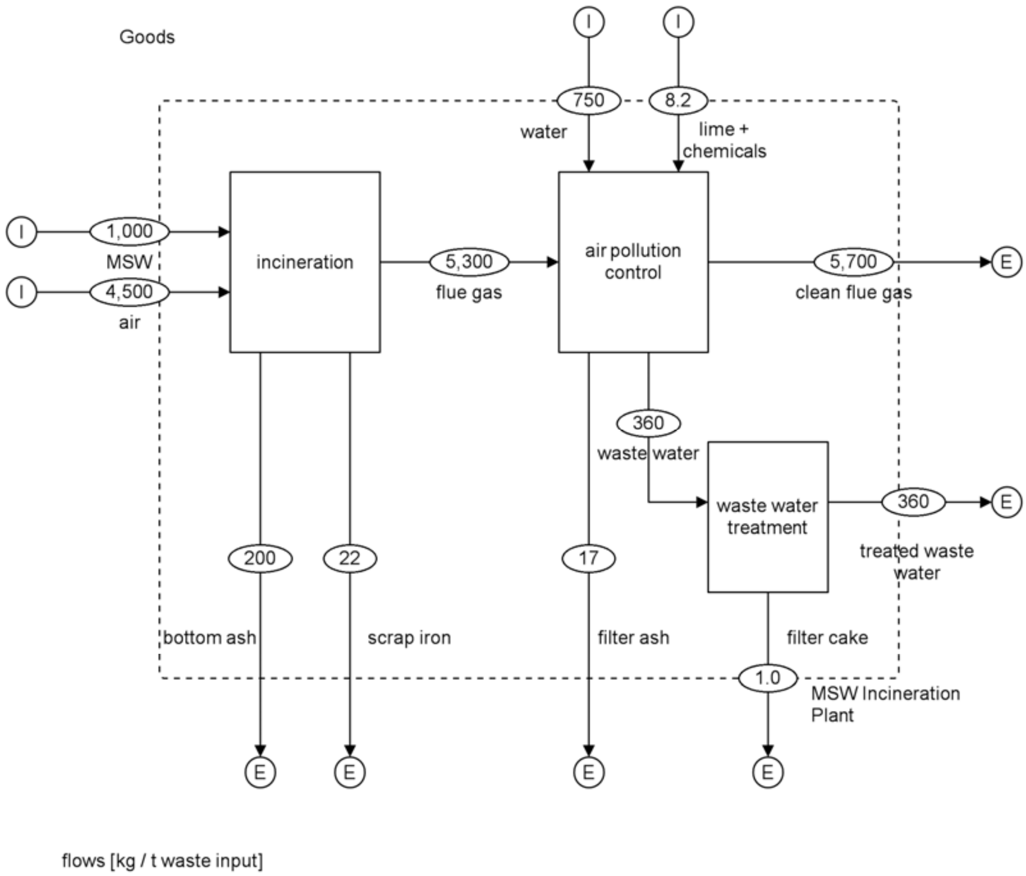


Figure 13: Mass flows for a MSW incineration plant

Mass data derive from mass balance of 2006 of the Incineration Plant Spittelau in Vienna, Austria (Wien Energie, 2007), and transfer coefficients were extracted from a material flow analysis at the Incineration Plant Spittelau (Morf, 2008).
Apparently, a MSW Incineration Plant consists of three main processes: the incineration itself, the air pollution control, and the waste water treatment. In this example (MSW, grate incineration) , around one fifth of the MSW input turns into bottom ash and around four percent leaves the plant as scrap iron, filter ash, and filter cake.

4.1.2 Scope of the Module

In this module, incineration was simulated according to the most common used technology for MSW, namely grate incineration, which represents 90 % of MSW incineration in Europe (Doka 2003; European Commission 2006). Therefore, the Spittelau, one of Vienna's MSW incinerators, is used, as the data for the material and substance flow analysis also refers to this plant. Built in 1971, Spittelau is not a new plant in Europe, but the process steps have not changed for grate incinerators, and important parts, like the flue-gas or waste water cleaning where installed later. To cope with the requirements of best available technique (BAT), the description will in case refer to the newer MSW grate incinerator in Wels (Austria) (Stubenvoll et al. 2002). Both plants are stated as examples in the BAT document on waste incineration of the European Commission (2006). Finally, emission values will be compared with BAT requirements as stated in European Commission (2006).

Mixed MSW is delivered by the waste collection vehicles and disposed in the waste bunker. The MSW has an average lower heating value of 8,822 (kJ/kg MSW), which lies in the European range of 7-15 (kJ/kg MSW) (European Commission 2006:8). From there, it is sent to the incineration chamber by a waste crane. The combustion takes place on the grate, which is moving so that the slag can drop to the deslagger. By removing the slag, iron scrap is removed to, depending on the feeding material between 10 and 25 (kg/t MSW) (Stubenvoll et al. 2002).

To start the incineration process, natural gas is added, about 20 (m^3/t MSW) at the Spittelau and 4.5 (m^3/t MSW) at the newer plant in Wels. However, the heating value also differs in both plants (Stubenvoll et al. 2002). The temperature in the chamber is about 850°C. This heat is converted to electricity and heat (steam) through the steam boiler. The plant can be designed to produce more heat (as in Spittelau) and less electricity or the other way round (as in Wels). The flue gas from the process is then sent to the flue gas cleaning, which contains usually of a multiple-step process design: removal of dust and non-volatile metals; removal of HCl, HF, SO_2 and Hg; removal of NO_X. Additionally secondary treatment of flue gas can be installed, as well as measurements for primary measures.

Dust removal can be obtained by an electrostatic precipitator (EP), filters or fine wet scrubbing (Stubenvoll et al. 2002; European Commission 2006). For instance, all MSW incinerators in Austria use EP. After dust removal, HCl, HF, SO_2 and Hg are removed, either in dry, semi-wet or wet systems (European Commission 2006:107). In Austria, most grate-incinerating MSW plants are using wet systems, except Wels, which applies wet-scrubber and activated coal filtering (Stubenvoll et al. 2002). NO_X is removed through catalytic and non-catalytic processes. All of the Austrian MSW incinerators are using catalytic NO_X removal. With these flue-gas treatment systems, the standards can be usually met easily (Stubenvoll et al. 2002). This system refers also to the requirements as suggested by the European Commission (2006:436ff).

Waste water usually derives from the wet scrubbers and the slag and ash treatment. Therein, sulphur compounds are usually the most important matter of concern, but also heavy metals. Thus, sedimentation, ph-neutralisation, precipitation, flocculation, flotation or filtering is used. For instance, the plant in Wels has a system of combined neutralisation-precipitation-flocculation-sedimentation-sludge dewatering and subsequent filtering (Stubenvoll et al. 2002). The system at Spittelau is somewhat different, using lime milk (for dissolved heavy metals bounding) and precipitation / flocculation agents. Separation is done by a laminar clarifier, the sludge is subsequently dewatered. Gypsum is settles after adding lime milk (Stubenvoll et al. 2002). Both systems are best available technique as defined by the European Commission (2006).

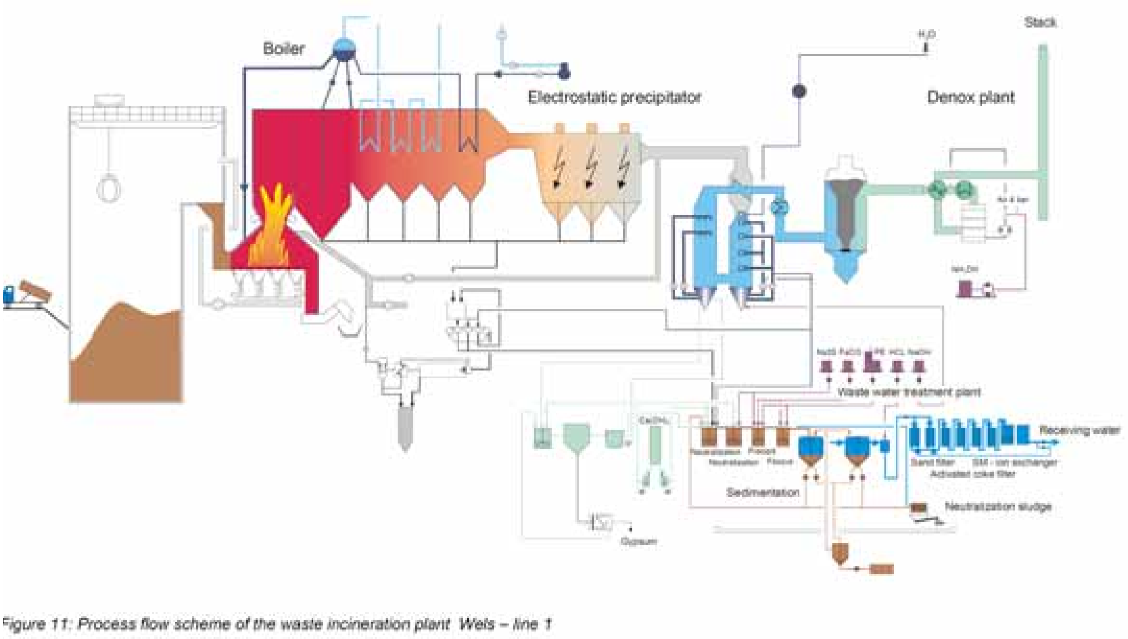


Figure 14: Scheme MSW Incinerator Wels (Stubenvoll et al. 2002)

Beside mixed waste, the inputs into the system are energy (electricity) and materials, such as natural gas to start-up the firing, fresh water, lime, sodium hydroxide, ammonia, in waste and precipitation agents in waste water cleaning (for Spittelau). The plant in Wels additionally consumes coke and some other chemical agents (Stubenvoll et al. 2002).

The outputs are energy (electricity, heat, steam), recyclables (iron, metals), solid residues (slag, ash, gypsum, filter and filter cake), air emissions and water emissions. While iron scrap can be recycled, ash and filter cake has to be landfilled in a safe underground landfill. For slag and ashes, recycling in building industry is generally possible, but due to the high heavy metal concentration particularly in the slag potentially problematic (European Commission 2006).

4.1.3 Elemental Composition Input Materials and Data Sources

Material and elemental composition of input waste widely differ among EU member countries, but also among regions within these countries. A literature search was conducted in order to find data for different technologies (Doka (2002), Hellweg (2000), Morf (1998), Riber et al. (2008), Doka (2003)). Finally, the data from Doka (2003:80) was used, but crosschecked with the data from other sources. Due to consistency, the same input data is used for all waste treatment processes (see Annex). The data is presented by Doka (2003) as 1) the composition of mixed waste by waste fractions (food, paper, plastics, cardboard, minerals, plastic coated paper, metals, glass, diapers, tetrapack, textiles, wood, other biomass, hazardous waste, bones) and 2) the elemental composition of each fraction. Base on this, the elemental input into the MSW incinerator was calculated.

4.1.4 Transfer coefficients

Elemental transfer coefficients were calculated after Doka (2003:30) and crosschecked with values from Morf (1998). Data from the first source refers to Swiss technology mix, but it is expected that it can be used as a good proxy for modern waste incineration.

The transfer coefficients were considered for all burnable wastes (paper and cardboard, plastics, food, wood, other biomass and textiles). For glass it was assumed that there are no waste related emissions, while emissions of Si, Ca, Al for mineral and Cu, Pb, Sn, Zn, Fe, Al, Mg for metal fraction are considered.

Based on these transfer coefficients, the amount of each element in the residuals (bottom slag from process incineration; boiler and filter ash from process air pollution control; scrubber sludge from process waste water treatment) and emissions (water emissions from process waste water treatment, air emissions from process air pollution control) was calculated. Finally, a balance for all outputs was calculated and crosschecked with the inputs. Values not in balance where crosschecked again (see ANNEX 7.1).

4.1.5 Materials and Energy Consumption and Production

The number and amount of materials and energy consumed in incineration was calculated due to data from the waste incineration plant Spittelau in Vienna, Austria (Wien Energie Fernwärme

undated; (Stubenvoll et al. 2002) and crosschecked with values from Doka (2003). The inputs are shown in table Table 15: Not-MSW inputs into the module MSW incineration
(additionally, see). Subsequently, inputs were disaggregated to each waste fraction. Note that for the NaOH and NH3 solutions the concentration (30 and 25% respectively) was considered in the calculation.
For the generation of energy, the lower heating value of each fraction was considered to, based on estimation from the Dulong's model.

Table 15: Not-MSW inputs into the module MSW incineration

Input type	Unit	Process and description
natural gas	kg/kg MSW	Natural gas for incineration
electricity	kWh/kg MSW	Electricity to maintain the process (e.g. for flue gas cleaning)
heat	kWh/kg MSW	For preheating of waste
CaCO3	kg/kg MSW	Air pollution control – SO_2 removal, Waste water treatment
NaOH solution (30%)	kg/kg MSW	Air pollution control – SO_2 removal
NH3 solution (25%)	kg/kg MSW	Air pollution control – NO_X removal
precipitation agents	kg/kg MSW	Waste water treatment

For outputs, data from Wien Energie Fernwärme (undated:15) and Stubenvoll et al. (2002:69) was used (see ANNEX 7.1). The amount of gypsum produces was taken from values for the grate incinerator in Wels (Stubenvoll et al. 2002:76).

Table 16: Not-MSW outputs from the module MSW incineration

Output type	Unit	Process and description
refined petroleum products and heat	kg/kg MSW	none
gypsum	kg/kg MSW	From waste water cleaning
electricity	kWh/kg MSW	From electricity production of the combined heat power plant
heat	kWh/kg MSW	From heat production of the combined heat power plant

Beside that, iron scrap is an important output to be considered. However, as the continuing LCA model considers outputs on elementary level, iron scrap output is expressed on elemental level in output the of slag.

4.1.6 Emissions

Three types of emissions can be distinguished. The first are inorganic elements which enter the incinerator as part of MSW, like heavy metals and they are calculated as shown in chapter 4.1.4 Transfer coefficients.

The second type is produced through the processes in the plant, mainly the combustion itself. These are mainly compounds of nitrogen, carbon and sulphur. Values are taken from Forwast deliverable 2-2 (Daxbeck et al. 2008) and Stubenvoll et al. (2002).

The third type is associated to the various material inputs which are used to run and maintain the incineration processes. Therein, the use of natural gas is considered. The values are taken from Forwast deliverable 2-2 (Daxbeck et al. 2008) (see also annex 7.1).

Table 17: Emission values for MSW incineration (Stubenvoll et al. 2002; Daxbeck et al. 2008)

Emission type	Type 2 in (kg/kg MSW)	Type 3 in (kg/kg MSW)
Emission source	From MSW Incineration[2]	Associated to material inputs[3]
Carbon Dioxie (CO2)	1.47	5.50E-02
Carbon monoxide (CO)	1.32E-04	5.00E-06
Methane (CH4)	nd	2.00E-06
Nitrogen Oxide (NO_X)	1.15E-04	4.10E-05
Dinitrogen Oxides (N2O)	nd	1.00E-06
Ammonia	3.50E-06	0.00E+00
NMVOC	nd	0.00E+00
PM	4.00E-06	0.00E+00
SO2	1.05E-05	1.00E-06

Table 18: Emission values for different fuels (from Daxbeck et al. 2008)

Emission Factor[1]

Gas Type	Unit	Fuel Derived Emission			
		Natural Gas	Diesel Oils	Landfill Gas	Remark
Carbon Dioxie (CO_2)	kg	5.50E-02	1.34E+02	5.45E-02	
Carbon monoxide (CO)	kg	5.00E-06	4.89E-01	5.00E-06	
Methane (CH_4)	kg	2.00E-06	6.89E-03	2.00E-06	
Nitrogen Oxide (NO_X)	kg	4.10E-05	1.89E+00	4.10E-05	
Dinitrogen Oxides (N_2O)	kg	1.00E-06	5.15E-03	1.00E-06	
Ammonia	kg	0.00E+00	8.58E-04	0.00E+00	
NMVOC	kg	0.00E+00	2.22E-01	0.00E+00	
PM	kg	0.00E+00	0.00E+00	0.00E+00	
SO2	kg	1.00E-06	4.34E-02	1.00E-06	

[1]FORWAST Deliverable 2-2

Net Calorific Value[1]

Fuel Type	Unit	Net Ccalorific	Remark
Natural Gas	MJ kg^{-1}	48.00	
Diesel Oils	MJ kg^{-1}	42.70	
Crude Oils	MJ kg^{-1}	42.30	
Lubricating Oils	MJ kg^{-1}	40.20	
Waste Oils	MJ kg^{-1}	40.20	
Landfill Gas	MJ kg^{-1}	50.40	

[2] Stubenvoll et al. 2002:70; average values, half-hourly measured

[3] Daxbeck et al. 2008

4.1.7 Best available technique

In waste incineration, the main focus of BAT lies on 1) emission levels and 2) energy efficiency. The emission levels as selected to calculate the emissions in this module are based on data from Stubenvoll et al. (2002) for the waste incinerator Spittelau in Vienna.

Table 19: Comparison air emission values from reference plant Spittelau with suggested emission values in BAT

	Spittelau min values	Spittelau average values	Spittelau max values	BAT min values	BAT max values
Unit	mg/Nm³	mg/Nm³	mg/Nm³	mg/Nm³	mg/Nm³
Source	Stubenvoll et al. 2002:70			European Commission 2006:440	
Carbon Dioxie (CO2)	nd	nd	nd	nd	nd
Carbon monoxide (CO)	1.4	26.3	91.2	5	100
Methane (CH4)	nd	nd	nd	nd	nd
Nitrogen Oxide (NO_X)	nd	22.9	92.8	40	300
Dinitrogen Oxides (N2O)	nd	nd	nd	nd	nd
Ammonia	nd	0.7		1	10
NMVOC	nd	nd	nd	nd	nd
PM	nd	0.8	12.6	1	20
SO2	nd	2.1	16.4	1	150

Table 18 shows the air emission values of the reference MSW incinerator Spittelau with BAT-suggested standards. Both, the selected values for calculation (column “Spittelau average values”) and the maximum values from the plant are lower than the maximum BAT-values. This can partially be explained through the high standards achieved in Spittelau, which is also manifested through its denomination in the BAT document as example (European Commission 2006:536ff.).

The second focus lies on energy efficiency. In waste incineration, energy can be transferred either into heat or electricity. The share between both is determined by the local situation. For instance, if there is a district heating network (as in Vienna) available, more heat rather than electricity should be produced (cp. European Commission 2006:281ff;438). For plants like Spittelau, the Commission claims a heat generation of 3 (MWh/tonne MSW) (European Commission 2006:451). This can not be achieved by this plant, which exports only 1.9 (MWh/tonne MSW). However, if considered that Spittelau also produces electricity (0.07 MWh/tonne MSW) and that the heating value of the MSW in Vienna is far below the assumption in the BAT document (9 MJ/kg MSW compared to 15 MJ/kg MSW), this requirement can be fulfilled by the plant.

Table 20: Comparison average air emission values from reference plant Spittelau with suggested maximum average emission values in BAT and maximum values EU-directive (European Parliament and European Council 2000)

	Spittelau average values	BAT max values	Directive max values
Unit	mg/Nm³	mg/Nm³	mg/Nm³
Carbon Dioxie (CO2)	nd	nd	nd
Carbon monoxide (CO)	26	100	100
Methane (CH4)	nd	nd	nd
Nitrogen Oxide (NO_X)	23	300	400
Dinitrogen Oxides (N2O)	nd	nd	nd
Ammonia	1	10	N
NMVOC	nd	nd	nd
PM	1	20	30
SO2	2	150	200

Table 21: Comparison average air emission values from reference plant Spittelau with suggested maximum average emission values in BAT and maximum values EU-directive (European Parliament and European Council 2000) in (mg/kg waste input)

	Spittelau average values	BAT max values	Directive max values
Unit	mg/kg waste	mg/kg waste	mg/kg waste
Carbon Dioxie (CO2)	nd	nd	nd
Carbon monoxide (CO)	1.32E-04	5.00E-04	5.00E-04
Methane (CH4)	nd	nd	nd
Nitrogen Oxide (NO_X)	1.15E-04	1.50E-03	2.00E-03
Dinitrogen Oxides (N2O)	nd	nd	nd
Ammonia	3.50E-06	5.00E-05	nd
NMVOC	nd	nd	nd
PM	4.00E-06	1.00E-04	1.50E-04
SO2	1.05E-05	7.50E-04	1.00E-03

4.2 Landfilling module

4.2.1 Introduction

Landfilling represents not only the oldest but also the most applied waste disposal method world-wide (El-Fadel et al., 1997). Even within the EU -27 almost 42% of the municipal waste generated has been landfilled in 2007. In some member states (e.g. Bulgaria) this share reached even almost 100% (Eurostat, 2009).

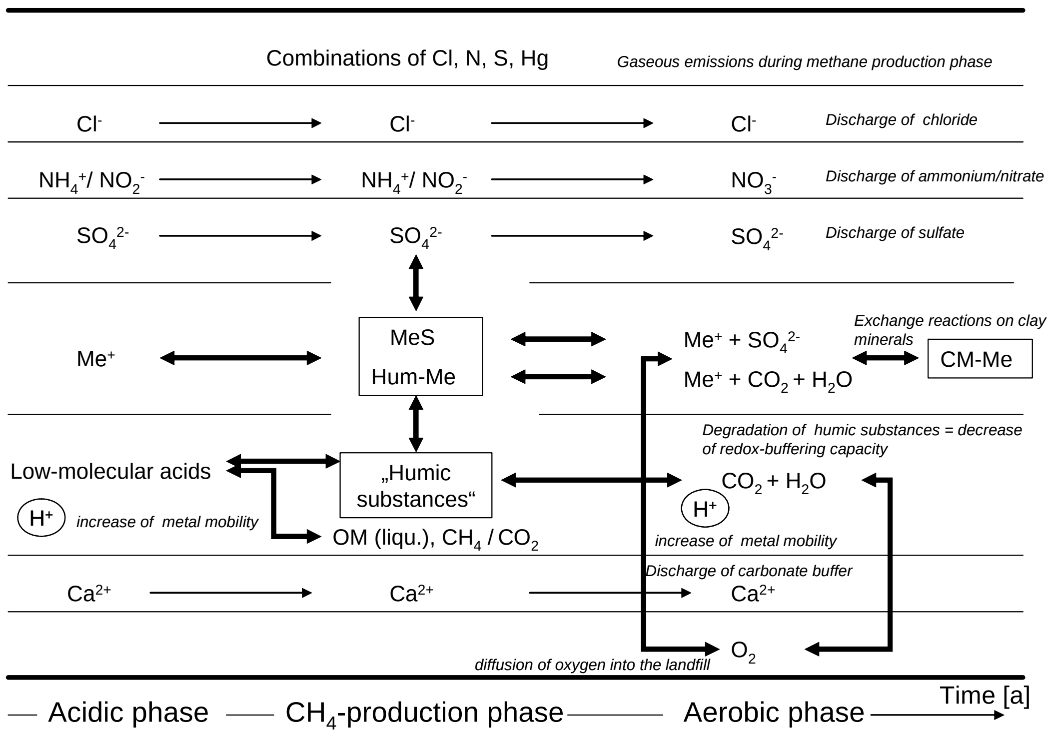
Beside a large variation in the share of landfilling within the EU, also the standards regarding landfilling differ largely. Although the EU landfill directive (1999/31/EC), which was released in 1999, requests stringent technical conditions for waste and landfills in order to minimize negative impacts on the environment, its implementation into practice is insufficient in many member states. Thus, current landfilling practice within the EU varies between open dumping (e.g., Romania) and sanitary landfilling, with sophisticated emission control measures.

The metabolism of landfills and thus their emissions are mainly determined by the composition of the waste disposed. For instance landfills for organic waste and landfills for inorganic waste showed distinctly different emissions characteristics (see Figure 15: Reaction and emission scheme for landfills containing organic wastes (e.g., municipal solid waste) (Source: Döberl et al., 2002 and Figure 16.

The metabolism of organic waste landfills is controlled by the biochemical degradation of organic matter that results in the production of biogas (CH_4 and CO_2) and organically polluted leachate. In addition, the elution of soluble salts and ammonium represent major substance release processes (see Figure 15: Reaction and emission scheme for landfills containing organic wastes (e.g., municipal solid waste) (Source: Döberl et al., 2002). The environmental impacts originating from organic waste landfills are mainly caused by landfill gas and leachate.

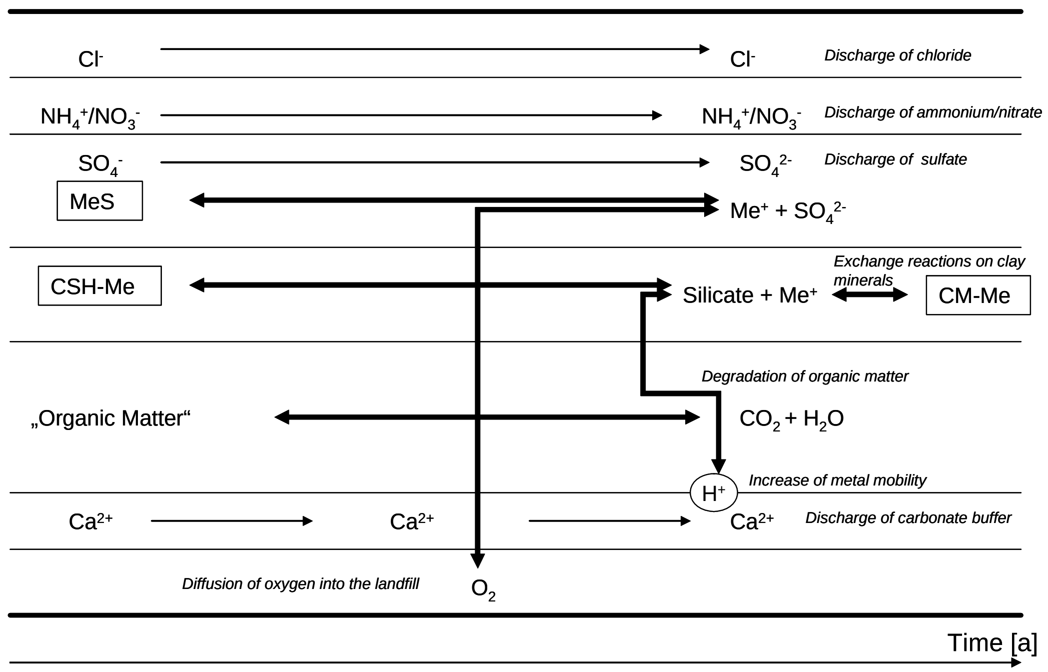
The emissions of inorganic waste landfills are mainly determined by the discharge of soluble substances, transformation of mineral phases and geochemical reactions (see Figure 16)

The reactions of the main waste components (in the case of bottom ashes from waste incineration they include calcium silicates and carbonate) determine the physical and chemical conditions (redox-potential and pH value), which again influence the release of some substances (e.g., heavy metals).



(Double arrow: chemical reactions; Single arrow: other processes; Me: metals; Hum: humic substances; CM: clay minerals; OM: organic matter; Boxes: solids)

Figure 15: Reaction and emission scheme for landfills containing organic wastes (e.g., municipal solid waste) (Source: Döberl et al., 2002



(Double arrow: chemical reactions; Single arrow: other processes; Me: metals; CM: clay minerals; OM: organic matter; Boxes: solids)

Figure 16: Reaction and emission scheme for landfills containing inorganic waste (bottom ash from waste incineration) (Source: Döberl et al., 2002)

In addition to the composition of the waste, the climatic and geological conditions at the landfill site, as well as the operation status (closed, capped) strongly influence the emission behaviour of landfills. In general emissions form landfills occur over an extended period of time with varying rates of pollutant release, which makes landfills and in particular the consideration of their emissions in life cycle assessments a complex issue (Laner, 2009), since their long term emission behaviour has to be predicted.

4.2.2 Scope of Module

The scope of this module is to describe the behaviour and associated emissions of landfills in the EU-27, considering specific wastes. The problem of constructing an average landfill module for the EU is more critical in comparison to other waste modules, since as mentioned above not only the landfill technology shows large differences between the members states but also the climatic conditions, which strongly influence landfill emissions. And even though there is a EU directive on landfilling (European Parliament, 1999), no EU-wide best available technique (BAT) on landfilling is provided, except by national agencies (cp. Environment Protection Agency 2003). Nevertheless the attempt was made to characterize the average situation of landfilling within the EU.

Beside waste related emissions (landfill gas and leachate) also emissions associated with the operation of a landfill haven been considered. In particular landfilling of 14 types of wastes have been evaluated, namely f*ood waste, paper, plastics, cardboard, minerals, plastic coated paper, metals, glass, diapers, tetra pack, textiles, wood, other biomass and bones*. The composition of the different waste types was derived from Doka (2003) and is summarized in Table 22: Composition of different waste fraction and their degradability in *landfills*.

The emissions required for the FORWAST model were obtained by combining transfer coefficients of substances or information about the degradability with the waste composition. The transfer coefficients used are preliminary based on data of Ecovinet (Doka, 2003) and a study of Technical University of Vienna on long term emissions of landfills (BEWEND, Brunner et al., 2001). The fact that landfill emissions occur over a long time period, was accounted for by considering the cumulative emission during the first 100 years after waste disposal.

An illustration of the landfill module is given in Figure 5. It shows the processes *Landfill*, *Landfill gas collection & treatment*, and *Waste Water Treatment*, whereby the latter is not considered within the landfill module. Treatment of the leachate will be accounted for by the waste water module.

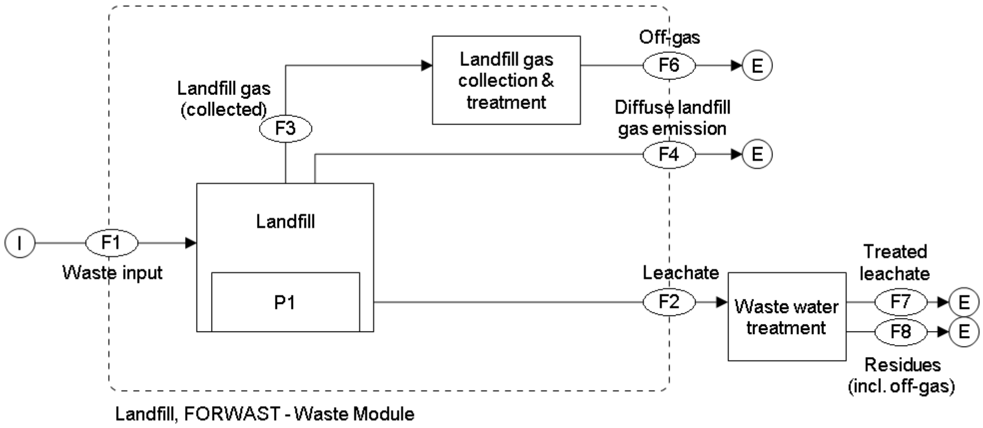


Figure 17: Landfill module for the FORWAST model

4.2.3 Composition of the waste input

As mentioned above the composition of the different waste types was largely derived from Doka (2003). In addition to the composition also information about the degradability of the different waste types was obtained from the same study. However, some data, which obviously seem to be implausible, have been replaced by own estimates. For instance Doka (2003) suggests that 50% of the metals are released from landfills within the first 100 years, whereby several investigations into landfills (e.g., Döberl et al., 2002; Baccini et al., 1987) clearly indicate, that only a small fraction (<2%) of the metals is released.

Table 22: Composition of different waste fraction and their degradability in landfills

Substance		Wates Type													
		Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetra-pack	Textiles	Wood	Other biomass	Bones
Degradability after 100 years		60%	27%	1%	32%	0%	18%	2%	0%	12%	18%	12%	3%	2%	0%
O	[kg/kg dry matter of waste]	0,32	0,49	0,02	0,45	0,25	0,47		0,49	0,46	0,33	0,36	0,41	0,5	0,28
H		0,05	0,052	0,15	0,065		0,063			0,063	0,073	0,067	0,06	0,053	
C		0,41	0,41	0,8	0,48	0,3	0,46			0,46	0,53	0,52	0,53	0,42	
S		0,0037	0,0007	0,0016	0,0017		0,00082		0,0024	0,00081	0,0016	0,0037	0,00083	0,0047	
N		0,01	0,001	0,003	0,0016		0,0018			0,0018	0,0024	0,041	0,0029	0,013	0,07
P		0,0028	0,00013												0,13
B		0,000026	0,00002												
Cl		0,01	0,0002	0,027	0,0024	0,011	0,0028		0,0002	0,0098	0,0064	0,0036	0,0011	0,00012	
Br		0,000015		0,000075							0,000002				
F		0,0005		0,000014	0,000048		0,000047				0,000003		0,000048		
I															
Ag															
As		0,000005	5,3E-07		0,0000037						9,6E-07			0,0000056	
Ba			0,00003		0,000052						0,000097			0,00026	
Cd			0,00001	0,00005	0,0000021		0,0000021	0,00004		9,3E-07	0,000008		0,0000012	0,0000038	1,1E-07
Co		0,000012									0,0000011				
Cr		0,00002	0,000034	0,00005	0,000025			0,0098			0,00001			0,000055	0,00035
Cu		0,000045	0,00003	0,000075	0,000089		0,000046	0,021	0,00001	0,0000064	0,000038		0,000015	0,000075	0,000073
Hg			3E-08	5E-08	0,00000096		9,4E-07	0,000005			2,6E-07		0,0000006	0,0000015	2,8E-08
Mn		0,000011	0,00005		0,00011						0,000085			0,00045	0,000028
Mo		0,000001	0,0000079												
Ni		0,000014	0,00001	0,000018	0,000027			0,003			0,000009			0,000022	
Pb		0,000046	0,00005	0,00009	0,000046		0,000033	0,016	0,00001	0,000013	0,00003		0,00037	0,00058	0,0000084
Sb			0,0000054					0,0009			0,0000021				
Se		0,0000012	8,5E-08		0,0000035				0,000003		0,0000026			0,0000037	
Sn		0,00002	0,0000084					0,0015			0,0000064				
V		0,0000075									0,00046				
Zn		0,00015	0,0001	0,0007	0,000064		0,000028	0,014	0,000004	0,000032	0,00012		0,000085	0,00044	0,00014
Si		0,1	0,022			0,25			0,34						
Fe		0,0015	0,0007	0,0039				0,8	0,001		0,00032				0,0067
Ca		0,054	0,004			0,17			0,042		0,00054				0,3
Al		0,025	0,013	0,0002		0,024		0,1	0,0079		0,055				
K		0,0087	0,001						0,0002						0,028
Mg		0,007	0,005					0,03	0,0027		0,00002				0,084
Na		0,0037	0,0007						0,11						0,098
Total		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

In addition to the degradability, information about the transfer coefficients is needed for calculating the emissions. The transfer coefficients indicate which percentage of the substance is released by landfill gas or leachate. This information again was taken from Doka (2003) and Brunner et al. (2001) and is summarized in Table 23.

Table 23: "Transfer coefficients" for landfill emissions (according to Doka (2003) and Brunner et al., (2001))

Substance	Output Type	
	Landfill Gas	Leachate
	[mass-% of specific emissions related to total emissions]	
O	97,1	2,9
H	97,1	2,9
C	97,1	2,9
S	14,9	85,1
N	6,44	93,56
P	0	100
B	0	100
Cl	1,38	98,62
Br	1,38	98,62
F	83,8	16,2
I	1,38	98,62
Ag	0,029	99,971
As	1,38	98,62
Ba	0,025	99,975
Cd	0,662	99,338
Co	0,025	99,975
Cr	0,025	99,975
Cu	0,029	99,971
Hg	28,6	71,4
Mn	0,025	99,975
Mo	0,025	99,975
Ni	0,025	99,975
Pb	0,033	99,967
Sb	0,025	99,975
Se	0,025	99,975
Sn	0,025	99,975
V	0,025	99,975
Zn	0,022	99,978
Si	0,025	99,975
Fe	0,025	99,975
Ca	0,025	99,975
Al	0,025	99,975
K	0,025	99,975
Mg	0,025	99,975
Na	0,025	99,975

Although the transfer coefficients and the degradability provide information for 100 years of landfilling and FORWAST uses data only on an annual basis, the cumulative emissions (over 100 years) were used for the model. This is due to the fact, that the precaution principle applied in waste management does not allow a discrimination regarding the temporal occurrence of emissions.

4.2.4 Landfill gas collection and treatment

Beside leachate emissions landfill gas represents the most important emission from landfills containing organic waste. The gas produced stems from the biodegradation of organic matter and consists mainly of CH_4 and CO_2 (seeTable 24).

Table 24: Composition of landfill gas (different sources)

Gas Type	Unit	Landfill Gas Composition				
		(% vol)[1]	(% vol)[2]	(% vol)[3]	(% vol)[4]	(% vol)[5]
Carbon Dioxie (CO_2)	kg	37	45	34	37	**41**
Carbon monoxide (CO)	kg					
Methane (CH_4)	kg	56	55	64	47	**59**
Nitrogen Oxide (NO_X)	kg					
Dinitrogen Oxides (N_2O)	kg					
Ammonia	kg					
NMVOC	kg					
PM	kg					
SO2	kg					

[1]Bart Eklund, B., Anderson, E., Walker, B. and Don B . Burrows, 1998, Characterization of Landfill Gas Composition at the Fresh Kills Municipal Solid Waste Landfill, Environ. Sci. Technol. vol. 32, pp. 2233 – 2237.

[2]US EPA, 2000, Facts About Landfill Gas.

[3]Riley, R., 2003, The Monitoring of Landfill Gas, Gas Detection Magazine, issue June 20

[4]Doka, G., 2003, Life Cycle Inventories of Waste Treatment Srvices, Ecoinvent Report No. 13, Part III Landfills Swiss Centre for Life Cycle Inventories, Dübendorf.

[5]This module

Due to the high content of methane landfill gas is not only relevant for greenhouse gas considerations, but it is also an energy source. A landfill sites with gas collection, the gas might be used in a combustion process to generate electricity and/or heat. At older landfills the amount of methane generated might not be sufficient for utilization. At these sites the landfill gas is simply flared without energy recovery or biologically oxidized using so called “biofilters”.

According to Doka (2003) the recovery rates of landfill gas (collected amount of gas referred to the total amount of gas generated) are considered to be in the range of 40 % to 50 %. The RMD GmbH[4] says in its webpage, that it is possible to collect 50-70 % of the gas. Caponi (2007) shows collection efficiency estimates between 50 and 100%. Lampert and Sachermayer (2008), on the other hand, obtained much smaller percentages for Austria: they calculated that 13 % of the total landfill gas was captured in 2007, whereby this figure includes also a number of older landfill without gas collection systems.

For Switzerland it was estimated that 47 % of the landfilled gas is emitted directly into the atmosphere and that only 53 % is captured (Ecoinvent). For the FORWAST landfill module it was assumed that 50 % of the landfill gas is captured and the other 50 % are emitted directly to the atmosphere. This figure is applied to sanitary landfills containing organic wastes. Landfills for residual materials and slag landfills do not have a gas collection system, thus gaseous emissions at theses sites are directly emitted into the atmosphere.

For calculating the energy recovered by the utilization of landiflll gas, the fraction of landfills that recover energy (or more precisely the proportion of waste in landfills with energy recovery) must be known. For Austria it was calculated that around 18 % of the landfill gas is flared without energy recovery (Lampert and Sachermayer, 2008). It must be noted here that the

[4] Rhein Main Deponie GmbH. Online: http://www.rhein-main-deponie.de/deponiegasnutzung.html

proportion of gas utilised depends on the concentration of methane in the gas, which decreases with time and depends on many factors (type of waste, landfill technology, climate, economic considerations). Since it was not possible to find average EU-27 data, it was assumed that 66% of the collected gas is used for energy recovery. This figure is in agreement with the assumptions made by Doka (2003).

Finally the efficiencies for electricity and heat production must be known. In this case, also data from Doka (2003) was taken: 27.8 % of electrical efficiency and 13.5 % of thermal efficiency. Furthermore a calorific value of 55.5 MJ/kg of methane was used.

The composition of the off gas from the landfill gas utilization unit was calculated using the following factors provided by Doka (2003):

- *CO_2:* *3.66 kg of CO_2 per kg of C in the combusted landfill gas.*
- *CO:* *0.000311 kg of CO per kg of C in the combusted landfill gas.*
- *CH_4:* *2.52E-5 kg of CH_4 per kg of C in the combusted landfill gas.*
- *NMVOC:* *5.88E-6 kg of NMVOC per kg of C in the combusted landfill gas.*
- *Particles:* *0.000104 kg of particles per kg of C in the combusted landfill gas.*
- *N_2:* *0.997 kg of N_2 per kg of N in the combusted landfill gas.*
- *NO_2:* *0.00853 kg of NO_2 per kg of N in the combusted landfill gas.*

4.2.5 Energy Consumption

The energy consumption considered in the landfill module include:

- Energy required for pumping leachate
- Energy required for collecting the landfill gas
- Energy required for compacting the waste

Doka (2000) calculated the average energy demands for these activities. The cumulative demand, expressed in energy per kg waste landfilled, are as follows:

- Use of diesel for the construction and compaction equipment: 27 kJ/kg waste
- Use of fuel oil: 1.6 kJ/kg waste
- Use of electricity 0.54 kJ/kg waste

A calorific value of 43 MJ/kg for fuel oil and diesel was assumed. A conversion factor of 3,600 kJ/kWh was used for transforming the electricity use into the units used in FORWAST. For calculating the fuel emissions, the same factors as mentioned in the incineration module were applied.

In addition, waste with a high content of easily degradable materials requires an additional use of 20 kJ/kg of diesel for compaction. This additional amount of fuel was included in the sub-module food landfilling.

4.2.6 Best available technique

As mentioned before, there is no BAT document for landfilling. If the standards for pre-treatment, site selection, lining, gas- and leachate collection + treatment as described in the BAT Guidance Notes for the Waste Sector: Landfill Activities of the Irish Environment Protection Agency (2003) are meet, a medium-term protection of human health and the environment can be guaranteed. Hence, countries were these standards are not meet yet should focus on meeting these standards. To meet the requirement of long-term and thus sustainable human health and environmental protection, particularly the pre-treatment is required. However, this is subject of the BAT document on Waste Treatment Industries (European Commission 2006).

4.3 Composting of Food Waste

4.3.1 Introduction

The European Landfill Directive (1999/31/EEC) requires member states of the European Union (EU) to reduce the direct landfilling of organic municipal solid wastes (MSW), which is believed as a main factor causing damages of the environment by emissions of landfill gas and leachate. The Directive sets up strict limits on the amount of biodegradable municipal waste that is allowed to be disposed in landfill. The amount of biodegradable municipal solid waste that can be disposed in landfill has to be reduced to 35% of the amount produced in 1995, by 2016. This target does not include non-domestic wastes such as sewage, forestry, agriculture, food processing, catering and other industries (e.g. paper processing and furniture)[5]. The Directive specifies two strategies that may lead to these targets:

- Recycling of source separated organic waste by aerobic (composting) or anaerobic (digestion in biogas plants) treatment

- Pre-treatment of residual waste before landfill by incineration, or mechanical-biological pre-treatment.

In general, compost can divided into two categories, namely mixed waste and biowaste composts. The mixed waste compost is usually produced aerobically from mixed biodegradable MSW without any pre-treatment process. Biowaste compost is produced from selected biodegradable matter of MSW called as green waste or biowaste. According to the European Commission (EC) decision number 2000/532/EC about MSW and its amendment with EC decision number 2001/118/EC, biowaste is defined as waste consisting of biodegradable materials from kitchen and catering, public market, and garden and park. Other biodegradable materials such as forestry or agricultural residues, manure, sewage sludge, paper or processed wood are excluded[6]. Therefore, compost produced from biowaste should contain a lower content of pollutants and/or hazard substances compared with compost produced out of MSW.

However, at the present the regulations regarding the composting of waste which are applied in European Union member states differ largely. In some countries the regulation is very ambitious, but in others it was still rather weak and unstressed. Countries which are applying ambitious

[5] Kingston, R., 2000, in Arnie R., and F. N. Wilson M.A., Composting for Soil Improvement in the United Kingdom, Proceeding 12th ISCO Conference, Beijing, 2002

[6] Commission of The European Communities, Green Paper On The Management of Bio-Waste in The European Union

policy introduced a strict regulation which only biowaste allow can process to be compost and used as fertilizer and soil conditioner in agriculture[7].

4.3.2 System Boundary of the Module

The composting process used in this module was assumed open pile composting method. The process was consisting of separation, mixing and bulking, and composting. In detail, composting process used in this module is presented in Figure 18**.**

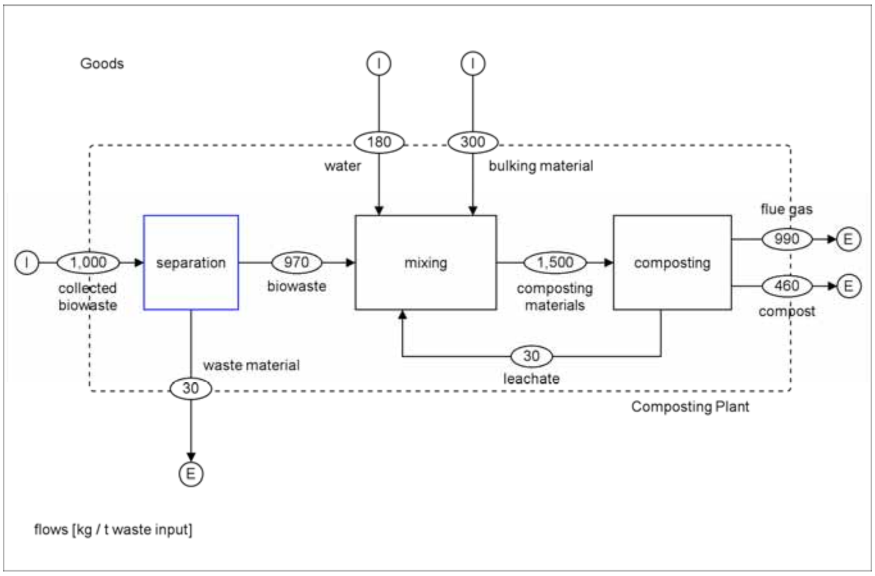


Figure 18: System boundary composting module

As illustrated in Figure 15, the energy used for delivery of biowaste from the sources and distribute compost product to end user was out-of system boundary. Therefore, the emission due to transportation of biowaste and compost was not account in this module. As additional information, some electricity was used for daily operation in composting plant (e.g. lighting, separator machine, and mixer). Electricity use for these purposes assumed was taken from available grid facility, therefore the emission released to generate the electricity also was not take account.

4.3.3 Process Description

Composition Biowaste Input

This different composition of municipal solid waste within EU countries is the most crucial issue for the development of the waste module. In order to use consistent data in the frame of the project, in this module was assumed that the waste input for composting is biowaste which

[7] European Compost Network ECN, Introduction and organic waste situation

extracted from municipal solid waste with an elementary composition as reported by Doka (2003)[8].

As described in the Chapter 2, production of compost generally structured from three steps: (a) preliminary treatment, (b) humidifying and adding bulking material, and (c) composting. During pre-treatment process, around 30 to 40 percent of the mass is separated and destined for other waste treatment processes (e.g., incineration or landfilling). There are three objectives for the pre-treatment process, namely (1) to recover recyclable or combustible materials; (2) reduce inert materials; and (3) reduce the content of chemical contaminant (e.g., heavy metal and household hazardous waste)[9].

Because of the differences in organic waste management within EU member countries and the limited data available about the composition of biowaste, the waste composition used in this module was subtracted from MSW data provide by Doka (2003) in accordance with biowaste as defined by EC decision number 2001/118/EC. Subsequently, the amount of waste was separated during preliminary process assumed proportionally on its share on the waste composition.

Water Content

The next step of composting process is the addition of water (humidification) and bulky material. The humidification of biowaste is aimed to increase the water content of the biowaste, and thus insure appropriate conditions for degrading microorganisms. Most decomposition processes occur in thin water films at surface of biowaste particles, therefore a sufficient water content is crucial for the decomposition. A water content of biowaste of 50 to 60 percent is recommended for composting[10]. However, the optimum composting process usually starts at the water content at level about 52 percent. Therefore, the average water content level was adopted in this module. In order to reach this condition, the fresh water was assumed to be spread onto the biowaste. The water content in the treated mixed biowaste determined based on summation of multiple fraction of waste type with its water content by the following equation:

$$G = \frac{(Q_1 \times M_1) + (Q_2 \times M_2) + (Q_3 \times M_3) + ...}{Q_1 + Q_2 + Q_3 + ...}$$

where:

Q_n : mass of material n ("as is", or "wet weight")

[8] Doka, G., 2003, Life Cycle Inventories of Waste Treatment Service Part II Waste Incinerator, Ecoinvent Report No. 13, Swiss Center for Life Cycle Inventories, Dübendorf

[9] Richard, T. L., 1993, Municipal Solid Waste Composting: Physical Processing, MSW Composting Fact Sheet Series Part I, Cornell Waste Management Institute.

[10] Richard, T. L., 1993, Municipal Solid Waste Composting: Biological Processing, MSW Composting Fact Sheet Series Part II, Cornell Waste Management Institute.

M_n : water content (%) of material n

G : water content of biowaste (%)

Bulking materials used to adjust the physical properties of composting materials. Adjustments are usually made to improve the porosity, structure, texture, and particle size of compost. In term of the compost humidity of compost materials is very high, applying sawdust is often carryout especially for windrow composting process.

Carbon and Nitrogen Ratio

Carbon and nitrogen are the two most important elements in the composting process. Carbon represents primarily an energy sources for microorganisms (MO), while nitrogen is essential for the metabolism of microorganisms (it amounts to over 50 mass-percent of dry microorganism cells). If the nitrogen content is less than microorganism requirements, the growth rate of the microorganism drops significantly. While, if the nitrogen content exceeds the requirement of the MO, N will be lost from the system in the form of as ammonia or other nitrogen compounds. The typical recommended carbon and nitrogen (C/N) ratios for composting are around 25:1 to 40:1 by weight.

The C/N ratios of the compost material can be directly calculated based on the carbon and nitrogen content of the compost material. For this purpose, the carbon and nitrogen content should be measured at laboratory. The C/N ratio of wastes mixtures composed of two or more different types of waste can calculated using the following formula:

$$R = \frac{Q_1 \times (C_1 \times 100 - M_1) + Q_2 \times (C_2 \times 100 - M_2) + Q_3 \times (C_3 \times 100 - M_3) + ...}{Q_1 \times (N_1 \times 100 - M_1) + Q_2 \times (N_2 \times 100 - M_2) + Q_3 \times (N_3 \times 100 - M_3) + ...}$$

where:

R : C/N ratio of compost materials

Q_n : mass of material *n* ("as is", or "wet weight")

C_n : carbon (%) of material *n*

N_n : nitrogen (%) of material *n*

M_n : moisture content (%) of material *n*

Using the above equation and data about the elementary composition of MSW (Doka, 2003) the C/N ratio of treated biowaste was calculated. The results of calculation indicate a C/N ratio of around 45 g of carbon per g nitrogen. This value is slightly higher compared to recommended levels of C/N ratios for composting, which could extend the time required for the decomposition process, and thus increase the time required for complete composting.

4.3.4 Emissions Derived from Composting

There are four emission sources during composting process: namely 1) emission due to fossil fuel combustion of machinery used for composting, 2) emission due to electricity generation, which is consumed during the composting process, 3) emission due to energy generation which is consumed for waste treatment, and 4) emission due to conversion of carbon and nitrogen compounds of the waste itself during the composting process. In this module the emission of the composting process include only the sources metioned above. Thus, the emission released due to transportation of biowaste to the composting plant and the final product (compost) to the user was not taken into account.

During the composting process a large fraction of degradable organic matter in the biowaste is converted into carbon dioxide (CO_2) and water. Beside that, also methane (CH_4) and nitrogen dioxide (N_2O) are produced during the composting of biowaste. CH_4 is formed under anaerobic conditions, which can locally prevail in the compost heaps. The estimated CH_4 release into the atmosphere ranges from less than one percent to a few percent of the initial carbon content in the biowaste[11]. The N emissions in form of N_2O are estimated to vary between 0.5 and 5 percent of the initial nitrogen content of the biowaste. In this module, the gases released during the composting process are determined based on the amount of carbon and nitrogen degraded. Carbon is predominantly mineralized to CO2, while only a small part of degraded carbon emits as CH4. For nitrogen, almost all nitrogen degraded is assumed to be release to the atmosphere as free nitrogen and only a small amount of is assumed to react with oxygen and hydrogen to form N_2O and NH_3-N, respectively.

The gases released during the composting process depend on rate of biodegradation of the organic matter. There are many factors influencing the degradation rate, such as particle size and composition of organic matter, biodegradation time, and environmental conditions[12]. In this module optimal condition for the composting process were assumed. Thus, the gases releases are only influenced by rate of biodegradation.

Because limited data have been published regarding the electricity consumption during composting process, data used in this module was adopted from a single literature source (Nemecek and Kägi, 2007) without comparison. Nemecek and Kägi (2007) assumed in their study, that electricity used by the composting plant was taken from available grid facility.

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[11] IPCC 2006 Guidelines for National Greenhouse Gas Inventories, vol. 5, International Panel on Climate Change

[12] Kayhanian, M., 1995, Biodegradability of Organic Fraction of Municipal Solid Waste in High-solid Anaerobic Digester, Waste Management & Research, vol. 13, pp. 123-136.

4.3.5 Composition of Compost

As well as the regulation of organic waste management, the quality standard of produced compost among European Union member countries also largely differs. Countries which apply ambitious goals of waste management aiming to produce high quality compost usually emphasize on separate collection prior composting. Other countries however, only consider the quality of the final product (compost). Both usually set up standards for the quality of composts based on the concentration of harmful substance in the produced compost, such as heavy metals. The maximum permissible contents for common heavy metals in the compost do not differ too much among EU countries. As reference, the maximum concentration of heavy metals in compost of household waste from separate collection of regulated by European Commission in Annex II/A of 2092/91/EC with amendment in 1488/97/EC were adopted in this module.

In this module, the composition of the compost produced was calculated based on the rate of biodegradation of each composted material. The elemental composition of the compost produced was calculated through subtracted elemental composition of treated biowaste with multiple result of each elemental composition with biodegradation rate. The biodegradation rate was used to calculate elemental compositions of compost are same which use to calculated emission of during composting process.

As a main objective of the production of compost is to partly substitute nitrogen fertilizer, the composition of the compost should fulfil nutrient requirements of growing plants and improve soil conditions. In this module, the concentration of main nutrients of the compost was determined by subtracting the elemental composition of treated biowaste with degraded component during composting process. A comparison of the content of main nutrients of compost, nitrogen fertilizer and other fertilizer is presented in Table 25**.**

Table 25: Comparison composition main nutrient content of compost, nitrogen fertilizer and other fertilize (g/kg dry biowaste)

Substance	Fertilizer Type			
	Nitrogen Fertilizer[1]	Other Fertilizer[1]	Compost[2]	Remark
Carbon	126.6	0.0	253.2	
Copper	0.0	0.0	0.0	
Iron	0.0	0.0	0.9	
Metal n.e.c	0.1	3.4	52.4	
Mineral n.e.c	4.4	3.6	57.6	
Oxygen	3.2	2.5	198.7	
Clay and soil	0.0	0.0	0.0	
Sand, gravel and stone	0.0	0.0	62.3	
water	1.0	0.5	374.8	

[1]Default compositions N-fertilizer and other fertilizer of FORWAST Module.

[2]Calculation results.

4.3.6 Best available technique

Up to now, composting is not treated separately in the BAT documents of the European Union. Thus, no best available technology regarding energy efficiency or emissions of compost production are presented. Beside that, the directive on the treatment of biowaste is still drafted[13]. Standards are only given for the pollutants content in the final product (compost) on both, national and EU level.

A similar process to composting with BAT standard suggestion is the aerobic mechanical-biological treatment (MBT) of mixed waste (European Commission 2006A). However, the input material is usually different, thus using MBT-BAT is not recommended. With increasing composting rates, BAT on composting should be defined.

[13] EurActive 29.06.2009, download from http://www.euractiv.com/en/sustainability/eu-biowaste-directive-moves-step-closer/article-183575, accessed 07.12.2009

4.4 Biogasification module

4.4.1 Introduction

Biogasification is the microbial conversion of solid biomass to form a combustible gas compound. A wide variety of physical, chemical, and biological reactions take place in the process[14]. The first step of biogasification is the hydrolysis of complex organic matter, such as carbohydrates, fats, protein etc., to soluble organic constituents. This step is carried out by a variety of bacteria through the release of extra-cellular enzymes that reside in close proximity to the bacteria. The soluble organic substances produced through hydrolysis consist of sugars, fatty acids, and amino acids. Those soluble constituents are converted to carbon dioxide and a variety of short chain organic acids by acid forming bacteria. This process called as acidogenic process. The next step of biogasification process is acetogenic process, where the groups of bacteria reduce the hydrogen toxicity by scavenging hydrogen to produce ammonia, hydrogen sulphide, and methane. Finally, a group of bacteria converts acetic acid to methane gas. This process called as methanogenic process.

Biogasification is widely used to treat wastewater sludge and other organic waste since it provides volume and mass reduction of the input material. As part of an integrated waste management system, anaerobic digestion could reduce the emission of landfill gas into the atmosphere. In addition, biogasification could allow the substitution of fossil fuels and thereto again reduce greenhouse gas emissions. Moreover, the solid residues left after the biogasification process contain nutrients which could be applied as fertiliser.

Biogasification provides a variety of environmental benefits, as mentioned above. In addition the utilization of the biogas produced could also result in an economic gain. In order to maximize the benefits of anaerobic digestion, the treatment facility must be designed with respect to the characteristics of the input material.

4.4.2 System Boundary of the Module

In this module, biogasification was assumed in a closed digester system. This method was selected in order to achieve the benefits of this method as described above. In addition to biogas production, nutrient losses during the process were evaluated and compared with other methods.

The treatment of organic wastes for generating biogas may be possible and reasonable for miscellaneous organic wastes, including co-digestion of liquid manure and organic matter of house hold waste. However, in this module only three types of wastes have been considered,

14 Burke, D. A., 2001, Dairy Waste Anaerobic Digestion Handbook, Options for Recovering Beneficial Products From Dairy Manure, Environmental Energy Company.

namely household waste or biowaste, sewage sludge waste, and liquid manure. The mass balances for the bio-gasification process were carried out for each type of waste input considered.

The biogases obtained from the conversion of organic matter were accounted as product, while the unconverted solid matters leave the process as residues. The utilization of the biogas produced was considered to take place outside the system of the bio-gasification unit. Therefore, no emissions due to utilization of produced biogases were accounted. In addition, the gases released due to diesel oil or other fuels used for transportation of materials from and to bio-gasification site, and emissions associated with electricity consumption (for pre-heating of input materials), as well as emissions due to the application of residues as organic fertilizer were also not accounted in this module. Based on this approach, the scope bio-gasification module is presented in Figure 18.

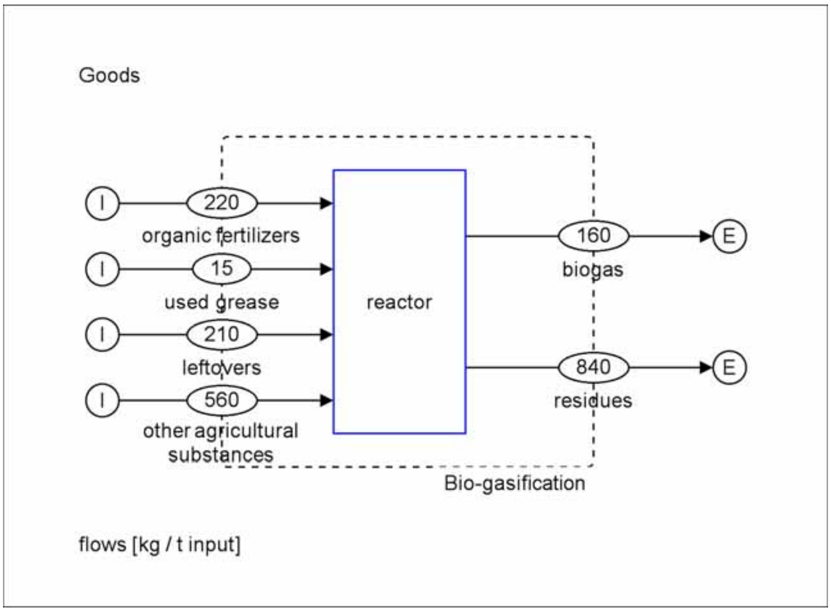

Figure 19: System boundary biogasification module

4.4.3 Process Description

The composition of waste input

The characteristic of poultry and livestock manures depend on several factors such as animal species, diet type, digestibility and animal age, housing, environment, and type of production. Common forms of animal manure are farmyard manure and liquid manure. Farmyard manure also contains plant material which has been used as bedding for animals and has absorbed the faces and urine. Liquid manure, also wells known as slurry, is produced by more intensive livestock rearing systems where concrete or slats are used, instead of straw bedding. Therefore, animal waste may not have the same characteristics as municipal wastewater.

Due to limited data availability, the characteristic of poultry and livestock manures used in this module was extracted from various references. While, the elemental composition of household waste was adopted from the same source as used in pervious modules. The elemental composition of poultry, dairy, and swine manures as well as sewage sludge was extracted from various sources and harmonized. The elemental composition manure of poultry, cow, swine and sewage sludge used in this module as well as biowaste are summarized in Table 26**.**

Table 26: Elemental composition of the inputs of bio-gasification module (based on dry weight basis, given in mass-percentage)

Substance	Unit	Input					
		Biowaste a)	Poultry Manure b)	Cow Manure c)	Swine Manure d)	Sewage Sludge e)	Remark
O	%	31.620	16.703	18.975	1.272	27.724	
H	%	5.003	1.490	2.535	0.429	6.630	
C	%	40.626	54.564	73.328	48.799	45.262	
S	%	0.37524	0.62586	0.29792	0.10319	0.76305	
N	%	1.001	7.651	0.84475	0.87067	3.869	
P	%	0.275177	4.319	0.484054	3.341	1.831	
B	%	0.002502	0.003185	0.001122	0.008484	0.063600	
Cl	%	1.001	2.338	0.152377	0.0	0.088005	
Br	%	0.001501	0.0	0.0	0.0	0.003421	
F	%	0.0	0.0	0.001303	0.0	0.047182	
I	%	0.000025	0.0	0.0	0.0	0.004616	
Ag	%	0.0	0.0	0.0	0.0	0.0	
As	%	0.000500	0.005271	0.002383	0.001408	0.057680	
Ba	%	0.0	0.003162	0.031651	0.0	0.333739	
Cd	%	0.0	0.000235	0.000	0.000195	0.072618	
Co	%	0.001251	0.000363	0.002262	0.002780	0.049991	
Cr	%	0.002001	0.002208	0.005679	0.003539	3.150	
Cu	%	0.004503	0.014942	0.002729	0.062000	0.407211	
Hg	%	0.000	0.0	0.0	0.0	0.674034	
Mn	%	0.001076	0.055110	0.020372	0.023525	0.179012	
Mo	%	0.000100	0.000345	0.004566	0.004335	0.063651	
Ni	%	0.001351	0.002254	0.003519	0.0	0.299173	
Pb	%	0.004653	0.001721	0.000844	0.002500	0.557489	
Sb	%	0.0	0.0	0.000	0.0	0.001711	
Se	%	0.000125	0.0	0.071910	0.0	0.001335	
Sn	%	0.002001	0.0	0.001033	0.0	0.047055	
V	%	0.000750	0.000945	0.001024	0.0	0.014549	
Zn	%	0.014559	0.064032	0.014092	0.063344	0.837740	
Si	%	10.001	0.169011	1.434	0.0	0.0	
Fe	%	0.150097	0.253686	0.112293	0.296477	0.753724	
Ca	%	5.454	6.9130266	0.370687	23.472	0.597723	
Al	%	2.500	0.117226	0.009681	0.0	4.286	
K	%	0.875563	3.309	0.976589	2.582	0.693104	
Mg	%	0.705454	0.761202	0.253947	4.699	0.457830	
Na	%	0.375241	0.631533	0.061782	13.963	0.178045	
Total		100	100	100	100	100	

a) Jungbluth et.al (2007).

b) Yanagida et.al (2007); Adewumi, et.al (2005); Charest and Beauchamp (2002); Moore et.al (1995); Ihnat and Fernandes (1996); and Zublena et.al (1997).

c) Lar and Xiujin (2009); Chesworth ed. (2008); Müller (2007); Wright et.al (1998); and Senesi et.al (1999).

d) Haun et.al (2006); Chesworth ed. (2008); Müller (2007); Senesi et.al (1999); and Zublena et.al (1997).

e) Adewumi, et.al (2005); Dote et.al (1992); Sieger et.al (2002); Moo et.al (2008); Goto et.al (1999); Akhter (1990); and Senesi et.al (1999).

Characteristic Input Materials

The input of bio-gasification plants includes different types of organic matter, such as biowaste, poultry and livestock manures. Generally, biogas produced contains between 60 to 70 % of methane, 30 to 40% of CO_2 and a trace amount of other gases. However, the composition strongly depends on the characteristics of the waste input (content of total solid, volatile organic acid, carbon and nitrogen ratio) and on the operational conditions of the bio-gasification (e.g., retention time, temperature).

The key factors determining the yield of biogas are content of volatile solids and the content of water. The latter one is due the facts that the initial step of bio-gasification is based on the hydrolyses of the organic matter, and that the metabolism of microorganisms responsible for the decomposition of the organic matter require a certain content of water.

The content of volatile solids in the input of bio-gasification plants was reported to vary within a wide range, depending on the type of the material input, the capacity and type of digester. Generally, optimum conditions for hydrolyses are obtained at a content of dry solid[15] of 7 to 9 % (thus, the water content amounts to 91 to 93%). Based on these figures, an optimal average content of dry solids of 8 % for input material was assumed in this module. Since the water content in poultry and livestock manures strongly depends on the farm type, manures handling, and climate condition of farm location, the characteristics of manure used for the calculation is based on figures for excreted manure. Thus in order to reach the optimal water content required for the decomposition, addition of water to the excreted manure is considered in calculative way. The amount of the water added was determined with analogously to the method applied in composting module. There, amount the dilution water should be added are equal with subtracting final water content is required with initial water content of biowaste and livestock manures. The characteristics of biowaste, poultry and livestock manure used in the present module are summarized in Table 27**.**

Table 27: Characteristics of biowaste, poultry and livestock manures used as input for bio-gasification

Characteristic	Unit	Input				
		Biowaste	Poultry Manure	Cow Manure	Swine Manure	Sewage Sludge
Moisture*	%	60.0	75.0	88.4	90.0	52.9
TS	%	40.0	25.0	11.6	10.0	47.1
N	%	1.0	7.7	0.84	0.87	3.9
P	%	0.27	4.32	0.48	3.3	1.8
K	%	0.87	3.31	0.98	2.6	0.69
C:N Ratio	%	40.6	7.1	86.8	56.0	11.7
Dilution Water	kg/kg	0.212	0.225	0.049	0.020	0.391

* initial moisture content

[15] Brulé, M. R. and S. S. Sofer, 1976, A Biogasification System at a Dairy, Proc. Okla. Acad. Sci. vol. 56, pp. 18-23.

Energy Consumption

Biogasification is carried out by a group of bacteria, where each type of bacteria shows a very specific contribution of whole process of decomposition and biogas production. The different types of bacteria involved in the whole process show different sensitivities to environmental conditions, such as pH-value, redox potential, temperature. Changes in the temperature for instance strongly affect the metabolism of bacteria. The activity of bacteria decreases with declining temperature. The biogas production during the winter will decrease for about 30% compared to the production during summer (Brulé and Sofer, 1976). On the other hand some bacteria could die off at increasing temperature[16].

The optimum temperature for bacteria is distinguished into three temperature ranges, namely (1) psychrophilic at range temperature 10 to 20 ^oC; (2) mesophilic at range temperature 20 to 40 ^oC; and (3) thermophilic at range temperature 40 to 60 ^oC. Many studies addressing the impact of the temperature on the digestion of organic matter have been carried out and reported. For instance, Escobar and Heikkilä (1999) stated that the digestion time of a digester which is operated at thermophilic condition is up to 14 hours shorter in comparison to a digester which is operated at mesophilic condition. However, most bio-gasification plants of dairy manure are operated at mesophilic temperature, because this method is more feasible especially in term of energy consumption for preheating the input material and controlling temperature of the digester during the winter season.

Many studies reported the possibility of utilizating of biogas produced to generate steam or electricity, which is used to heat the digester and thus reduce the energy consumption of a biogasification plant. However, only a few studies evaluated the net energy consumption (total energy consumption minus energy production from biogas produced) of a full scale biogasification plant. In this module mainly data from Nemecek and Kägi (2007) were used. However, some assumptions used in this module may differ from the work of Nemecek and Kägi. For instance, in this module it was assumed that no energy was recovered within the bio-gasification plant. Energy for pre-heating input material and maintenance digester temperature was assumed to stem from a districting heating system. Furthermore, the electricity required for lighting and other utility equipments was assumed to stem from available grid facility. These assumptions taken to obtain net emissions are generating form bio-gasification process. This approach aimed to provides emission factor which is applicable for whole bio-gasification size without any exception, excluding input material type. The energy required for the biogasification of kg dry matter input material d is presented in Table 28**.**

[16] Sakar, S., Yetilmezsoy, K. and E. Kocak, 2009, Anaerobic Digestion Technology in Poultry and Livestock Waste Treatment – A Literature Review, Waste Management and Research, vol. 27, pp. 3-18.

Table 28: Energy consumption of bio-gasification per kg dry matter input by input type

Energy type	Unit	Input Materials					Remark
		Biowaste	Poultry manure	Cow manure	Swine manure	Sewage sludge	
Heat	MJ	1.485		1.831	2.716	80.4822	
Electricity	kWh	0.1		0.03543	0.05311	5.0411	
Diesel oil	kg	1.039E-3	0.0	0.0	0.0	0.0	
Gas	MJ	0.0	0.0	0.0	0.0	0.0	
Coal	kg	0.0	0.0	0.0	0.0	0.0	

4.4.4 Emission Derived from Biogasification

In this module two emission sources were considered, namely emission derived from the decomposition of organic matter and emission derived from fuel combustion. The amount and source of the emissions are described in the following paragraph.

Emission derived from the decomposition of organic waste

The decomposition of organic matter occurs under aerobic and anaerobic conditions. Anaerobic decomposition takes place inside the digester, while aerobic decomposition occurs after the organic matter leaves of digester. Emissions from both processes were considered.

As mentioned above the biogas produced consists mainly of CH_4 and CO_2. Emissions of those gases during the decomposition process may occur due to leakage of digester and piping system. In this module we assumed no leakage of the digester and piping system. Therefore, CH_4 and CO_2 emissions due to the decomposition organic matter were not accounted in this module.

According to Jungbluth (2007) about 12% of the total nitrogen input is converted into ammonia (NH_3-N). However, ammonia emission can be reduced up to 95.5% by bio-filter systems[17]. Thus, the bio-filter we assumed was utilized in bio-gasification plant. In contrast to ammonia, bio-filter cannot reduce dinitrogen monoxide (N_2O), which will be release to the air. According to Jungbluth (2007) around 700 g N_2O are produced per ton of dry matter.

The organic matter which is not degraded during anaerobic decomposition process will leave the digester as “biogasification residue”. This residue will further decompose mainly under aerobic conditions. Nevertheless the degradation of the biogasification residues is small in comparison the decomposition within the digester. Emissions associated with the decomposition of the

[17] Pagans, E., Font, X. and A. S´anchez, 2005, Biofiltration for ammonia removal from composting exhaust gases, Chemical Engineering Journal, vol. 113, pp. 105–110.

residue are mainly CO_2 and CH_4. Methane emissions are caused by anaerobic microorganism activity inside the dewatered residue piles.

The decomposition of the residues will continue after their application onto soils as organic fertilizer. However, gaseous emissions associated with the application of the residues are not considered in this module. Decomposition rates and gases emitted during digestion and post-treatment of residues are presented in Table 29**.**

Table 29: Decomposition rates and emissions associated with the decomposition organic matter during digestion and post-treatment (per kg dry matter)

Emission Type	Unit	Bio-gasification Type					
		Biowaste	Poultry Manure	Cow Manure	Swine Manure	Sewage Sludge	Remark
Decomposition Rate	%	55.0		29	49	45	
Digestion	%	41.8					
Post-digestion	%	13.2					
Carbon Dioxide	kg	0.282		1.68E-02	3.32E-02	2.00E+0 0	
Methane	kg	0.00341		4.69E-03	1.30E-02	6.73E-02	
Dinitrogen Oxides	kg	3.99E-05					
Ammonia	kg	1.28E-04		2.26E-03	3.37E-03		
Hydrogen Sulfide	kg	9.80E-05					

Emission Derived by Fuel Combustion

A small amount of gases is released to the atmosphere due to fossil fuel combustion (required for the machinery used during bio-gasification). Theses gases consist of CO_2, CH_4, N_2O, as well as other pollutants such as carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs), sulphur dioxide (SO_2), particulate matter (PM) and oxides of nitrogen (NO_X). The amount of gases released due to fossil fuel combustion was determined by multiplying the mass of fuel consumed per weight of input with standard emission factors of the FORWAST project provided by Daxbeck et.al (2008). The results of these calculations, the gaseous emissions per kilogram of dry weight input into the digester, are presented in Table 30**.**

Table 30: Emission due to fuel combustion for the biogasification (per kg dry matter input)

Emission Type	Unit	Bio-gasification Type					
		Biowaste	Poultry Manure	Cow Manure	Swine Manure	Sewage Sludge	Remark
Carbon Dioxie (CO_2)	kg	7.58E-05					
Nitrogen Oxide (NO_X)	kg	3.92E-04					
NMVOC	kg	4.64E-05					
Methane (CH_4)	kg	2.66E-06					
PM	kg	5.00E-05					
Carbon monoxide (CO)	kg	2.08E-04					

4.4.5 Composition Digested Matter

Livestock manures represent a valuable source of nutrients required for crop growing. The nutrient contents of manure can be characterized as macro and micro nutrients. A macro nutrient, primarily nitrogen, phosphorous and potassium are required in adequate amount for plant growing-up. The secondary element such as sulphur, calcium and magnesium are required in a substantial amount. While, a micronutrient including zinc, boron, iron and copper are required in trace quantities. Application of manure onto soils for consecutive years could improve crop production and soils quality. Manure application not only provides adequate nutrients for crop production, but also could be alter microbiological activities and phosphorous cycling in the soils[18].

Biogasification of livestock manure does not reduce the nutrient content of manures, exclude nitrogen. Around 12% of the total nitrogen input is converted and released into air in form of ammonia. Since ammonia can act as inhibitor for methanogenic bacteria activity, the ratio of livestock manure digested together with other biogenic materials should be limited.

The composition of digested matter produced from biogasification was calculated based on the rate of biodegradation of each digested material. The biodegradation rates of the materials were obtained from various sources (Chang, J. I., et.al, 2006; Doka, G., 2003; and Davies, P., et.al, 2007). As comparison, the composition of the digested matter of biogasification and nitrogen and other fertilizers is presented in Table 25.

[18] Parham, J. A., Deng, S. P., Raun, W. R. and G.V., 2002, Johnson Long-term cattle manure application in soil I. Effect on soil phosphorus levels, microbial biomass C, and dehydrogenase and phosphatase activities, Biol Fertil Soils, vol. 35, pp. 328 – 337.

4.4.6 Best available technique

The BAT document for the waste treatment industries (European Commission 2006) refers to biogasification too. Therein, particularly two aspects are considered: 1) energy efficiency and 2) emissions.

Energy efficiency should be improved firstly through close integration of the system, for instance in waste water treatment (cp. European Commission 2006:524ff.). There, most of the electricity and heat produced can be directly used in the system complex. Secondly, the energy generation efficiency should be improved. There is still a potential to increase the efficiency of combined heat-power plants which are fed with biogas. However, the energy generation lies outside of the system boundary. A third measure would be to reduce the energy demand of the plant. Therein, the focus should lie on electricity, as there is usually sufficient heat for the fermenter (cp. Arlt 2003). According to Arlt (2003), the electricity demand of dry systems treating municipal solid biowaste is slightly lower than for wet systems (Arlt 2003:101). There, the range lies between 210-280, compared to 200-300 (kWh/t dm). However, the electricity demand of dry systems is lower. European Commission states electricity demand values of current plants between 50-55 (kWh/t biowaste) (European Commission 2006:144). Even though not stated there, it is very likely that this refers to wet waste. Considering the 60% water content of food waste, this would be between 125-138 (kWh/t dm). Detailed figures cannot be found in the BAT section of the document. Fourthly, the biogas generation can be enhanced. Arlt (2003) states that the conversion of organic carbon for municipal biowaste in dry fermenters is only about 40%, compared to 65% in wet fermenters, even though the residence time is longer (20 days compared to 12 days) (Arlt 2003:92,94,96).

For wastes from agriculture used to produce biogas, the same recommendations regarding energy efficiency are made as for municipal biowaste gasification (European Commission 2005). No additional information is provided there. As the waste input differs, for instance in the water content, wet digesters are more likely to be used.

Regarding emissions from biogasification, the European Commission document on BAT states that the emissions from the gas production are usually negligible if compared to emissions from the energy generation, for instance through a CHP (European Commission 2006:146). Thus, most emissions in the biogas become negligible, as long as the CHP or the land application of residues lies outside of the system boundaries (cp. Jungbluth et al. 2007). However, the only emission which can be reduced in the biogas itself is hydrogen sulphide (H_2S) through iron salt scrubbing or biofiltering (cp. European Commission 2006:524). This emission is not required for the calculation model.

Table 31: Comparison average air emission values from reference plant Spittelau with suggested maximum average emission values in BAT and maximum values EU-directive (European Parliament and European Council 2000) in (mg/kg waste input)

	Unit	Arlt 2003 biowaste average	BAT average	Directive max values
Electricity demand	kWh/t dm	250	135	nd
Carbon dioxide (CO_2)	kg/kg	nd	nd	nd
Carbon monoxide (CO)	kg/kg	nd	nd	nd
Methane (CH4)	kg/kg	nd	nd	nd
Nitrogen Oxide (NO_X)	kg/kg	nd	nd	nd
Dinitrogen Oxides (N2O)	kg/kg	nd	nd	nd
Ammonia	kg/kg	nd	nd	nd
NMVOC	kg/kg	nd	nd	nd
PM	kg/kg	nd	nd	nd
SO2	kg/kg	nd	nd	nd

4.5 Land Application of waste module

4.5.1 Introduction

The application of animal manure to soil for farmland is an economical and environmentally sustainable mechanism for increasing crop production. Nutrients in animal manure can replace commercial fertilizers. However, the value of manure is more than the accumulated value of the individual nutrients. Animal manure is an excellent soil amendment capable of increasing soil quality. Manure can increase crop yields by providing large inputs of nutrients and organic material. The benefit of the nutrients and organic material may not be immediately evident. Therefore, the value of the manure can best be thought of as the overall crop yield and quality response over several years.

However, beside these beneficial properties, manure is a potential environmental threat too. Where nutrients in manure exceed the intake capacity of soils, terrestrial eutrophication can become a problem, and the transfer of nitrogen and/or phosphorus to ground water or open water bodies through leaching and erosion will negatively affect these water sources (cp. Brady and Weil 1999). Thus, the European Council has passed the so called nitrate directive, which aims to reduce nitrogen emissions to the ground water (Council Directive 91/676/EEC, ANNEX III). Through this directive, governments are required to limit the annual nitrogen application.

Another emission of regard are gaseous emissions to the atmosphere, in form of ammonia (cp. Brady and Weil 1999).

Important organic fertilizers and soil conditioners are manures, composts, sewage sludges and residuals of anaerobic treatment processes.

4.5.2 System Boundary of the Module

Three types of animal manure and compost made of biowaste were considered in this module: poultry, cattle, swine manures, and compost. In term to estimate environmental impact due to application these waste into soils, the application of each waste was dependently. Moreover, we assumed that the manure waste and compost was available or produced at surrounding farmland, therefore emission due to transportation waste from sources into site was not accounted. Based on above assumption, the system boundary of this module is presented in Figure 20 below.

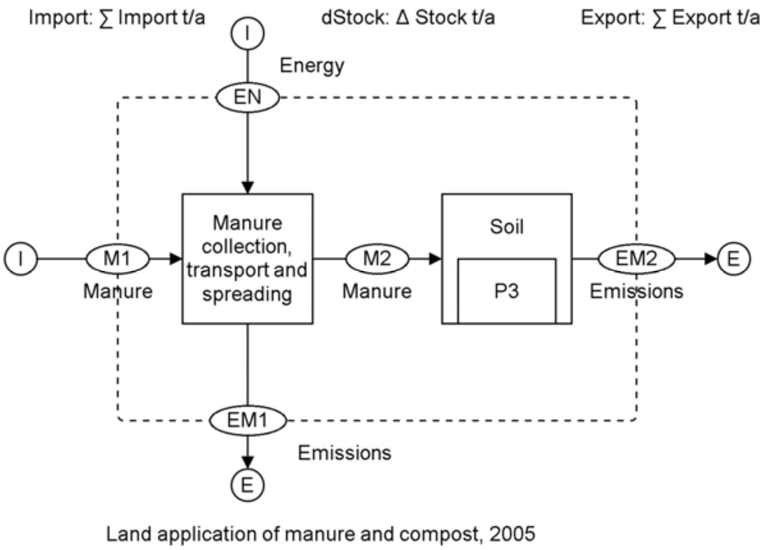

Figure 20: System boundary composting module

First, the manure is collected at the farm and transferred to the field, where it is spread to the soil. Therefore, energy is required. On the soil, parts of the manure are degraded and released to the air, another share is subject of leaching, while the residual is stored as biomass, nonhumic or humic compounds (cp. Brady and Weil 1999).

4.5.3 Process Description

The composition of waste input

The composition animal manure use in this module was same composition used for compiled form some with biogasification module, while compost composition achieved from composting module was selected. The elemental composition manure of poultry, cow, swine and sewage sludge used in this module as well as biowaste are summarized in Table 32.

Table 32: Elemental composition of the compost and manure applied into land farming (based on dry weight basis, given in mass-percentage)

Substance	Unit	Input				
		Biowaste Compost[a)]	Poultry Manure[b)]	Cow Manure[c)]	Swine Manure[d)]	Remark
Water	%	60	59	88	90	
Dry matter	%	40	41	12	10	
Conversion wet-dry		2.5	2.4	8.6	10	
O	%	31.773	16.703	18.975	1.272	
H	%	4.988	1.490	2.535	0.429	
C	%	40.502	54.564	73.328	48.799	
S	%	0.37391	0.62586	0.29792	0.10319	
N	%	0.99757	7.651	0.84475	0.87067	
P	%	0.28181	4.319	0.484054	3.341	
B	%	0.00255	0.003185	0.001122	0.008484	
Cl	%	0.99757	2.338	0.152377	0.0	
Br	%	0.00150	0.0	0.0	0.0	
F	%	0.04988	0.0	0.001303	0.0	
I	%	0.0	0.0	0.0	0.0	
Ag	%	0.0	0.0	0.0	0.0	
As	%	0.00050	0.005271	0.002383	0.001408	
Ba	%	0.0	0.003162	0.031651	0.0	
Cd	%	0.0	0.000235	0.000	0.000195	
Co	%	0.00125	0.000363	0.002262	0.002780	
Cr	%	0.002	0.002208	0.005679	0.003539	
Cu	%	0.00449	0.014942	0.002729	0.062000	
Hg	%	0.0	0.0	0.0	0.0	
Mn	%	0.00107	0.055110	0.020372	0.023525	
Mo	%	0.0001	0.000345	0.004566	0.004335	
Ni	%	0.00135	0.002254	0.003519	0.0	
Pb	%	0.00463	0.001721	0.000844	0.002500	
Sb	%	0.0	0.0	0.000	0.0	
Se	%	0.00012	0.0	0.071910	0.0	
Sn	%	0.00199	0.0	0.001033	0.0	
V	%	0.00075	0.000945	0.001024	0.0	
Zn	%	0.01452	0.064032	0.014092	0.063344	
Si	%	9.971	0.169011	1.434	0.0	
Fe	%	0.14964	0.253686	0.112293	0.296477	
Ca	%	5.437	6.9130266	0.370687	23.472	
Al	%	2.493	0.117226	0.009681	0.0	
K	%	0.8729	3.309	0.976589	2.582	
Mg	%	0.7033	0.761202	0.253947	4.699	
Na	%	0.3741	0.631533	0.061782	13.963	
Total		100	100	100	100	

a) FORWAST Module.

b) Yanagida et.al (2007); Adewumi, et.al (2005); Charest and Beauchamp (2002); Moore et.al (1995); Ihnat and Fernandes (1996); and Zublena et.al (1997).

c) Lar and Xiujin (2009); Chesworth ed. (2008); Müller (2007); Wright et.al (1998); and Senesi et.al (1999).

d) Haun et.al (2006); Chesworth ed. (2008); Müller (2007); Senesi et.al (1999); and Zublena et.al (1997).

The Degradation Rate

There are many factor were involves to degradation rate of applied waste into farming land. Soil moisture content is one of the most important environmental factors affecting the rate of decomposition of organic materials in soil.

Shiga (2009) reported that the decomposition rate of waste applied into soil was very fast, almost half the carbon had been lost within 40 days after applied into soils. Brady and Weil (1999) estimates that after one year, about 60-80 % of the carbon has been released to the atmosphere in form of CO_2.

Energy Consumption

Solid manure collection, transport and spreading uses 0.00019 hours per kg manure (Nemecek and Kägi, 2007). This leads to a value of $5.31*10^{-4}$ kg fuel (diesel) per kg wet manure (ibid.). Regarding the conversion rates in Table 32, the diesel demand per kg dry matter yields:

Table 33 Conversion rates wet->dry waste and fuel consumption for land application

Substance	Unit	Input				
		Biowaste Compost[a)]	Poultry Manure[b)]	Cow Manure[c)]	Swine Manure[d)]	Remark
Water	%	60	59	88	90	
Dry matter	%	40	41	12	10	
Conversion wet-dry	-	2.5	2.4	8.6	10	
Diesel	kg	0.0013	0.0013	0.0046	0.0053	

Emissions from energy consumption are calculated according to Daxbeck et al. (2008).

4.5.4 Emissions Derived from Land Application of Waste

In this module two emission sources were considered, namely emission derived from compounds of carbon and nitrogen in the manure and emission derived from fuel combustion. The amount and source of the emissions are described in the following paragraph. Elemental emissions, like heavy metals, have been calculated too, but are not required in the model. In the long run, most of these will remain in the soil, while a smaller portion is subject to erosion, leaching into water bodies and plant uptake.

a) Emission derived from compounds in manure

According to Nemecek and Kägi (2007), the emissions of NH_3, N_2O and NO_X should be considered. Additionally, the emission of CO_2 from degradation was calculated.
After Brady and Weil (1999), about 70% of the carbon applied as manure is degraded as CO_2 after one year. The conversion factor of C -> CO_2 is 3.66.

NH_3 emissions to the air are about 25% of the total nitrogen input through manure, which has been calculated in the material flow calculation (see Table 32) (Nemecek and Kägi, 2007). The conversion of N-> NH_3 is 1.22. Beside that, 2.5% of nitrogen input is released as N_2O (ibid.). The conversion of N-> N_2O is 3.14. A small amount of nitrogen is also released as NO_X. Nemecek and Kägi (2007) use the factor of 0.21 times the emissions of N_2O.
Relevant emissions into water are, beside heavy metals and other substances, NO_3 and phosphorus. Even though both are not considered in the model, they can be quantified. For instance, phosphorus run-off and leachate to the hydrosphere can be quantified as 17.5% of the input (Rechberger and Klonk, 2008). NO_3 to the hydrosphere can be calculated according to Nemecek and Kägi (2007).

b) Emission Derived by Fuel Combustion

A small amount of gases is released to the atmosphere due to fossil fuel combustion (required for the machinery used during bio-gasification). Theses gases consist of CO_2, CH_4, N_2O, as well as other pollutants such as carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs), sulphur dioxide (SO_2), particulate matter (PM) and oxides of nitrogen (NO_X). The amount of gases released due to fossil fuel combustion was determined by multiplying the mass of fuel consumed per weight of input with standard emission factors of the FORWAST project provided by Daxbeck et.al (2008). The results of these calculations, the gaseous emissions per kilogram of dry weight input into the digester, are presented in Table 34**.**

Table 34 Conversion rates wet->dry waste and fuel consumption for land application. Emission factors according to Daxbeck et al. (2008)

Substance	Emission factor	Input				
		Biowaste Compost[a)]	Poultry Manure[b)]	Cow Manure[c)]	Swine Manure [d)]	Remark
Diesel oils (kg/kg waste)		**0.0013**	**0.0013**	**0.0046**	**0.0053**	
Carbon Dioxie (CO2)	5.50E-02	7.30E-05	7.01E-05	2.51E-04	2.92E-04	
Carbon monoxide (CO)	5.00E-06	6.64E-09	6.37E-09	2.28E-08	2.66E-08	
Methane (CH4)	2.00E-06	2.66E-09	2.55E-09	9.13E-09	1.06E-08	
Nitrogen Oxide (NOX)	4.10E-05	5.44E-08	5.23E-08	1.87E-07	2.18E-07	
Dinitrogen Oxides (N2O)	1.00E-06	1.33E-09	1.27E-09	4.57E-09	5.31E-09	
Ammonia	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
NMVOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
PM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
PM	1.00E-06	1.33E-09	1.27E-09	4.57E-09	5.31E-09	
SO2	5.50E-02	7.30E-05	7.01E-05	2.51E-04	2.92E-04	

4.5.5 Best Available Technique

Actually, there is no BAT document on manure and compost application. However, good agricultural practise can be considered as a BAT, and it is also required, for instance through the EC nitrate directive (Council Directive 91/676/EEC).

Good agricultural practise regarding manure application refers to different measures. The time when manure should be applied is an important factor, as the plant uptake of nutrients and the microbiological activities in the soil differs. Manure should never be applied on frozen soils, for instance (Brady and Weil, 1999). This counts even more for liquid than gaseous emissions. Also, the type of application of manure has an impact on emissions (ibid.), as well as the coordination between manure and crops or cultivation type. Another impact can be found for the feeding of animals. Low protein feeding can significantly reduce nitrogen emissions (Oenema et al., 2007). Oenema et al. (2007) assumes a reduction potential of NH_3 of 14% for the full implementation of the EC nitrate directive until 2020, based on the emissions from 2000. Similar emission reductions of other nitrogen compounds can be achieved through these measures.

Herein, we refer to a reduction potential of 5% of nitrogen compounds for a medium and 10% for stricter implementation of the nitrate directive. This will be achieved to the measures as stated for instance in the Austrian National Action Program on nitrate (BMLFUW 2003).

4.6 Manure treatment module

4.6.1 Introduction

Within the scope of this module, the storage of manure is considered, while the land application of manure and the treatment through biogasification are dealt with separately.
Manure from cattles, pigs and poultry has to be stored, no matter what the subsequent process comprises of (biogasification, land application). However, the storage time is usually longer for land application, as a farmer cannot fertilize his fields throughout the year (cp. Brady and Weil, 1999). This is first because of practical reasons, as for instance manure cannot be applied the weeks before harvesting. The second reason is due to water pollution, as aimed through the nitrate directive of the European Council (cp. Council Directive 91/676/EEC, ANNEX III). Therein, member states of the EU require fertilizing periods, which depend on factors like climate, soil or the manure quality. Then, the member states also must regulate the manure storage capacity for a farmer, which is up to 9 months in the EU (European Commission 2007). If the manure is fermented in a biogas plant, the storage time of the manure is much lower, as there is a continuous demand in biogas production. What then has to be stored is the residual from the biogas plant, namely the slurry.
Manure is usually stored in open or closed systems. The latter have the advance of lower losses of nitrogen to the atmosphere. For cow and pig manure, solid and liquids can either be stored separately or together, in a slurry tank. There is no such a distinction for poultry manure.

4.6.2 Process Description

Figure 21 shows the average material flow in manure storage for an average manure composition in the EU 27. Due to own calculations based on data from Eurostat (Eurostat 2007) and ASEA Statistics (ASEA 2003), this average manure comprises of 76% bovine, 21% pig and 3% poultry manure. The manure is considered fresh, and not on dry basis.

According to Oenema et al. (2007), manure storage in the EU 27 countries comprises of:

Table 35 Manure management in the EU 27 (Oenema 2007:263)

Manure management	Characteristics	Share (%)
Pasture/range	Dung and urine from grazing animals, not handled	30-40
Solid storage	Dung is stored in bulk (open/closed)	20-30
Liquid/slurry	Collection of liquids and solids mixed, storage in tanks (open/closed)	20-30
Slurry in pit storage	Collection of liquids under the confinement (closed)	20-30
Other	Composting, biogasification, etc.	negligible

Uncertainties in data are quite high, and it is clear that some of the systems mentioned above can only work together. However, due to these figure, the manure storage was defined as 1) “no handling storage, open-air" (35%); 2) "solid storage open air with liquid collection, closed" (30%); 3) "mixed storage, closed system" (15%); and 4) "mixed storage, open system" (20%). With these figures, the basic material flow calculation was conducted. The average storage time is assumed with 90 days.

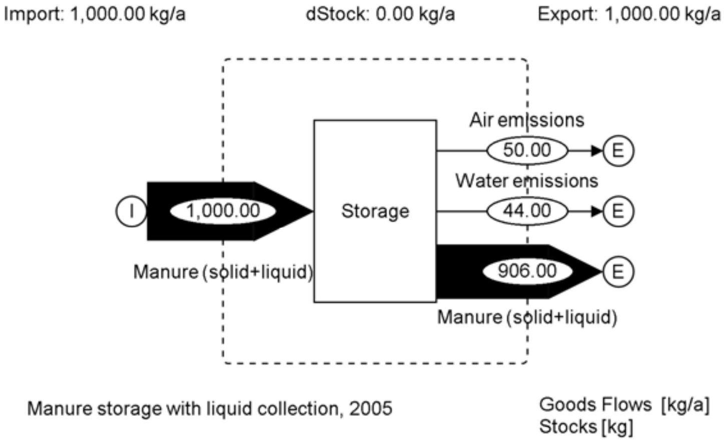

Figure 21 Material flow manure storage, based on average values for the EU 27 (Eurostat 2007; ASEA 2003; Oenema et al. 2007; Chadwick 2005; NRCS 1999)

Characteristic Input Materials

Unlike the statistical data on treatment methods, the quality of the input material is well investigated. Table 36 gives an overview of the elemental composition of dry manure compared to biowaste and sewage sludge, including the usual water and dry matter content of fresh mixed waste (solids + urine). The data derives from the biogasification module.

Table 36 Elemental composition of the inputs of manure treatment module (based on dry weight basis, given in mass-percentage)

Substance / Material	Unit	Input					
		Biowaste[a)]	Poultry Manure[b)]	Cow Manure[c)]	Swine Manure[d)]	Sewage Sludge[e)]	Remark
Dry matter content	%		25	15	13		Of fresh substance (ASEA 2003)
H_2O content	%		75	85	87		Of fresh substance (ASEA 2003)
O	%	31.620	16.703	18.975	1.272	27.724	
H	%	5.003	1.490	2.535	0.429	6.630	
C	%	40.626	54.564	73.328	48.799	45.262	
S	%	0.37524	0.62586	0.29792	0.10319	0.76305	
N	%	1.001	7.651	0.84475	0.87067	3.869	
P	%	0.275177	4.319	0.484054	3.341	1.831	
B	%	0.002502	0.003185	0.001122	0.008484	0.063600	
Cl	%	1.001	2.338	0.152377	0.0	0.088005	
Br	%	0.001501	0.0	0.0	0.0	0.003421	

Substance / Material	Unit	Input					
		Biowaste[a)]	Poultry Manure[b)]	Cow Manure[c)]	Swine Manure [d)]	Sewage Sludge[e)]	Remark
F	%	0.0	0.0	0.001303	0.0	0.047182	
I	%	0.000025	0.0	0.0	0.0	0.004616	
Ag	%	0.0	0.0	0.0	0.0	0.0	
As	%	0.000500	0.005271	0.002383	0.001408	0.057680	
Ba	%	0.0	0.003162	0.031651	0.0	0.333739	
Cd	%	0.0	0.000235	0.000	0.000195	0.072618	
Co	%	0.001251	0.000363	0.002262	0.002780	0.049991	
Cr	%	0.002001	0.002208	0.005679	0.003539	3.150	
Cu	%	0.004503	0.014942	0.002729	0.062000	0.407211	
Hg	%	0.000	0.0	0.0	0.0	0.674034	
Mn	%	0.001076	0.055110	0.020372	0.023525	0.179012	
Mo	%	0.000100	0.000345	0.004566	0.004335	0.063651	
Ni	%	0.001351	0.002254	0.003519	0.0	0.299173	
Pb	%	0.004653	0.001721	0.000844	0.002500	0.557489	
Sb	%	0.0	0.0	0.000	0.0	0.001711	
Se	%	0.000125	0.0	0.071910	0.0	0.001335	
Sn	%	0.002001	0.0	0.001033	0.0	0.047055	
V	%	0.000750	0.000945	0.001024	0.0	0.014549	
Zn	%	0.014559	0.064032	0.014092	0.063344	0.837740	
Si	%	10.001	0.169011	1.434	0.0	0.0	
Fe	%	0.150097	0.253686	0.112293	0.296477	0.753724	
Ca	%	5.454	6.9130266	0.370687	23.472	0.597723	
Al	%	2.500	0.117226	0.009681	0.0	4.286	
K	%	0.875563	3.309	0.976589	2.582	0.693104	
Mg	%	0.705454	0.761202	0.253947	4.699	0.457830	
Na	%	0.375241	0.631533	0.061782	13.963	0.178045	
Total		100	100	100	100	100	

a) Jungbluth et.al (2007).
b) Yanagida et.al (2007); Adewumi, et.al (2005); Charest and Beauchamp (2002); Moore et.al (1995); Ihnat and Fernandes (1996); and Zublena et.al (1997).
c) Lar and Xiujin (2009); Chesworth ed. (2008); Müller (2007); Wright et.al (1998); and Senesi et.al (1999).
d) Haun et.al (2006); Chesworth ed. (2008); Müller (2007); Senesi et.al (1999); and Zublena et.al (1997).
e) Adewumi, et.al (2005); Dote et.al (1992); Sieger et.al (2002); Moo et.al (2008); Goto et.al (1999); Akhter (1990); and Senesi et.al (1999).

Energy Consumption

In manure storage, no energy consumption is considered.

4.4.1 Emission Derived from Storage

Emissions to the atmosphere

Emissions of main concern from storage are nitrogen and carbon compounds released to the atmosphere or – in case of open storage without liquid collection – liquid emissions.
Gaseous emissions are: ammonia (NH_3), methane (CH_4), and dinitrogenoxides (N_2O). Oenema et al. (2007) calculate the total emissions from storage of manure for the EU27 in 2000, while

IPCC gives values for both, N_2O and CH_4. Additional, values are presented by Moller et al., 2004, for cattle and pig manure at 15 °C and 90 days.

Table 37 Emissions from manure storage

Emission	Unit	Poultry Manure	Cow Manure	Swine Manure	Source
NH_3	kton/EU27	45	237	103	Oenema et al. 2007
N_2O	kton/EU27	7	36	9	Oenema et al. 2007
$CH_{4,\ western\ europe}$	kg CH_4 / head / yr	0.02	29	10	IPCC 2006
$CH_{4,\ eastern\ europe}$	kg CH_4 / head / yr	0.02	15	4	IPCC 2006
$CH_{4,\ europe\ average}$	kg CH_4 / head / yr	0.02	22	7	IPCC 2006
CH_4	kg CH_4 / manure dm	nd	0.0057	0.033	Moller et al. 2004 at 90 days storage

For the calculation of specific emissions, following assumptions are used to get the results as listed below:

Table 38 Calculation of gaseous emissions from manure storage

Item	Unit	Poultry Manure	Cow Manure	Swine Manure	Source
Number of animals in EU27	Head	1,453,500,000	88,838,600	151,988,800	Eurostat 2007
Amount of manure	kg/ t living animal / day	85	85	85	ASEA 2003
Average weight	kg/head	1	380	60	ASEA 2003
CH_4	kg CH_4 / head / yr	0.02	20	7	IPCC 2006
NH_3	kg NH3/ kg manure raw	0.00023	0.00036	0.00100	calculated
N_2O	kg N2O/ kg manure raw	0.00005	0.00005	0.00024	calculated
CH_4	kg CH4/ kg manure raw	0.00064	0.00170	0.00376	calculated
NH_3	kg NH3/ kg manure dm	0.0040	0.0015	0.0028	calculated
N_2O	kg N2O/ kg manure dm	0.00098	0.00036	0.00038	calculated
CH_4	kg CH4/ kg manure dm	0.0026	0.011	0.029	calculated based on IPCC 2006

Emissions to the soil and hydrosphere

The major concern regarding manure storage emissions are N-emissions to the hydrosphere of storage systems. Oenema et al. (2007) assumes that about 4% nitrogen is lost due to leaching and runoff of manure storage. However, nitrogen emissions to soil and hydrosphere from manure storage are not considered in the model.

4.6.3 Best available technique

The European Commission document on best available technique of emission from storage (European Commission 2006c) also deals with the storage of manure. Beside that, Nicholson et al. (2002) did a literature review on emissions for different manure storage systems, aiming to assess their desirability regarding emissions.
Harris and Smith (2004) give following values of N-losses during storage of different systems:

Table 39 N-losses of different manure storage systems

System	Nitrogen Lost, %	Nitrogen Retained, %
Daily scrape and haul	20-35	65-80
Manure pack	20-40	60-80
Open lot	40-55	45-60
Deep pit (poultry)	25-50	50-75
Litter	25-50	50-75
Under floor pit	15-30	70-85
Aboveground tank	10-30	70-90
Holding pond	20-40	60-80
Anaerobic lagoon	70-85	15-30

Most of these emissions accounts for NH_3, which is about 10-30 times higher than N_2O emissions (Oenema et al. 2007)
According to the herein assumed systems, following recommendations are made:

1) “no handling storage, open-air” (35%)

The manure in this category derives mostly from grazing cattle and can be termed as un-handled. The afford to collect these manures and store them, in order to return it to the field, is to big to be practicable. The BAT document does not refer to this type of “storage”, as it also can be seen as land application. Thus, no suggestion is made herein for this application.

2) “solid storage open air with liquid collection, closed” (30%)

A common type of storage is open systems for solid storage combined with closed systems for liquid storage. While the latter is seen positively by the BAT document, the open storage of solids should be avoided through coverage (European Commission 2006c,60). Also, the field heap storage of solids should be avoided (Nicholson et al. 2002). Through storing the manure in a covered and sealed system, the NH_3 emissions can be reduced from an N-loss of 30% to 20%, hence reducing the emission of about 50% of the initial emissions from solid manure storage. The reduction of N_2O and CH_4 can be assumed as negligible (Harris and Smith 2004; Nicholson et al. 2002).

3) “mixed storage, closed system” (15%)

This system is preferred by the BAT document. Nicholson et al. (2002) did a literature review on emissions for different manure storage systems, concluding similarly. Thus, no additional measure is necessary to reach BAT.

4) “mixed storage, open system” (20%).

Unlike no. 3), this system requires a cover, in order to reduce the NH_3 emissions of about 50% of the initial emissions from solid manure storage (Harris and Smith 2004; Nicholson et al. 2002). As before, N_2O and CH_4 can be assumed as negligible.

Table 40 Reduction of emissions (only for NH3), relative to 1

Manure management	Share (%)	NH3 score	Reduction potential	Total reduction
"no handling storage, open-air"	35	0	0	0
"solid storage open air with liquid collection, closed	30	0.33	0.5	0.167
"mixed storage, closed system"	15	0.22	0	0
"mixed storage, open system"	20	0.45	0.5	0.22
Total	100	1		0.39

For the BAT consideration, a stepwise reduction of first 20, than 40 % is assumed. The mean value of NH_3 emissions for the waste types considered is 0.0028 (kg/kg dm manure) (see Table 38).

4.7 Waste Water Treatment module

4.7.1 Introduction

The waste water treatment (WWT) module consists of the treatment of waste water. Waste water is produced in many processes, such as the household, public buildings, but also industry and small and medium enterprises. Thus, WWT is usually distinguished for the type of waste water which has to be treated. The first distinction is usually between waste water which is similar to waste water from households and industrial waste water. The first refers to waste water from households, public buildings and other sources, which is similar to waste water from households. The other refers to waste water from industries and small and medium enterprises. The difference between both is the quantity and quality, as different substances are in the waste water.

The waste water is collected by sewer systems and transferred to the waste water treatment plant (WWTP). Figure 22 shows the scheme for a WWTP (cp. Doka 2007).

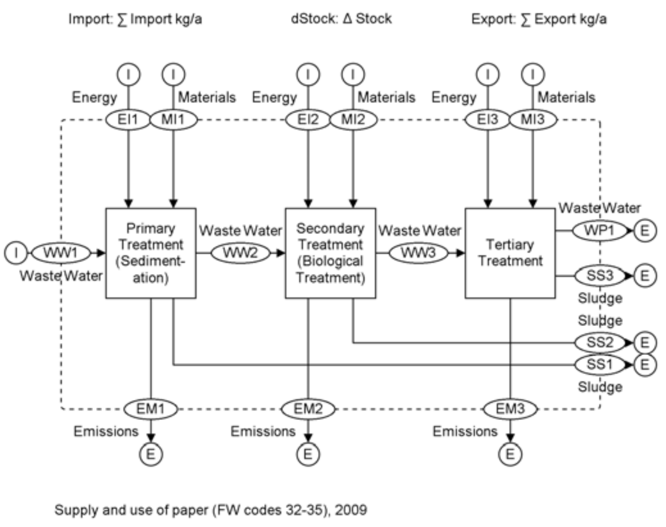

Figure 22 Scheme of a Waste Water Treatment Plant

Common municipal systems do receive both, waste water from industries and waste water from other sources, hence municipal waste water (cp. Haberl et al. 2009).

In a WWTP, municipal waste water is treated in different steps (cp. Doka 2007; Haberl et al. 2009; Bischofsberger et al. 2001):

- Primary treatment – this is usually treatment based on physical principles, such as mechanical separation (screen) or sedimentation (sand and smaller particles in a sedimentation tank).
- Secondary treatment – this is usually biological treatment, where with the aid of microorganisms organic carbon and also nitrogen is removed (batch reactor, biological filter)
- Tertiary treatment – with chemical agents, phosphate is removed from waste water through precipitation
- Additional treatment – after the steps mentioned above, additional measures can be applied, such as ozone or ultraviolet treatment, in order to reduce the discharge of pathogens; however, these treatments can be rarely found, as they are kind of costly

4.7.2 System Boundary of the Module

The system does not regard the waste water collection, hence the waste water treatment only is considered. Thus, the system boundary starts at the sewer inlet into the WWTP.

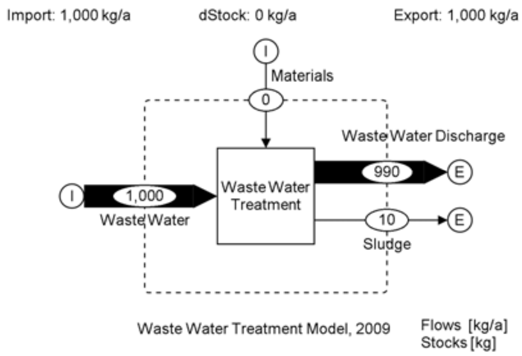

Figure 23 WWTP, material flows based on values from Haberl et al. 2009, wich a dry matter content of sludge of 5% and an dry matter content in the input of 0.095% (=0.19 kg/capita/day)

In the WWTP, the waste water is treated through primary and secondary treatment, hence reduction of organic carbon and nitrogen. Primary treatment consists of settling tanks, secondary treatment of an activated sludge tank. The tertiary treatment is assumed only to be partially installed, thus only 30% of the waste water does receive a phosphorus precipitation. This is a hypothetical assumption in order to reflect common practise.
Imports into the systems are waste water, materials (e.g. iron oxides for precipitation), energy, while the exports are primary, secondary and tertiary sludge and the discharged cleaned waste water respectively.
The base unit for the calculation is 1 kg waste water. The dry matter content in the input is 0.095%, the dry matter content in the sludge 5% (Haberl et al. 2009). The element flow can then also be presented for the functional unit of 1 kg dry matter in waste water input. The waste water is assumed to be a mixture of industrial and municipal waste water.

4.7.3 Process Description

As mentioned before, the module contains of primary, secondary and tertiary treatment (cp. Doka et al. 2007). In primary treatment, the waste water is send through a settling basin. There, primary sludge is collected and send to the sludge treatment, meaning outside of the module boundary. Therefore, electricity is used, for instance to pump the sludge.
In the secondary treatment, the waste water is send to an activated sludge tank. This tank is aerated, and dissolved or particles which did not settle in the primary stage, are partially digested herein. The release to the atmosphere consists of nitrogen compounds and carbon dioxide. Energy is consumed for the aeration of the tank.
The tertiary treatment consists of a separate phosphorus precipitation (cp. Doka et al. 2007). Only 30% of waste water is hypothetically treated, with an treatment efficiency of 70% (cp. Doka et al. 2007). Therefore, not only energy, but also a precipitation agent is required. This is either an aluminium or an iron compound. Herein, we assume an iron compound. The amount of precipitation agents is 7.5 g $FeSO_4$ per g phosphorus which is removed (Doka et al. 2007; Haberl et al. 2009).

The total amount of sewage sludge was calculated based on Haberl et al. (2009) with 100 g/capita/day, which is based on the assumption of 200 kg waste water per capita and day and a 5% dry matter content in the sludge, 0.0005 kg dry matter / kg waste water or 0.01 kg raw sludge/kg waste water.

The electricity demand of the system is due to pumping and aeration. According to Doka et al. (2007), an electricity demand of 0.28 kWh/m³ waste water, whereas 70% is for aeration, 20% for the sludge digestion and 10% for pumping. As sludge digestion is not considered in this module, the final electricity demand is 0.22 kWh/m³ waste water or 0.000224 kWh/kg waste water or $2.1*10^{-7}$ kWh/kg waste water dry matter.
The oil demand for pumps is, according to Doka et al. (2007) assumed to be 0.14 MJ/m³ waste water or 0.000039 kWh/kg waste water or $3.7*10^{-8}$ kWh/kg waste water dry matter.

Doka et al. (2007) gives transfer coefficients for different substances. Unlike other processes before, not the total elemental composition, hence also not all transfer coefficients of elements where collected. That is due to the fact that the model as programmed by the project partners did not require most of the substances and only some of the emissions calculated. Those average transfer coefficients are listed in Table 41.

Table 41 Transfer coefficients for various elements, taken from Doka et al. (2007) and own calculations for phosphorus

Substance	TCs each substance(%)			
	Wastewater input	**Degradation / Air emission**	**Effluent**	**Sewage sludge**
C	100%	25%	10%	66%
S	100%	0%	4%	96%
N	100%	5%	73%	22%
P	100%	0%	79%	21%
As	100%	0%	78%	22%
Cd	100%	0%	50%	50%
Cr	100%	0%	50%	50%
Cu	100%	0%	25%	75%
Hg	100%	0%	30%	70%
Ni	100%	0%	60%	40%
Pb	100%	0%	10%	90%
Se	100%	0%	50%	50%
Zn	100%	0%	30%	70%

Various sources are considered when determining the substance flows in this module. Thornton et al. (2001) gives values for the waste water which has to be treated. Doka et al. (2007) gives substance flow schemes for the waste water treatment process for the elements of carbon, sulphur, nitrogen and phosphorus. Phosphorus and nitrogen are shown in PO_4-P and Kjeldahl nitrogen. Table 42 and Table 43 show the substance flows. The input was selected due to Haberl et al. (2009), Doka et al. (2007) and Thornton et al. (2001). The transfers to air, effluent and sewage sludge was calculated based on Table 41.

Table 42 Substance flows through the WWTP in (kg/kg waste water raw)

Substance	Waste Type (kg/kg wastewater raw)			
	Wastewater input	Degradation / Air emission	Effluent	Sewage sludge
Water[1]	0.99905			
Dry matter[1]	0.00095			
C[2]	6.73E-05	1.65E-05	6.53E-06	4.43E-05
S[2]	4.60E-05	0.00E+00	1.98E-06	4.40E-05
N[2]	2.81E-05	1.46E-06	2.04E-05	6.26E-06
P[2]	3.07E-06	0.00E+00	2.43E-06	6.45E-07
As[3]	2.20E-09	0.00E+00	1.72E-09	4.84E-10
Cd[3]	3.00E-08	0.00E+00	1.50E-08	1.50E-08
Cr[3]	3.00E-06	0.00E+00	1.50E-06	1.50E-06
Cu[3]	1.00E-05	0.00E+00	2.50E-06	7.50E-06
Hg[3]	5.00E-09	0.00E+00	1.50E-09	3.50E-09
Ni[3]	1.00E-07	0.00E+00	6.00E-08	4.00E-08
Pb[3]	1.00E-07	0.00E+00	1.00E-08	9.00E-08
Se[3]	4.00E-10	0.00E+00	2.00E-10	2.00E-10
Zn[3]	1.50E-06	0.00E+00	4.50E-07	1.05E-06

[1]Haberl et al. 2009, [2]Doka et al. 2007, [3]Thornton et al. 2001

Table 43 Substance flows through the WWTP in (kg/kg waste water dry matter)

Substance	Waste Type (kg/kg wastewater dry matter)			
	Wastewater input	Degradation / Air emission	Effluent	Sewage sludge
C[2]	7.08E-02	1.74E-02	6.87E-03	4.66E-02
S[2]	4.84E-02	0.00E+00	2.08E-03	4.63E-02
N[2]	2.95E-02	1.54E-03	2.14E-02	6.59E-03
P[2]	3.24E-03	0.00E+00	2.56E-03	6.79E-04
As[3]	2.32E-06	0.00E+00	1.81E-06	5.09E-07
Cd[3]	3.16E-05	0.00E+00	1.58E-05	1.58E-05
Cr[3]	3.16E-03	0.00E+00	1.58E-03	1.58E-03
Cu[3]	1.05E-02	0.00E+00	2.63E-03	7.89E-03
Hg[3]	5.26E-06	0.00E+00	1.58E-06	3.68E-06
Ni[3]	1.05E-04	0.00E+00	6.32E-05	4.21E-05
Pb[3]	1.05E-04	0.00E+00	1.05E-05	9.47E-05

Se[3]	4.21E-07	0.00E+00	2.11E-07	2.11E-07
Zn[3]	1.58E-03	0.00E+00	4.74E-04	1.11E-03

[1]Haberl et al. 2009, [2]Doka et al. 2007, [3]Thornton et al. 2001

4.7.4 Emissions derived from waste water treatment

Various emissions occur during WWT. Emissions derived from WWT are either compounds of nitrogen, carbon, and sulphur or shown in elemental values. Doka et al. (2007) provides a list of emissions, which is crosschecked by data from Haberl et al. (2009). Hence, the most important emissions are:

Table 44: Relevant emissions of waste water treatment

Emission Type	kg/kg raw ww	kg/kg ww dry matter	to	Source
Carbon dioxide	$6*10^{-5}$	$6.4*10^{-2}$	air	Doka et al. (2007)
Methane	0	0	air	IPCC 2006
Dinitrogen Oxides	$4.4*10^{-5}$	$8.8*10^{-4}$	air	IPCC 2006
Ammonia	0	0	air	Doka et al. (2007)
Hydrogen Sulfide	0	0	air	Doka et al. (2007)
Phosphorus (P)	$2.43*10^{-6}$	$2.56*10^{-3}$	water	Doka et al. (2007)
Nitrogen (N)	$2.04*10^{-5}$	$2.14*10^{-2}$	water	Doka et al. (2007)
Copper (Cu)	$2.5*10^{-6}$	$2.6*10^{-3}$	water	Doka et al. (2007); Thornton et al. (2001)

4.7.5 Best available technique

The European Commission has not BAT document on waste water treatment, except waste water from industrial processes. However, some considerations regarding BAT can be made herein.

It is widely recognized that the primary and secondary stage are absolutely necessary. However, the first step is to connect the households to the plant, as claimed through the water framework directive (European Council and European Parliament 2000). If the waste water is collected, at least the primary and secondary treatment is required, in order to meet the emission values for nitrogen and organic carbon.

There is also the claim that enhanced phosphorus precipitation should be implemented. Thus, not the installation value of 30% as used here, but 80% can be achieved, in order to protect water bodies from eutrophication (Haberl et al. 2009). The removal efficiency is 70%, which would lead to following emissions.

Table 45: Phosphorus release under different phosphorus precipitation installation rates

Installation rate (%)	30%	50%	80%	Unit
P-Release to hydrosphere	$2.43*10^{-6}$	$2.00*10^{-6}$	$1.08*10^{-6}$	kg/kg raw wastewater
P-Release to hydrosphere	$2.56*10^{-3}$	$2.10*10^{-3}$	$1.13*10^{-3}$	kg/kg waste water dry matter

Other installations, such as reverse osmosis for removal of heavy metals or disinfection is not considered, but can be also used. However, the energy demand will increase significantly with these installations.

4.8 Impacts of BAT

Through the implementation of BAT, significant reductions of emissions, but also of resource use, can be expected. In chapter 4, BAT has been briefly described. This chapter summarizes the impacts through using BAT as described in the modules.
The impacts reduction is summarized in Table 46.

Table 46 Summary emission reduction and energy efficiency through BAT

Module	Emission	to	unit	BAT low growth	BAT medium growth	BAT high growth
Waste incineration	CO	air	kg/kg dm input	0.00050	0.00050	0.00013
	NO_X	air	kg/kg dm input	0.0030	0.0015	0.0012
	NH_3	air	kg/kg dm input	0.000050	0.000050	0.0000035
	PM	air	kg/kg dm input	0.00015	0.0001	0.000004
	SO_2	air	kg/kg dm input	0.001	0.00075	0.000011
Landfill	nd	nd	kg/kg dm input	nd	nd	nd
Composting	nd	nd	kg/kg dm input	nd	nd	nd
Biogas	Electricity demand	-	kWh/kg dm input	0.25	0.135	0.135
Application Manure	NO_X	air	kg/kg dm input	0.00043	0.00041	0.00038
	N_2O	air	kg/kg dm input	0.0020	0.0019	0.0018
	NH_3	air	kg/kg dm input	0.0079	0.0075	0.0071
Manure storage	NH_3	air	kg/kg dm input	0.0028	0.0022	0.0017
WWT	P	water	kg/kg dm input	0.0026	0.0021	0.0013

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Sakar, S., Yetilmezsoy, K. and E. Kocak, 2009, Anaerobic Digestion Technology in Poultry and Livestock Waste Treatment – A Literature Review, Waste Management and Research, vol. 27, pp. 3-18.

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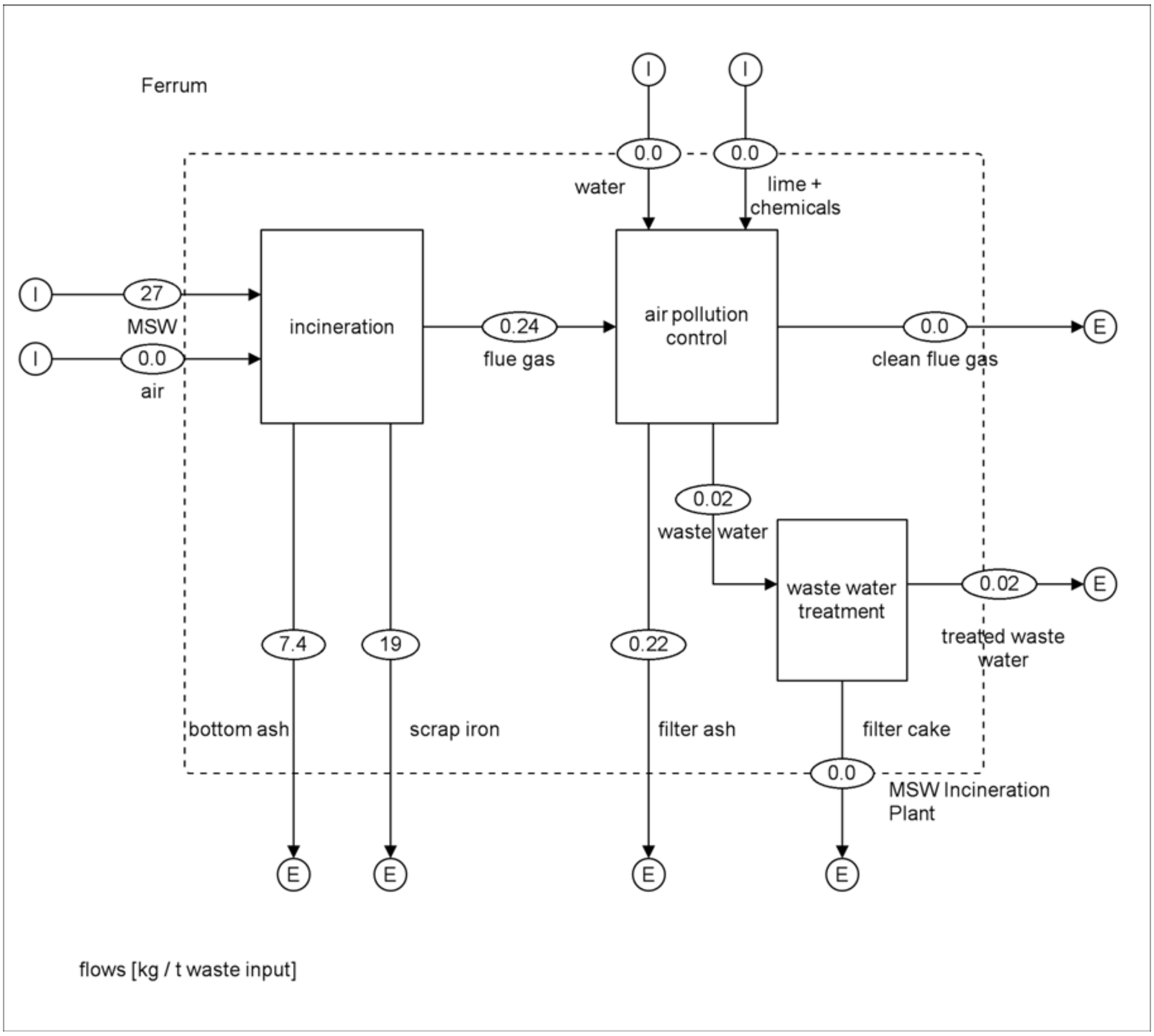
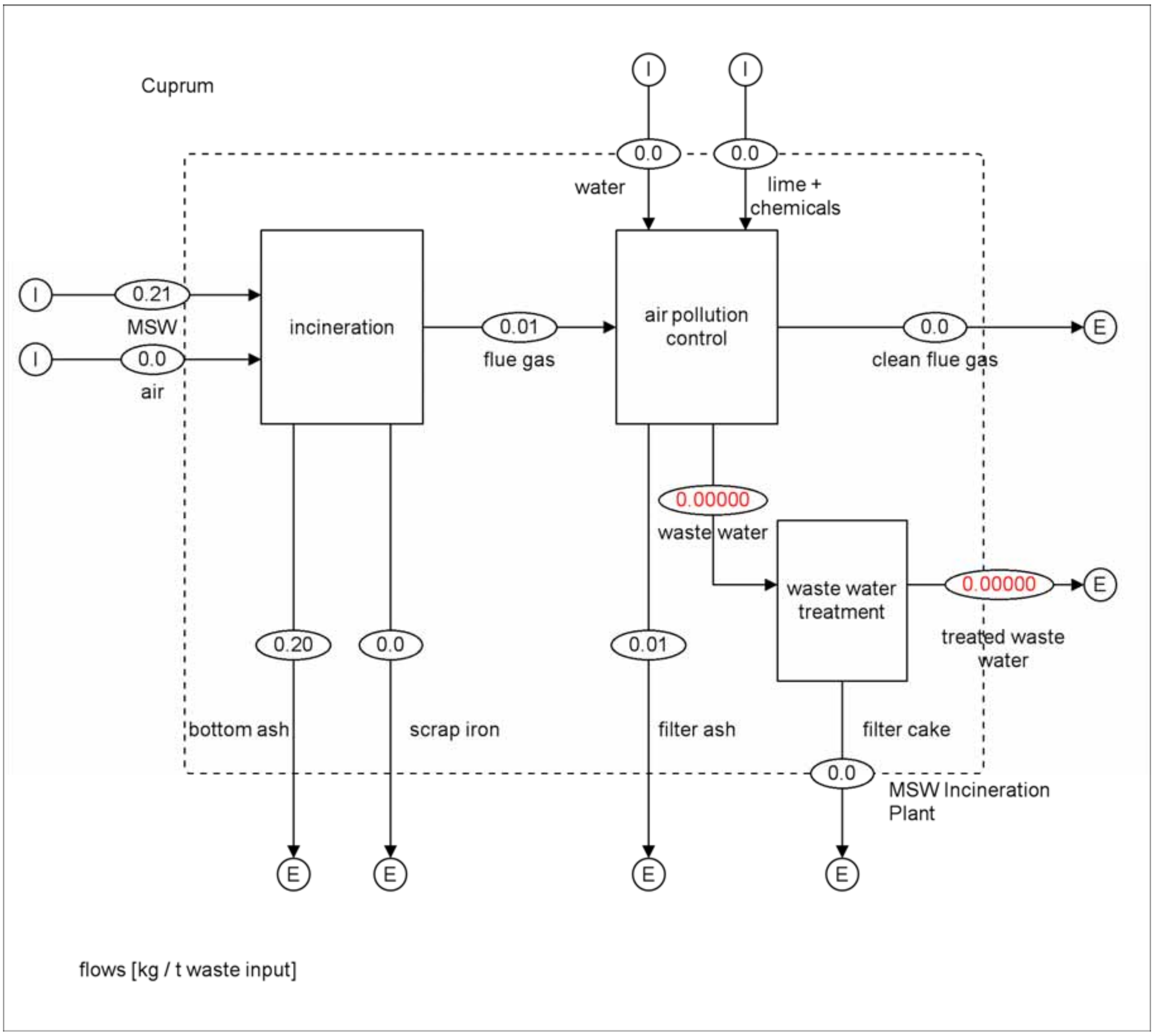
6 ANNEX I: Substance flows

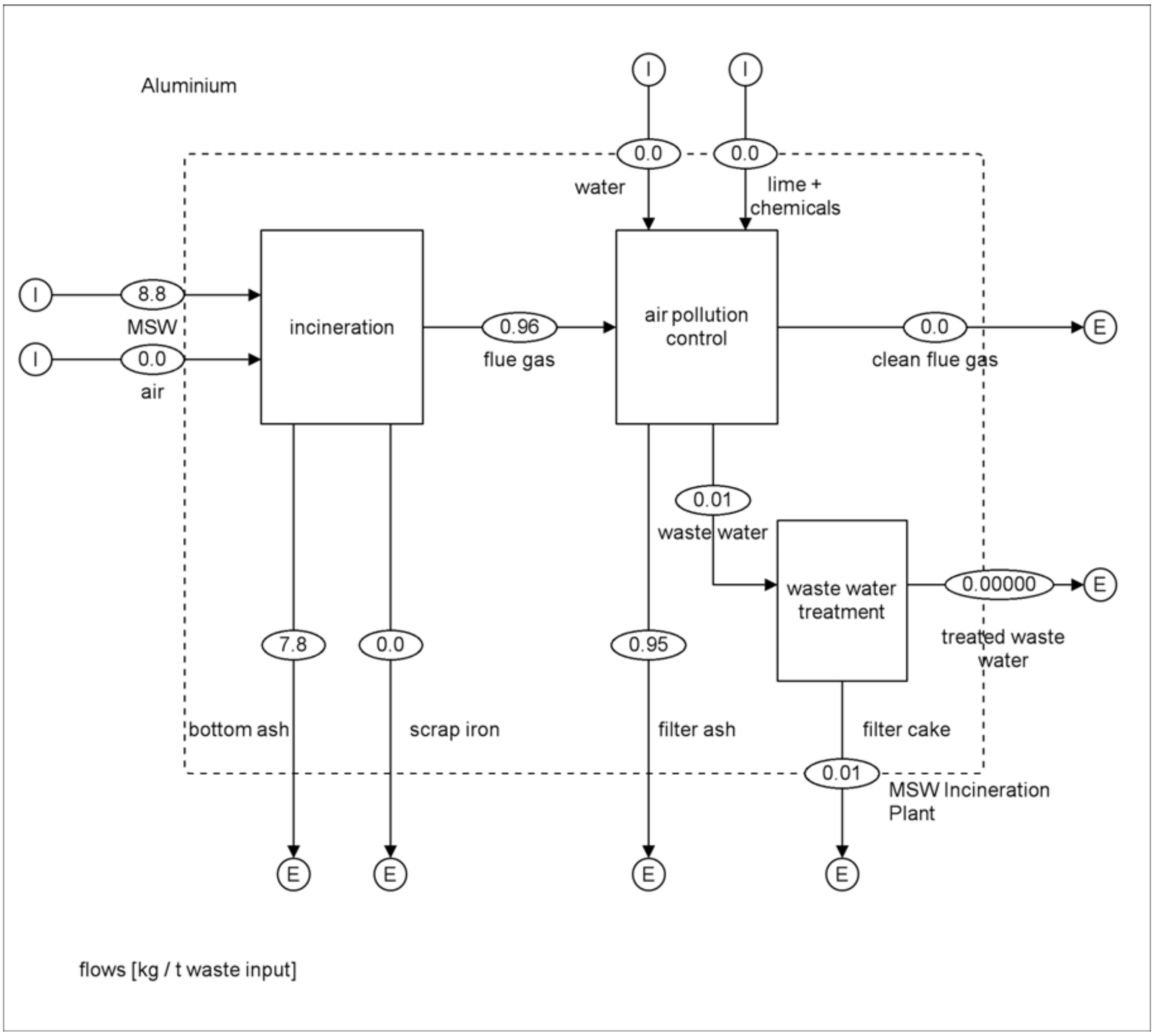
6.1 Incineration and mechanical-biological treatment

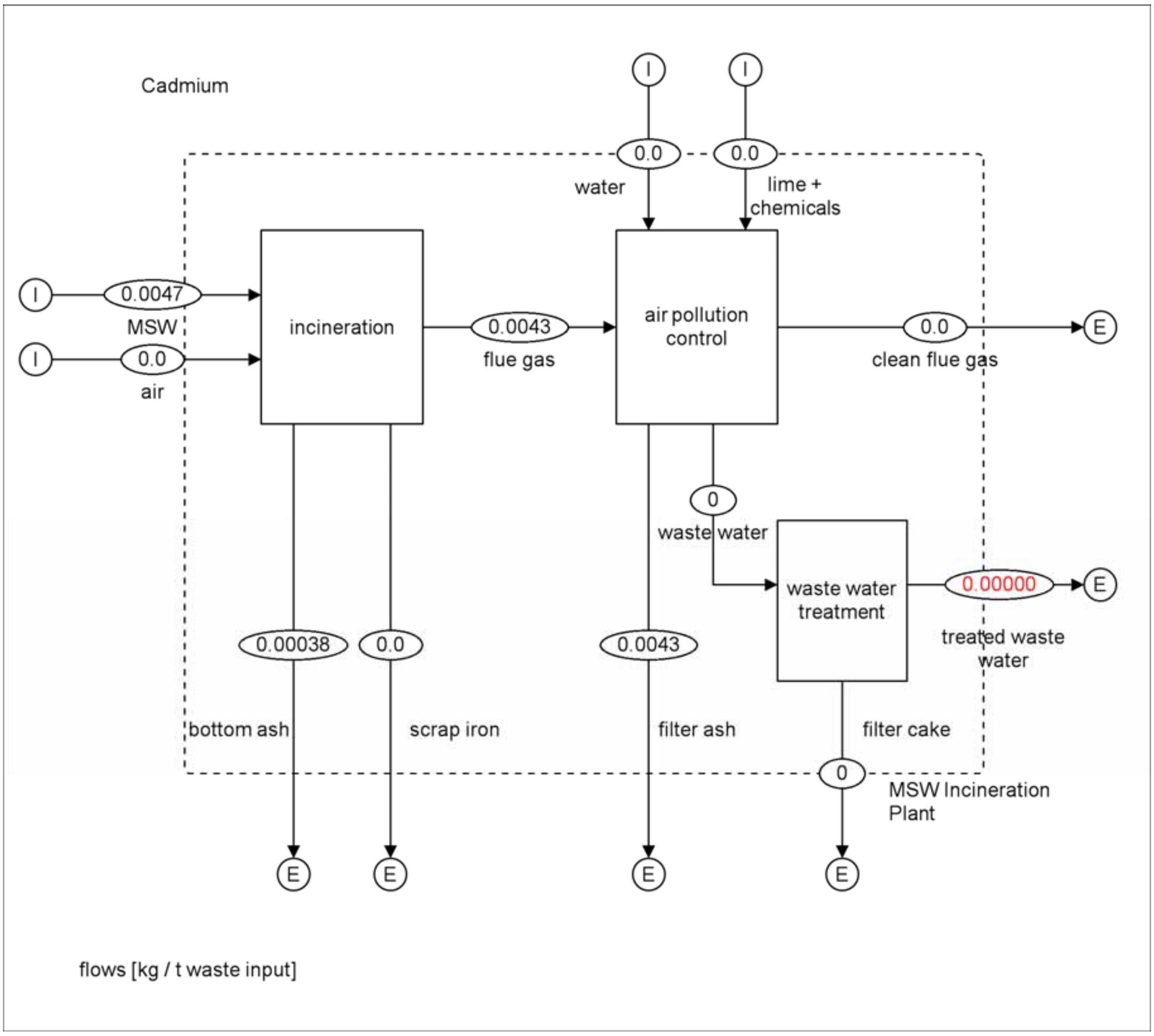
6.1.1 Incineration

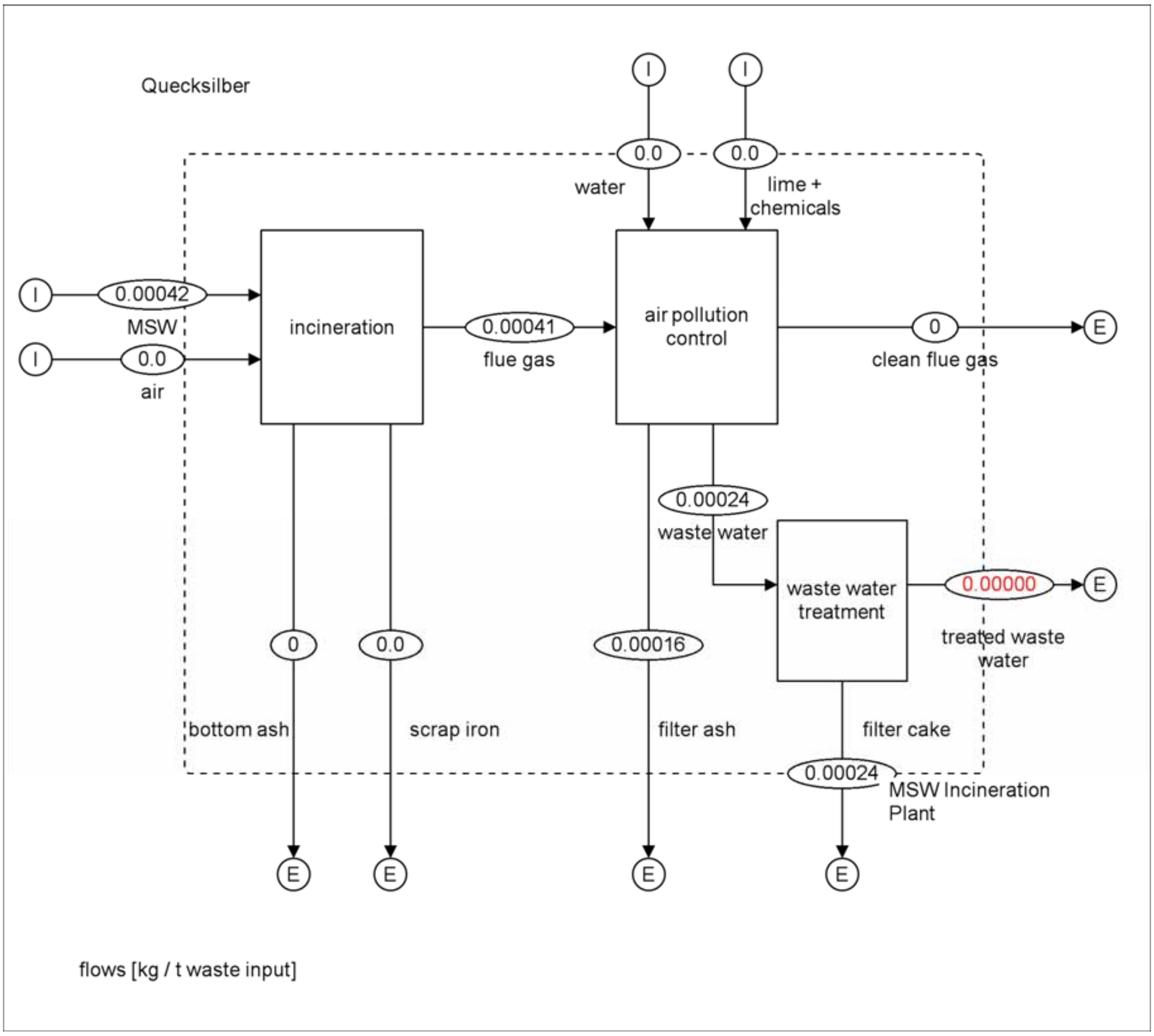
In the following figures the system of MSW incineration at MSW plants is shown with values of 6 different metals: three potential raw materials / resources (iron / Fe, copper / Cu, and Aluminium / Al) and three harmful substances (cadmium / Cd, mercury / Hg, and lead / Pb).

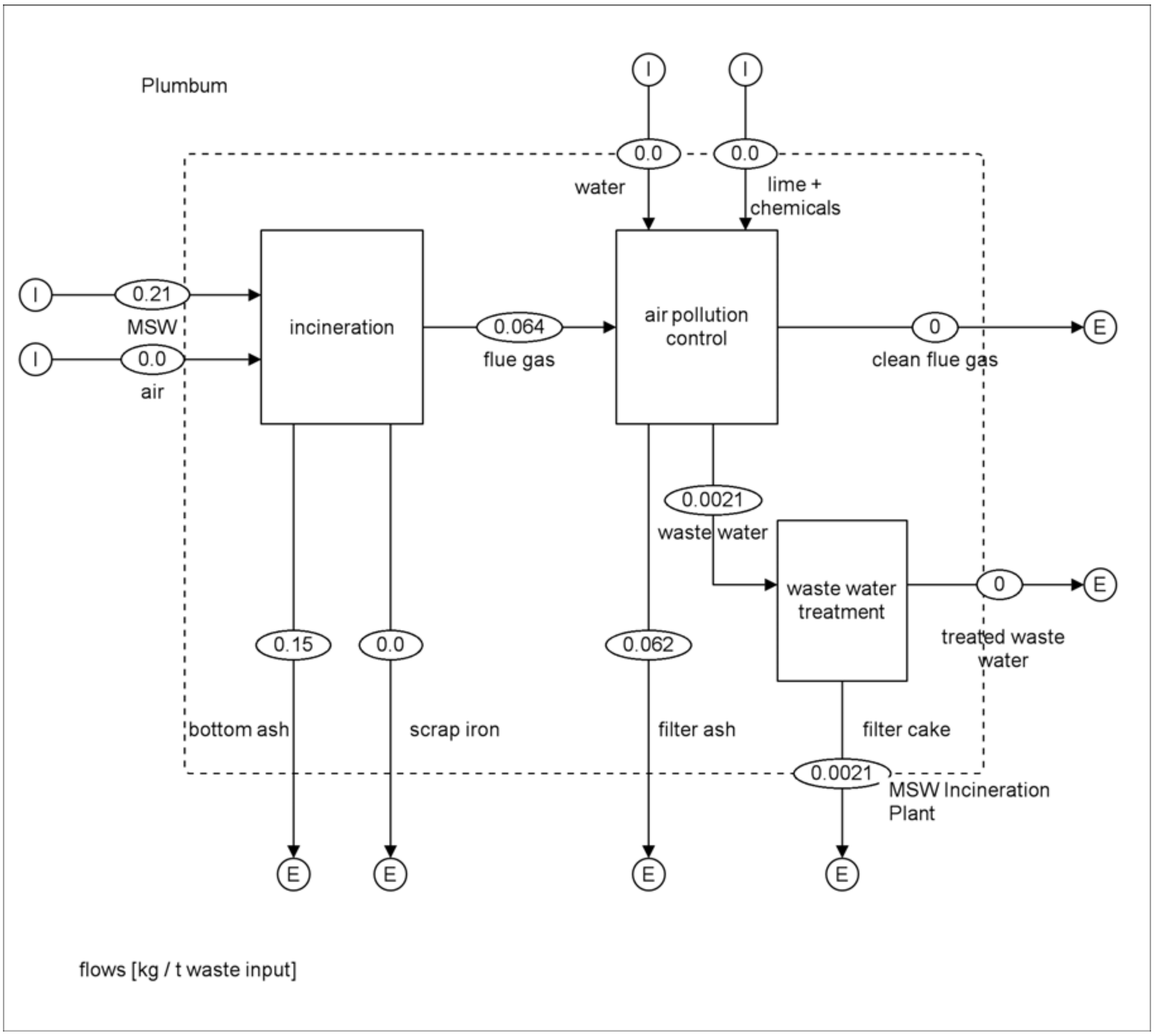



Cuprum
I
I
0.0
0.0
water
lime +
chemicals
I
0.21
MSW
I
0.0
air
incineration
0.01
flue gas
air pollution
control
0.0
clean flue gas
E
0.00000
waste water
waste water
treatment
0.00000
E
treated waste
water
0.20
0.0
0.01
bottom ash
scrap iron
filter ash
filter cake
0.0
MSW Incineration
Plant
E
E
E
E
flows [kg / t waste input]


Aluminium
I
I
0.0
0.0
water
lime +
chemicals
I
8.8
MSW
I
0.0
air
incineration
0.96
flue gas
air pollution
control
0.0
clean flue gas
E
0.01
waste water
waste water
treatment
0.00000
treated waste
water
E
7.8
0.0
0.95
bottom ash
scrap iron
filter ash
filter cake
0.01
MSW Incineration
Plant
E
E
E
E
flows [kg / t waste input]

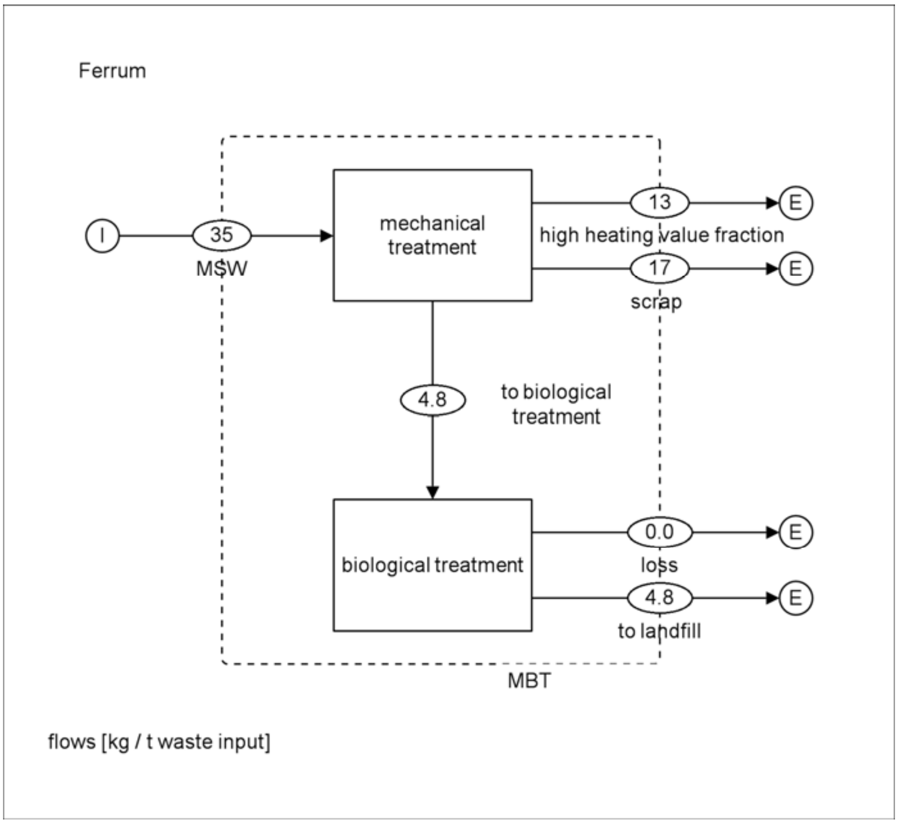

Cadmium
I
I
0.0
0.0
water
lime +
chemicals
I
0.0047
MSW
I
0.0
air
incineration
0.0043
flue gas
air pollution
control
0.0
clean flue gas
E
0
waste water
waste water
treatment
0.00000
E
treated waste
water
0.00038
0.0
0.0043
bottom ash
scrap iron
filter ash
filter cake
0
MSW Incineration
Plant
E
E
E
E
flows [kg / t waste input]

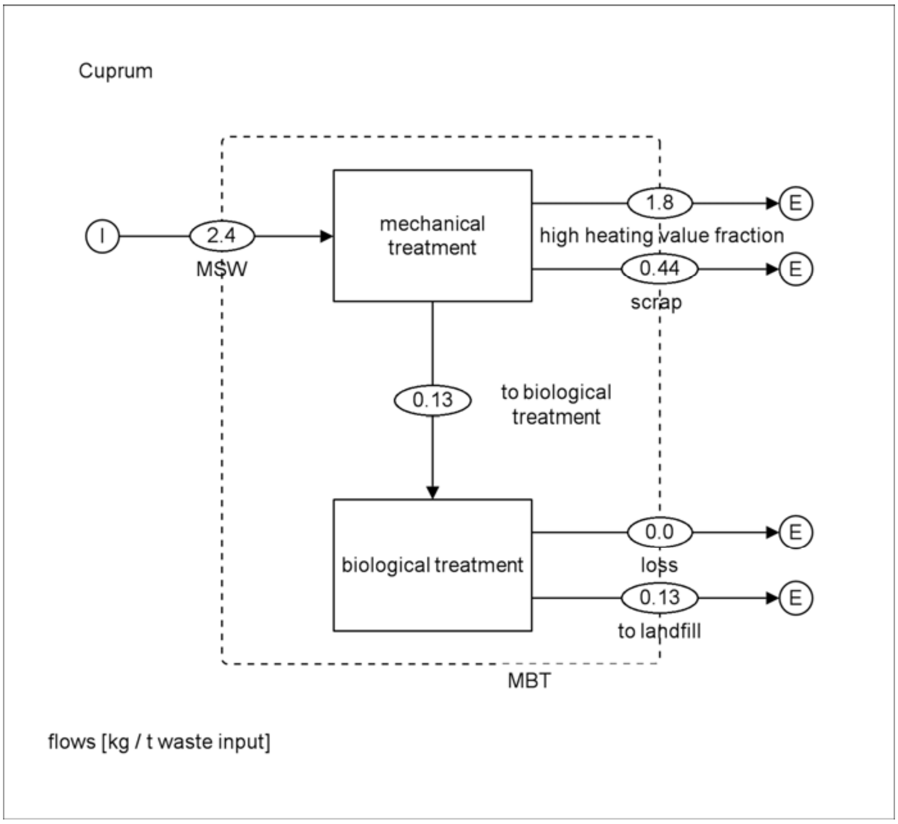

Quecksilber
I
I
0.0
0.0
water
lime +
chemicals
I
0.00042
MSW
I
0.0
air
incineration
0.00041
flue gas
air pollution
control
0
clean flue gas
E
0.00024
waste water
waste water
treatment
0.00000
E
treated waste
water
0
0.0
0.00016
bottom ash
scrap iron
filter ash
filter cake
0.00024
MSW Incineration
Plant
E
E
E
E
flows [kg / t waste input]

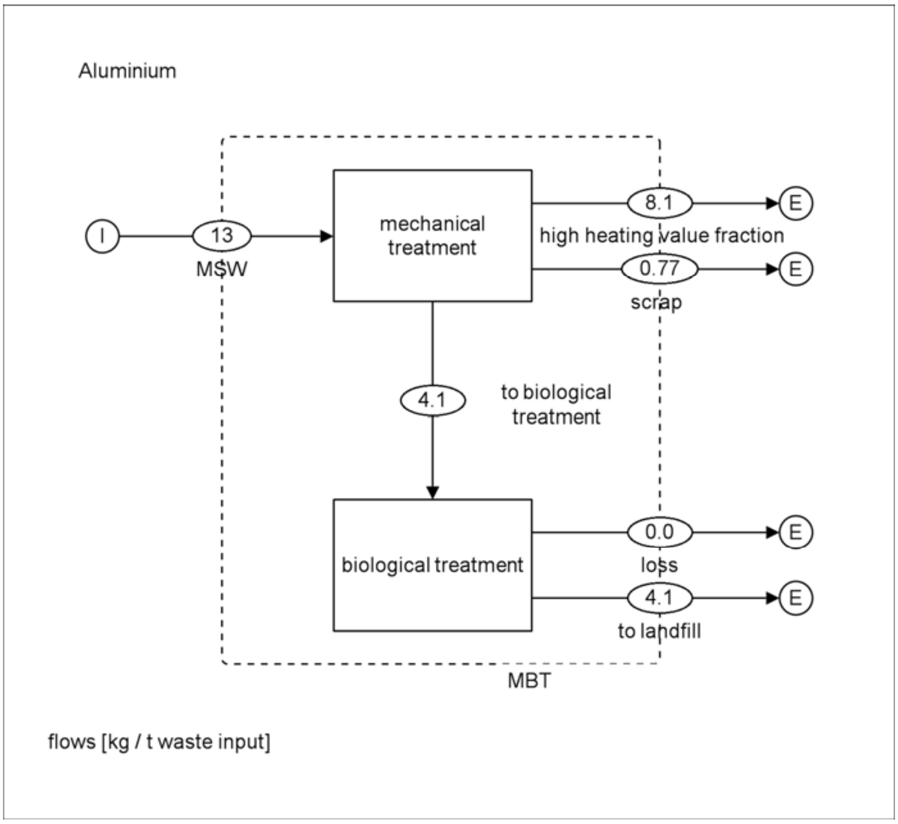


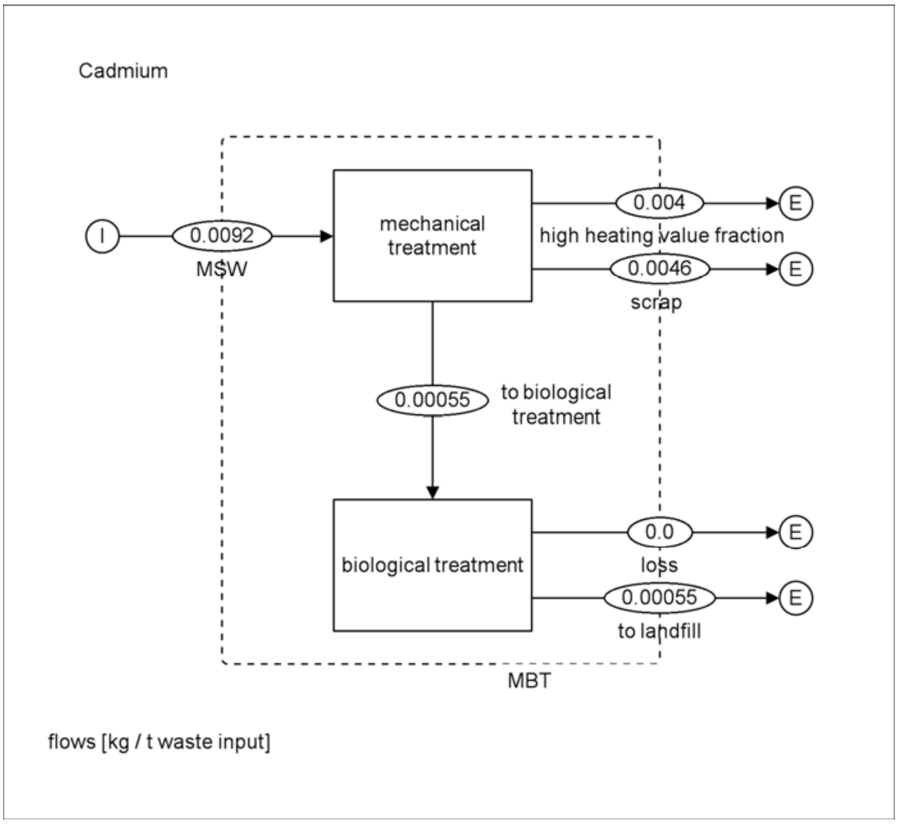
6.1.2 MBT – Mechanical Biological Treatment

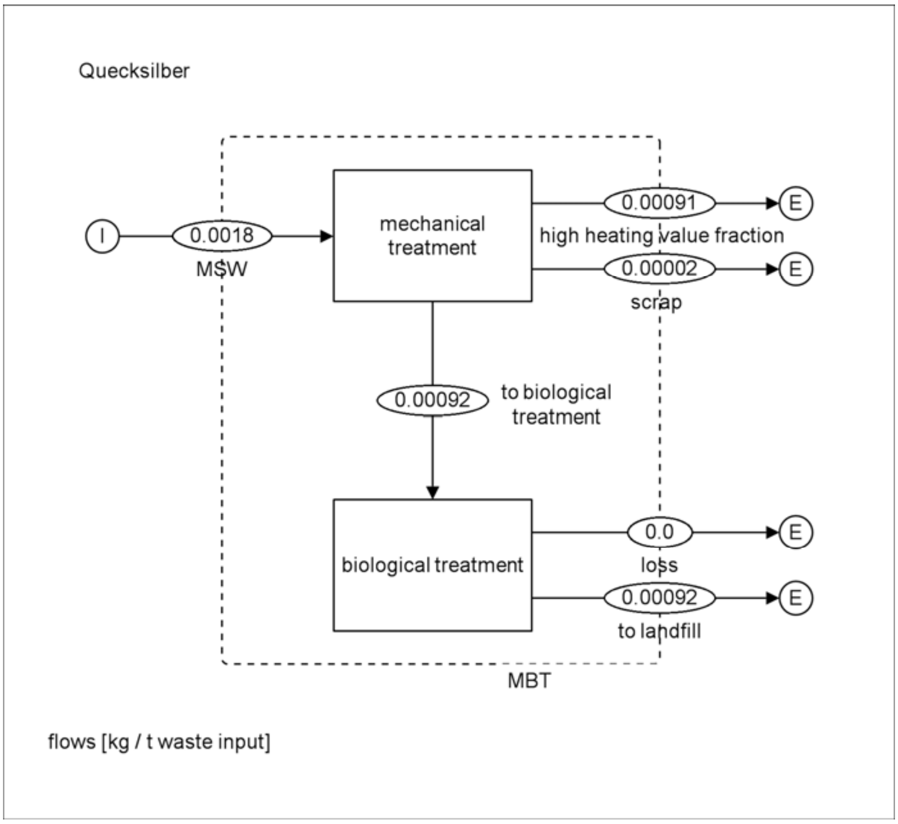
In the following figures the system of MBT is shown with values of 6 different metals: three potential raw materials / resources (iron / Fe, copper / Cu, and Aluminium / Al) and three harmful substances (cadmium / Cd, mercury / Hg, and lead / Pb). Data derives from Neubauer & Öhlinger, 2006, and Skutan & Brunner, 2006.

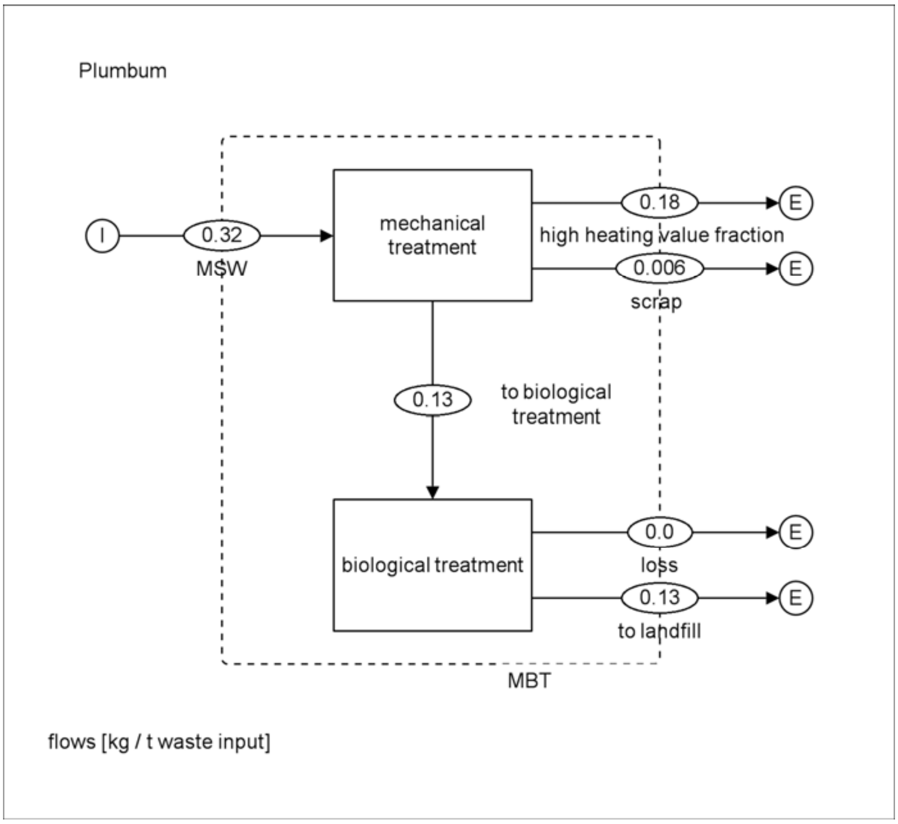

Ferrum
I
35
MSW
mechanical treatment
13
high heating value fraction
E
17
scrap
E
4.8
to biological treatment
biological treatment
0.0
loss
E
4.8
to landfill
E
MBT
flows [kg / t waste input]


Cuprum
I
2.4
MSW
mechanical treatment
1.8
high heating value fraction
E
0.44
scrap
E
0.13
to biological treatment
biological treatment
0.0
loss
E
0.13
to landfill
E
MBT
flows [kg / t waste input]


Aluminium
I
13
MSW
mechanical treatment
8.1
high heating value fraction
E
0.77
scrap
E
4.1
to biological treatment
biological treatment
0.0
loss
E
4.1
to landfill
E
MBT
flows [kg / t waste input]

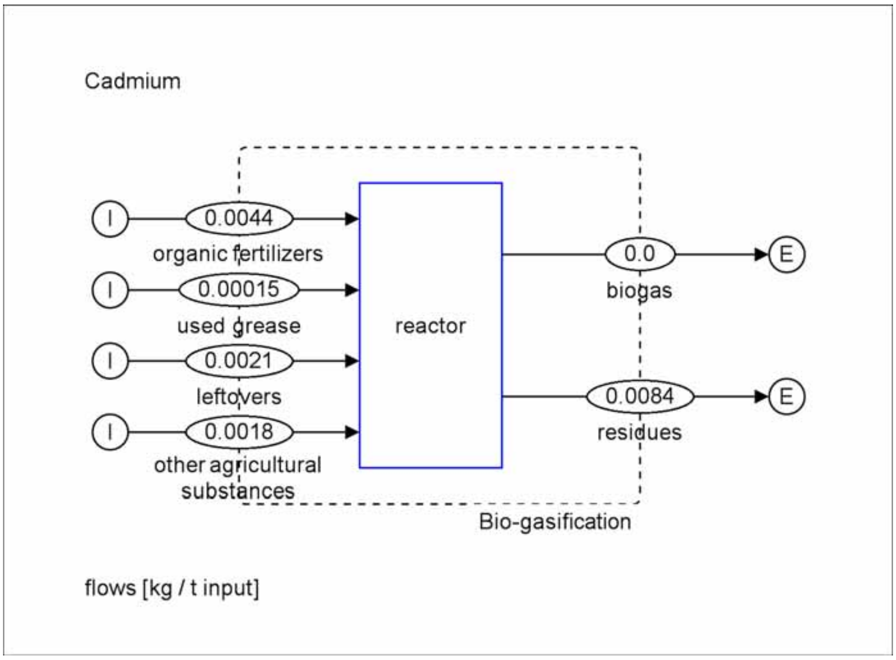

Cadmium
0.0092
MSW
mechanical treatment
0.004
high heating value fraction
0.0046
scrap
0.00055
to biological treatment
biological treatment
0.0
loss
0.00055
to landfill
MBT
flows [kg / t waste input]

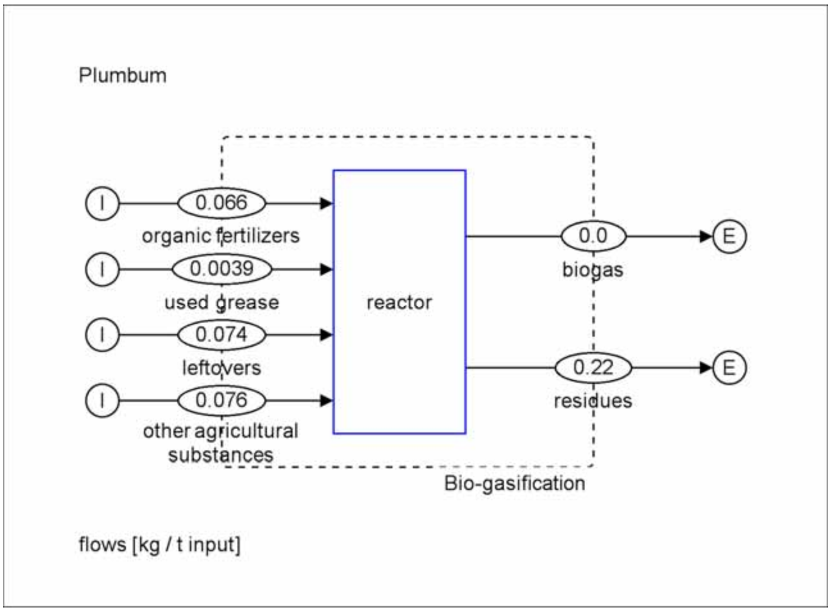

Quecksilber
0.0018
MSW
mechanical treatment
0.00091
high heating value fraction
0.00002
scrap
0.00092
to biological treatment
biological treatment
0.0
loss
0.00092
to landfill
MBT
flows [kg / t waste input]



6.2 Bio-gasification

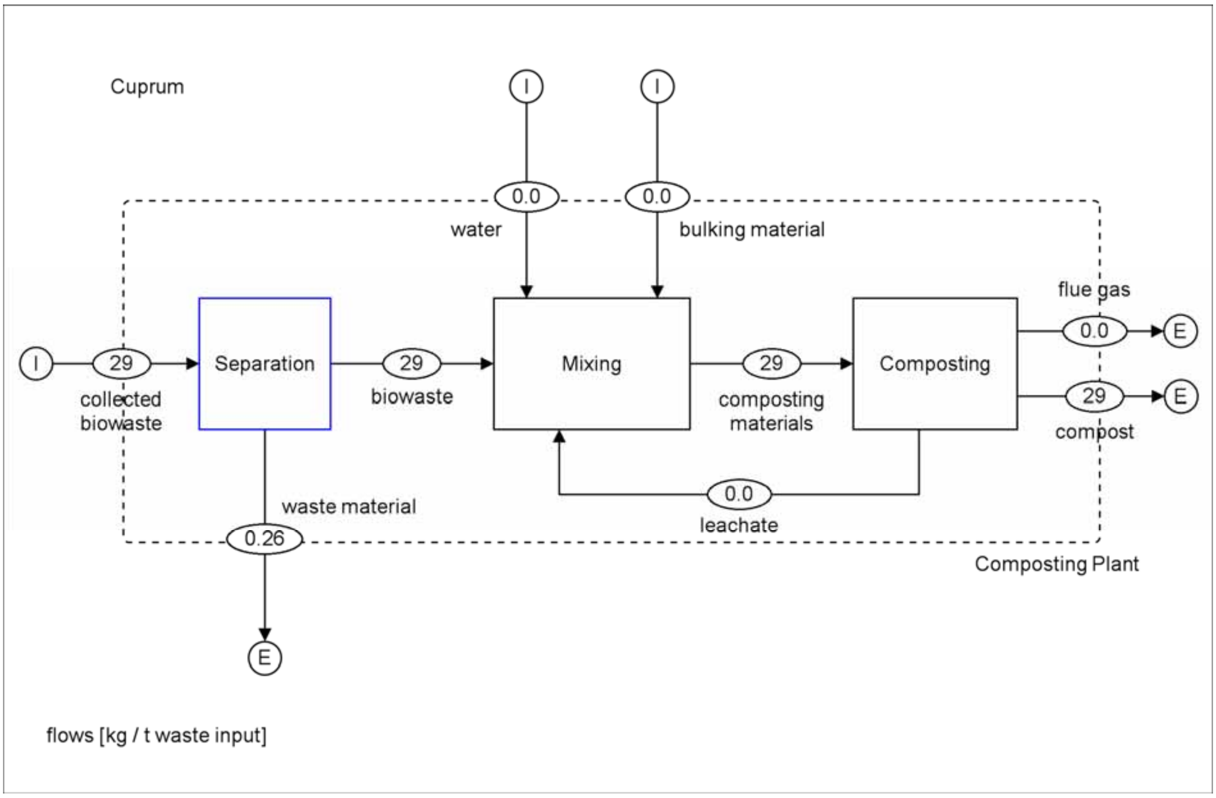
In the following figures the system of Bio-gasification is shown with values of cadmium / Cd, and lead / Pb. Data derives from Zethner et al., 2002, and Reichard, 2005.

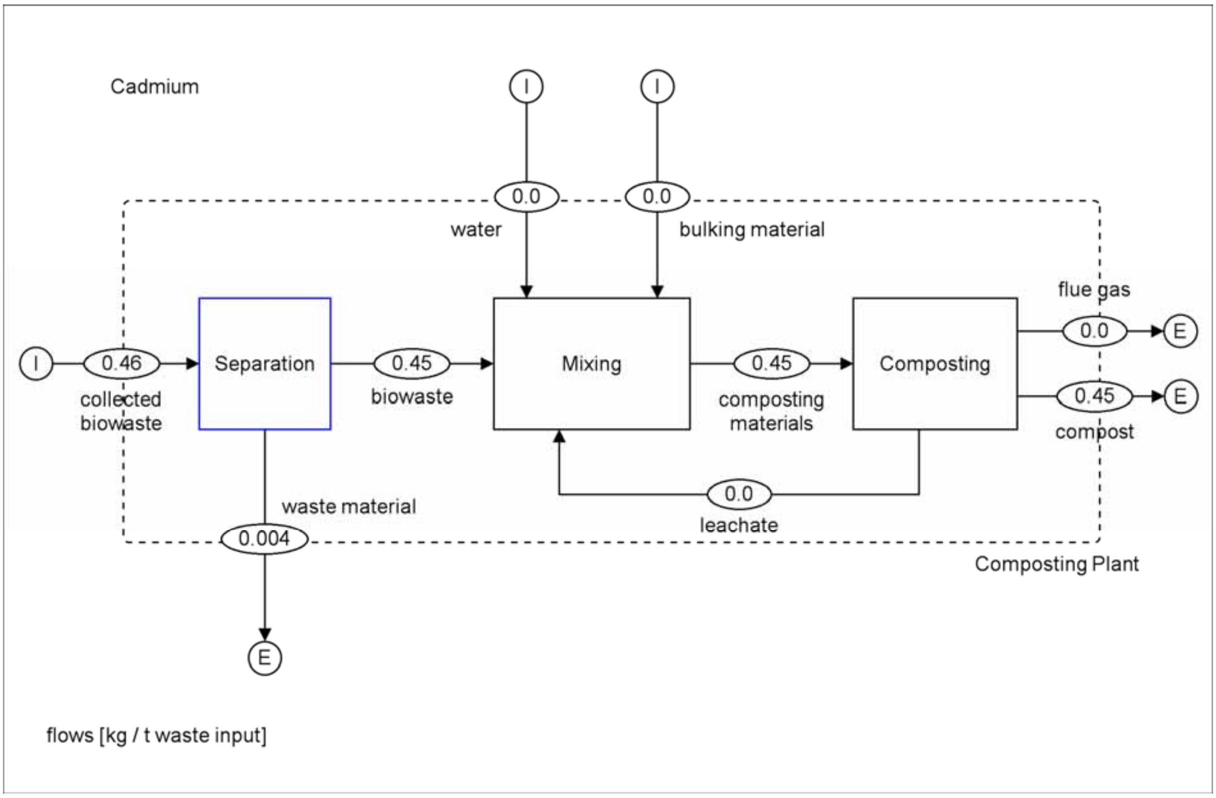


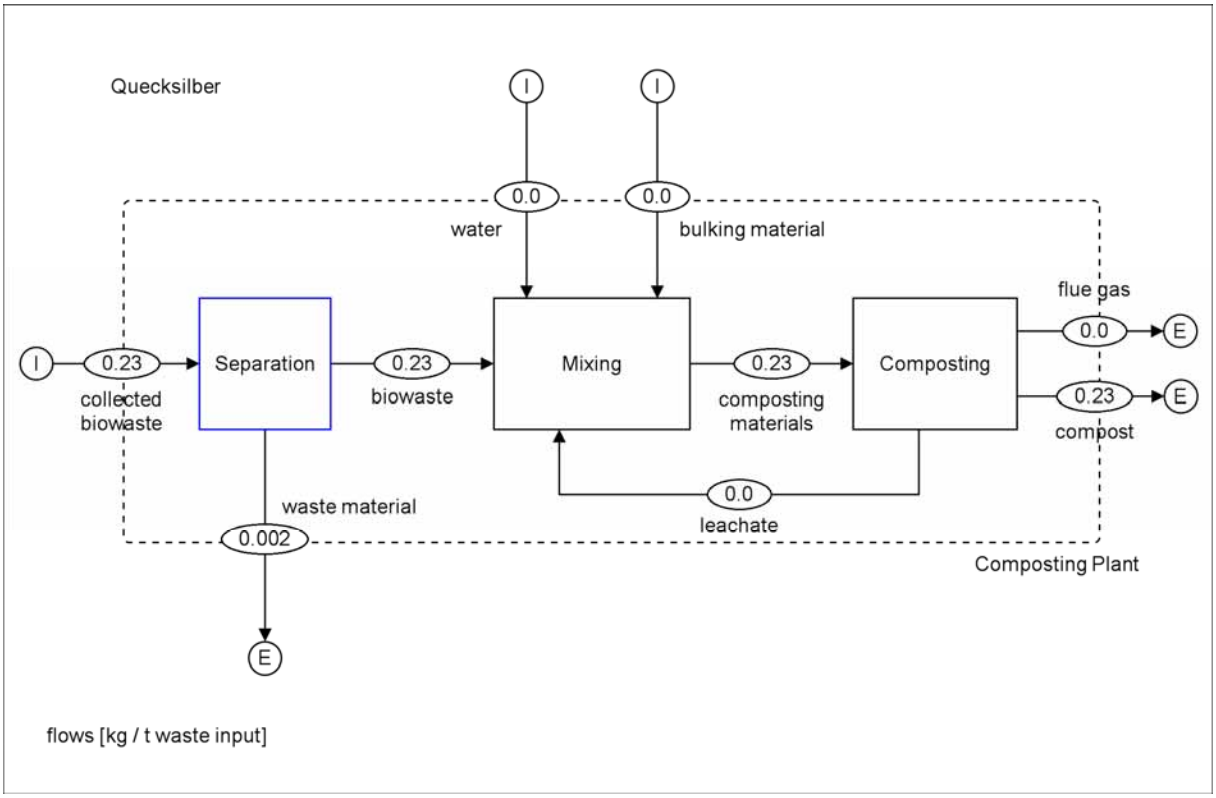


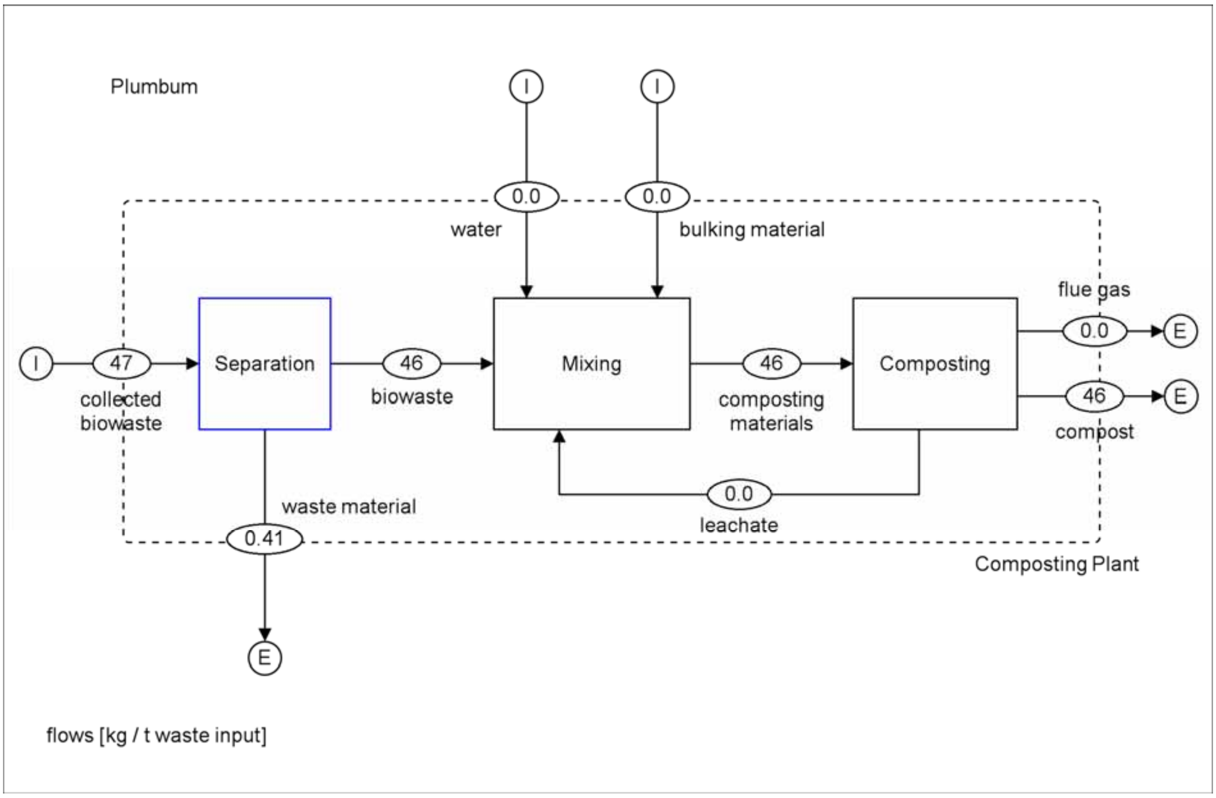
6.3 Composting

In the following figures the system of a Composting Plant is shown with values of 4 different metals: one potential raw material / resource (copper / Cu), and three harmful substances (cadmium / Cd, mercury / Hg, and lead / Pb). Data derives from Görner, & Hübner, 2002, Kontrollamt Wien, 2006.



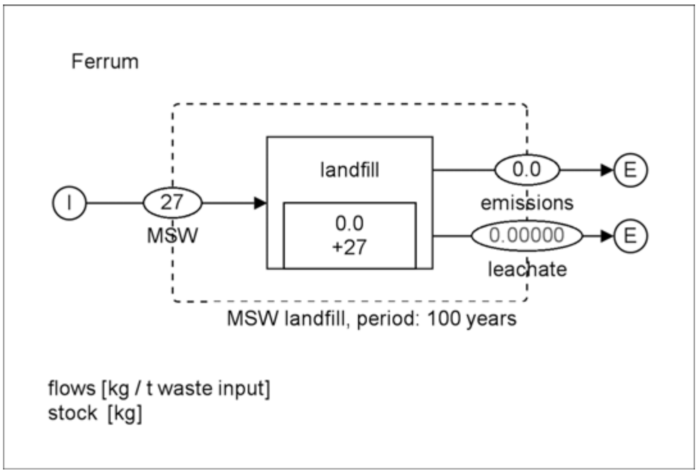

Cadmium
I
I
0.0
0.0
water
bulking material
flue gas
0.0
E
I
0.46
Separation
0.45
Mixing
0.45
Composting
0.45
E
collected
biowaste
biowaste
composting
materials
compost
waste material
0.0
leachate
0.004
Composting Plant
E
flows [kg / t waste input]

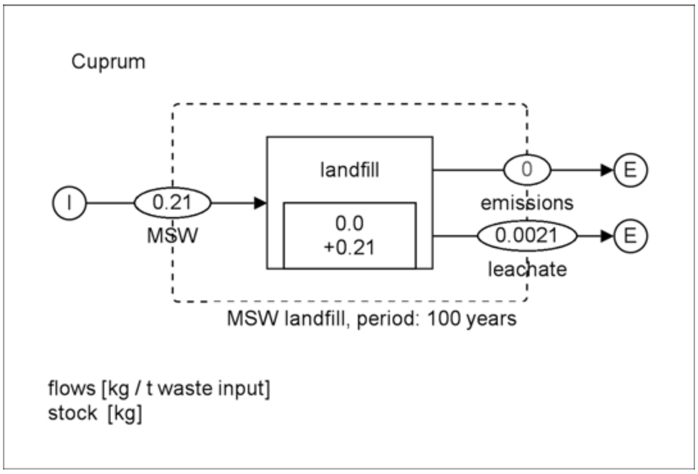

Quecksilber
I
I
0.0
0.0
water
bulking material
flue gas
0.0
E
I
0.23
Separation
0.23
Mixing
0.23
Composting
0.23
E
collected
biowaste
biowaste
composting
materials
compost
waste material
0.0
leachate
0.002
Composting Plant
E
flows [kg / t waste input]

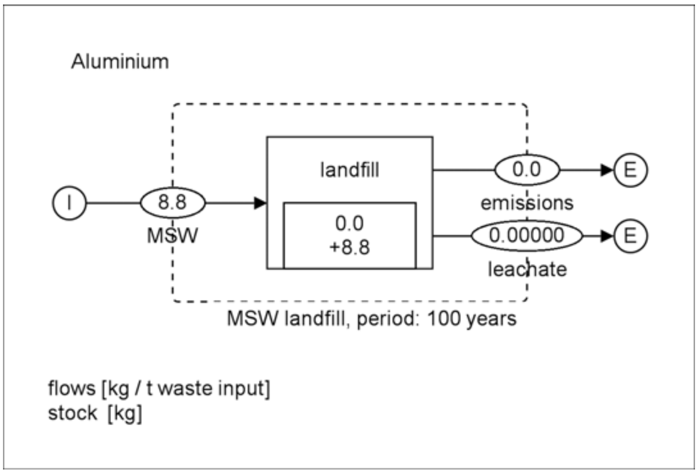


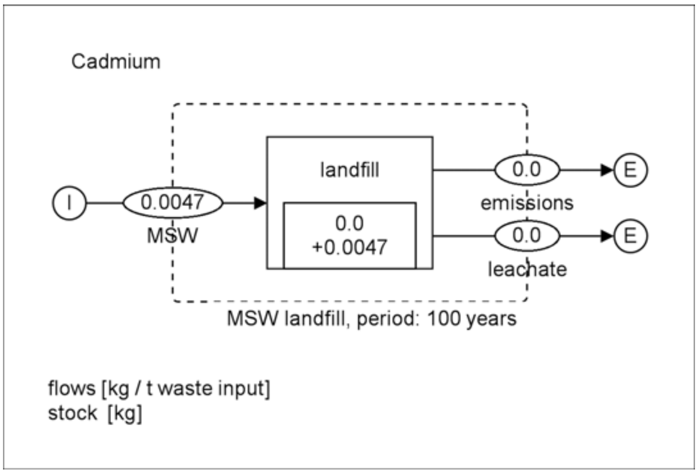
6.4 Land filling of MSW

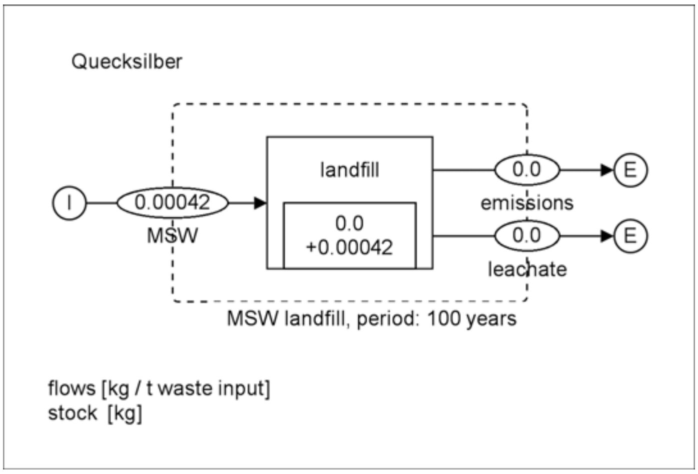
In the following figures the system of land filling of MSW is shown with values of 6 different metals: three potential raw materials / resources (iron / Fe, copper / Cu, and Aluminium / Al) and three harmful substances (cadmium / Cd, mercury / Hg, and lead / Pb). Data derives from Brunner et al., 2001.

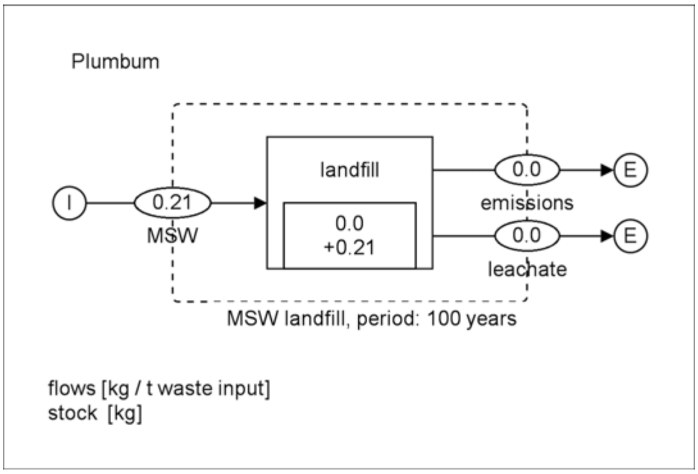



Cuprum
landfill
0.0
+0.21
I
0.21
MSW
0
emissions
0.0021
leachate
E
E
MSW landfill, period: 100 years
flows [kg / t waste input]
stock [kg]


Aluminium
landfill
0.0
+8.8
I
8.8
MSW
0.0
emissions
0.00000
leachate
E
E
MSW landfill, period: 100 years
flows [kg / t waste input]
stock [kg]


Cadmium
landfill
0.0
+0.0047
I
0.0047
MSW
0.0
emissions
0.0
leachate
E
E
MSW landfill, period: 100 years
flows [kg / t waste input]
stock [kg]





6.5 Recycling

6.5.1 Recycling of Paper

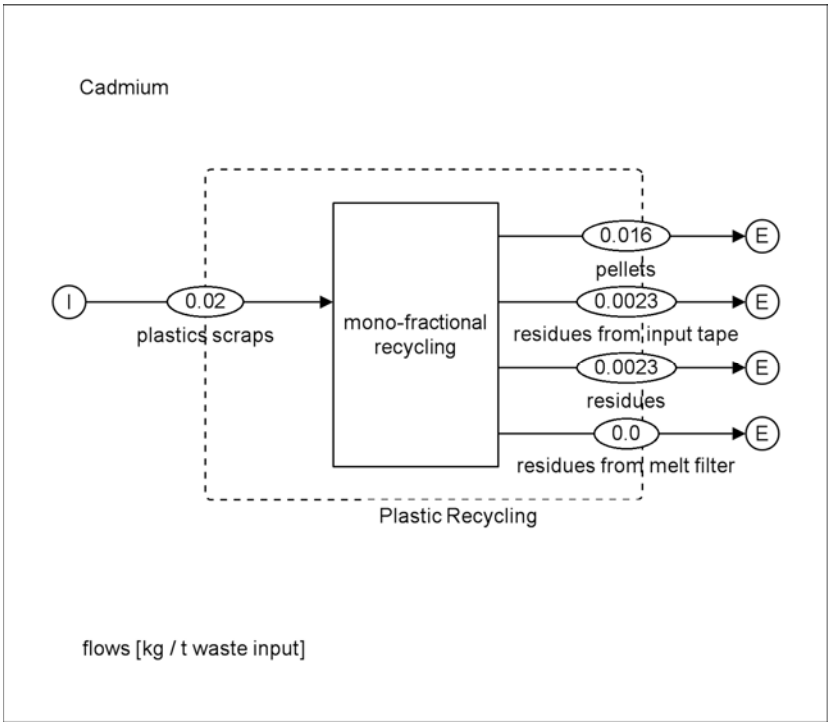
There are no figures available for the system of paper recycling.

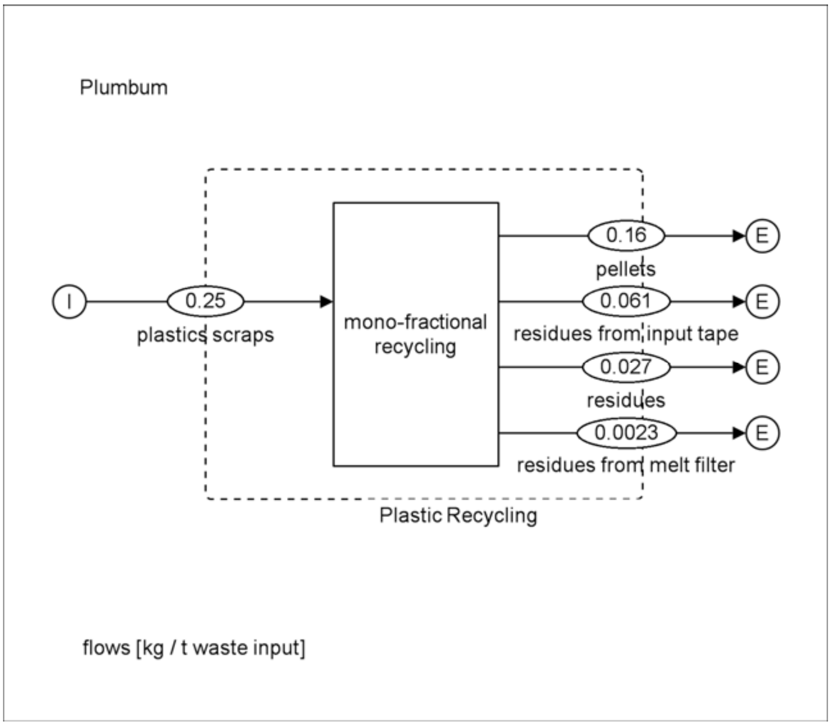
6.5.2 Recycling of Glass

There are no figures available for the system of glass recycling.

6.5.3 Recycling of Plastics

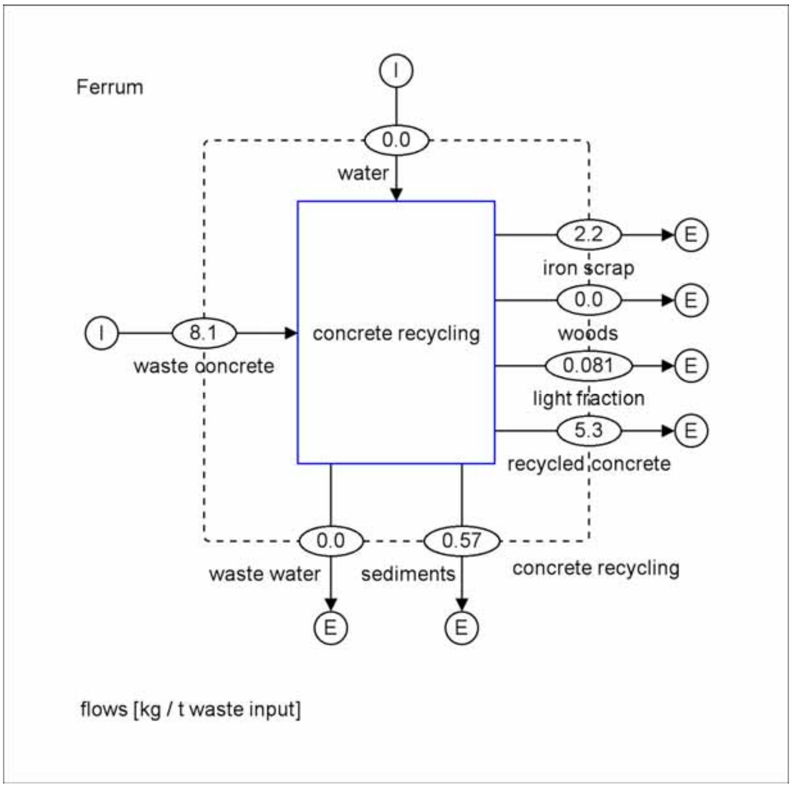
In the following figures the system of plastics recycling is shown with values of 2 different metals, which are considered as harmful substances: cadmium / Cd, and lead / Pb. Data derives from Fehringer & Brunner, 1997.

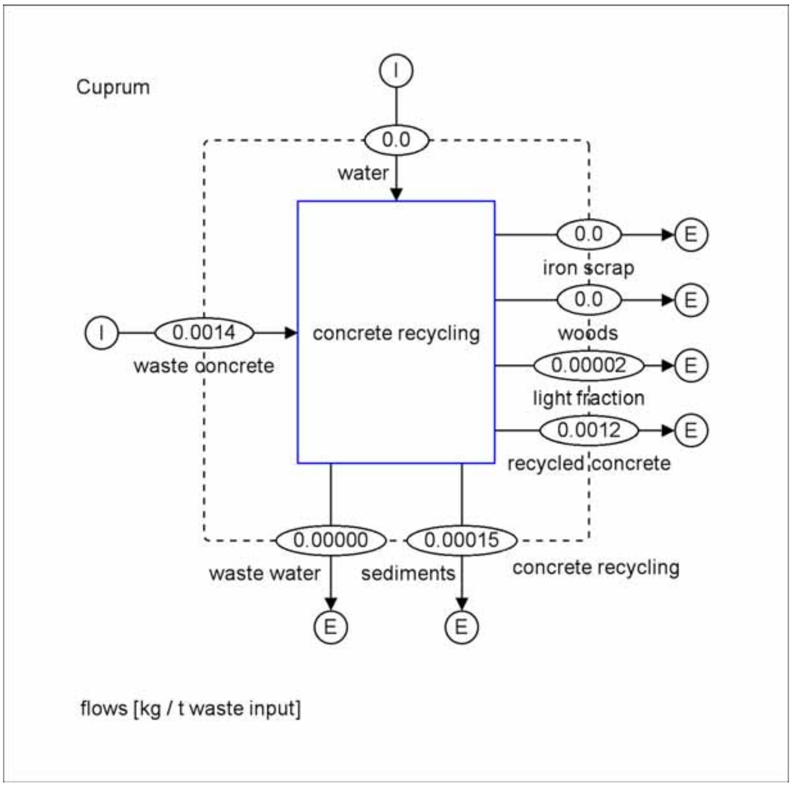

Cadmium
0.02
plastics scraps
mono-fractional recycling
0.016
pellets
0.0023
residues from input tape
0.0023
residues
0.0
residues from melt filter
Plastic Recycling
flows [kg / t waste input]

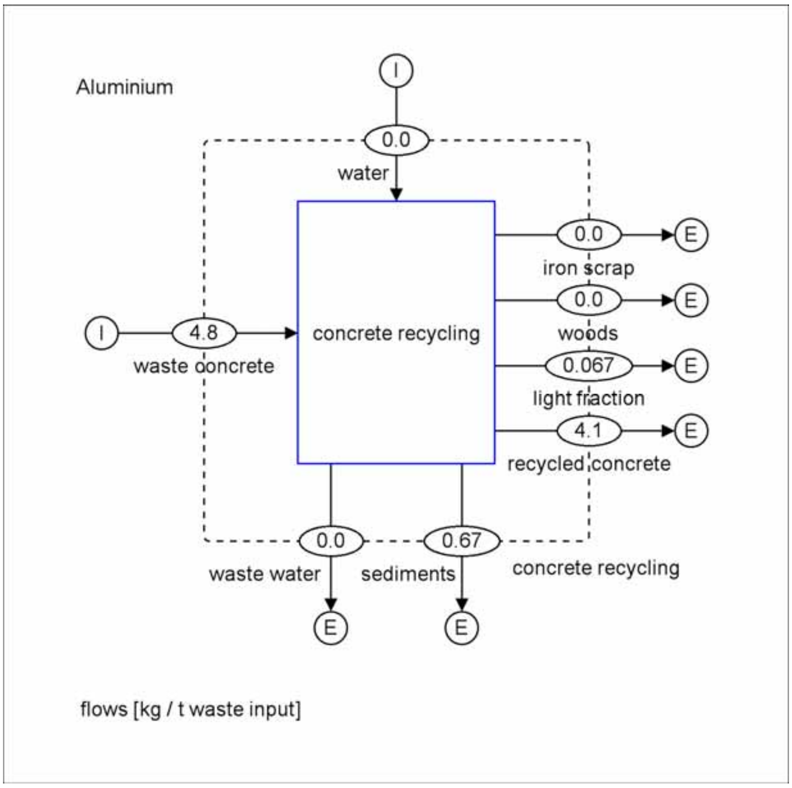

Plumbum
0.25
plastics scraps
mono-fractional recycling
0.16
pellets
0.061
residues from input tape
0.027
residues
0.0023
residues from melt filter
Plastic Recycling
flows [kg / t waste input]

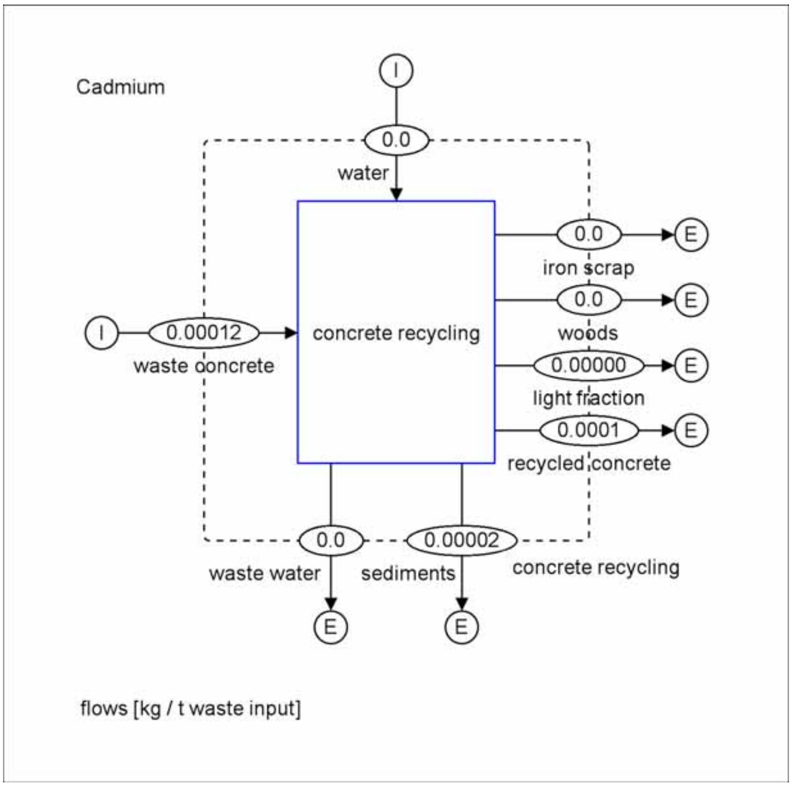
6.5.4 Recycling of Concrete

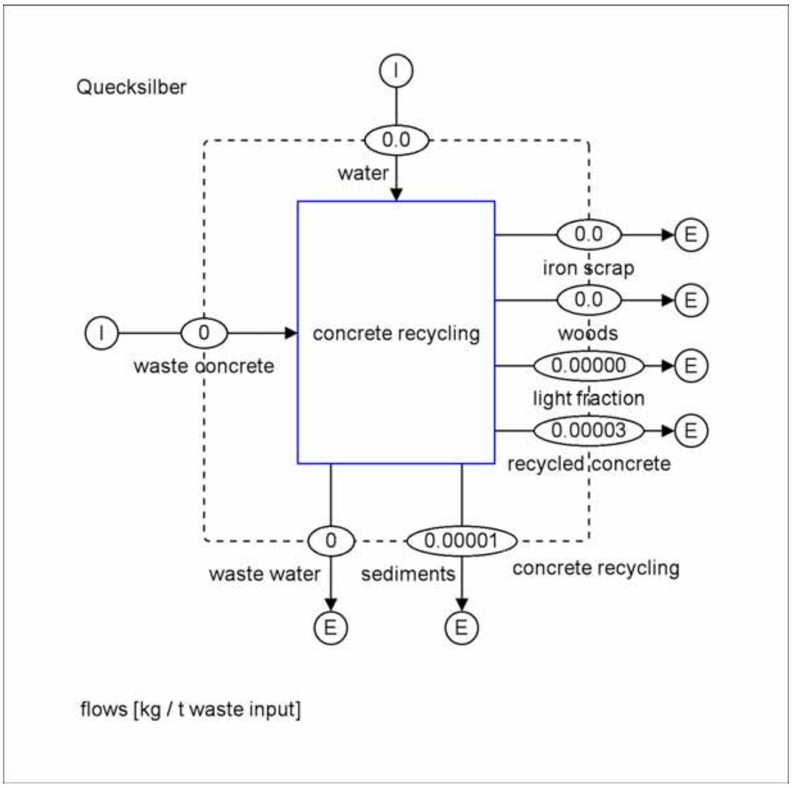
In the following figures the system of concrete recycling is shown with values of 6 different metals: three potential raw materials / resources (iron / Fe, copper / Cu, and Aluminium / Al) and three harmful substances (cadmium / Cd, mercury / Hg, and lead / Pb). Data derives from Schachermayer et al, 1998.

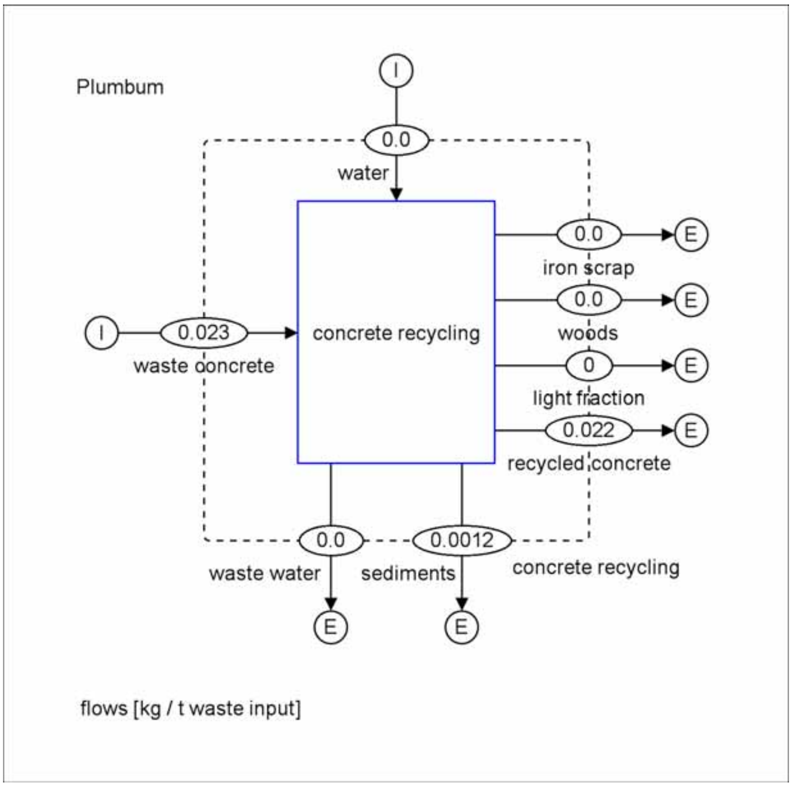



Cuprum
0.0
water
0.0
iron scrap
0.0
woods
0.00002
light fraction
0.0012
recycled concrete
0.0014
waste concrete
concrete recycling
0.00000
waste water
0.00015
sediments
concrete recycling
flows [kg / t waste input]


Aluminium
0.0
water
0.0
iron scrap
0.0
woods
0.067
light fraction
4.1
recycled concrete
4.8
waste concrete
concrete recycling
0.0
waste water
0.67
sediments
concrete recycling
flows [kg / t waste input]


Cadmium
0.0
water
concrete recycling
0.0
iron scrap
0.0
woods
0.00012
waste concrete
0.00000
light fraction
0.0001
recycled concrete
0.0
0.00002
waste water
sediments
concrete recycling
flows [kg / t waste input]


Quecksilber
0.0
water
concrete recycling
0.0
iron scrap
0.0
woods
0
waste concrete
0.00000
light fraction
0.00003
recycled concrete
0
0.00001
waste water
sediments
concrete recycling
flows [kg / t waste input]


Plumbum
I
0.0
water
0.0
E
iron scrap
0.0
E
woods
I
0.023
concrete recycling
waste concrete
0
E
light fraction
0.022
E
recycled concrete
0.0
0.0012
waste water
sediments
concrete recycling
E
E
flows [kg / t waste input]

6.5.5 Recycling of Iron

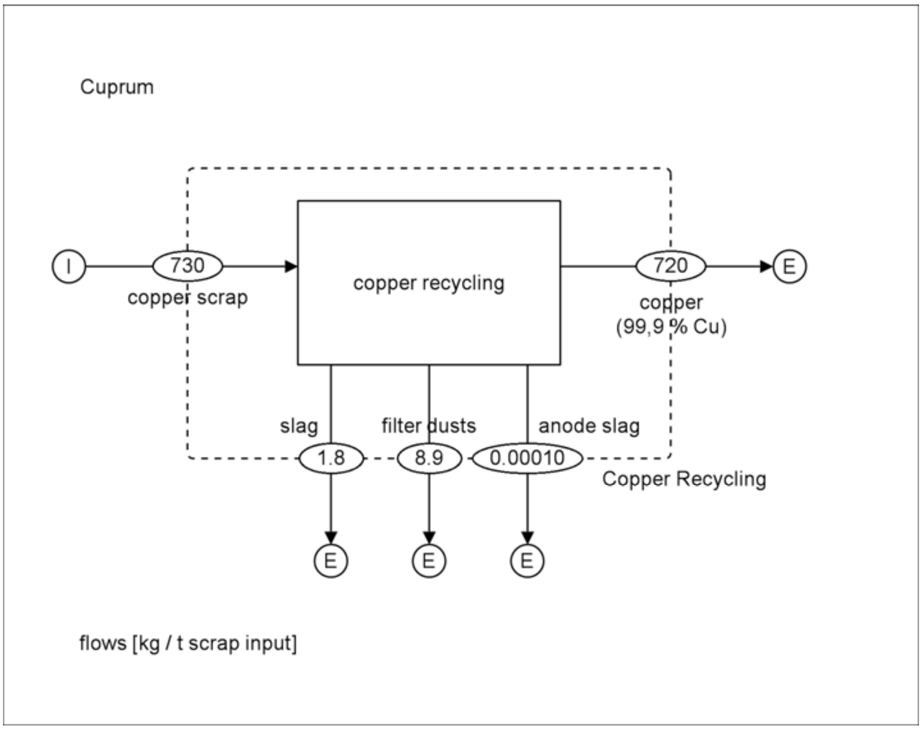
There are no figures available for the system of iron recycling.

6.5.6 Recycling of Aluminium

There are no figures available for the system of aluminium recycling.

6.5.7 Recycling of Copper

In the following figures the system of copper recycling is shown with values of copper / Cu. Data derives from Daxbeck et al., 2006.



7 ANNEX II: Data used for calculation in modules

7.1 Incineration

7.1.1 Composition of Waste

Elemental Compositions MSW by Wate Type (fraction)[1]

Substance	Waste Type: Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Hazardous waste	Bones
Share in Waste Input (%)	**26.0**	**21.0**	**15.0**	**8.0**	**8.0**	**4.0**	**3.5**	**3.0**	**3.0**	**2.0**	**2.0**	**2.0**	**1.5**	**0.5**	**0.5**
Water	60	5.75		6.11	0	4.71			4.71	8.857	25	16	18.385		28.8451
O	12.73	46.1227	2	41.92	25	44.4619		49.15187365	44.15187365	30.18	27.11	34.4	41.1		19.632
H	2	4.9	14.5	6.1		6.0292			5.987188142	6.674	5.02	5.03	4.3		
C	16.22	38.6	79.822	45.31	30	44.2665			43.95779948	48.19	39.21	44.13	34.6		
S	0.1497810	0.066	0.16	0.16		0.0782		0.24	0.077629668	0.1414	0.28	0.07	0.38		
N	0.4	0.0943	0.3	0.15		0.1759			0.174666753	0.2185	3.11	0.24	1.07		5
P	0.113	0.0123													9.5
B	0.001023	0.00189													
Cl	0.4	0.0189	2.7	0.23	1.1	0.2633		0.02	0.9358	0.5831	0.27	0.09	0.01	11.528514	
Br	0.0006		0.0075							0.0001831					
F	0.02		0.0014	0.0045		0.0045				0.0002747		0.004			
I															
Ag															
As	0.0002	0.00005		0.00035						0.0000876			0.00046		
Ba		0.00283		0.00487						0.008868			0.021		
Cd		0.000943	0.005	0.0002		0.0002	0.004		0.00008869	0.0007289		0.0001	0.00031	0.0104755	0.000008
Co	0.0005									0.0001009				4.5053151	
Cr	0.0008	0.0032	0.005	0.00232			0.98			0.0009311			0.00445	0.3667592	0.025
Cu	0.0018	0.00283	0.0075	0.0084		0.0044	2.078495062	0.001	0.0006116	0.003454		0.0013	0.00614		0.0052
Hg		2.83E-06	0.000005	0.00009		0.00009	0.0005			0.00002351		0.00005	0.00012		0.000002
Mn	0.00043	0.00471		0.01011						0.007714			0.03673		0.002
Mo	0.00004	0.000742													
Ni	0.000541	0.000943	0.0018	0.00255			0.3			0.0008163			0.00177		
Pb	0.001854	0.00471	0.009	0.0043		0.00316	1.558	0.001	0.001284	0.002694		0.0309	0.04751	0.0523931	0.0006
Sb		0.000513					0.09			0.0001926					
Se	0.0000499	0.000008		0.00033				0.0003		0.000233			0.0003		
Sn	0.0007988	0.000792					0.15			0.0005792					
V	0.0002996									0.0421					
Zn	0.005818	0.00943	0.07	0.006		0.0027	1.4	0.0004	0.003058	0.01138		0.0071	0.036	83.536543	0.01
Si	3.9941588	2.1			24.5			33.79							
Fe	0.06	0.066	0.39				80.44	0.1		0.0293					0.48
Ca	2.18	0.377			17			4.2		0.04945					21.5
Al	0.9985397	1.23	0.02		2.4		10	0.79		4.983					
K	0.35	0.0943						0.02							2
Mg	0.282	0.471					3	0.27		0.001831					6
Na	0.15	0.066						11.32							7
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

[1] Doka, G., 2003, Life Cycle Inventories of Waste Treatment Srvices, Ecoinvent Report No. 13, Part II Waste Incinerator, Swiss Centre for Life Cycle Inventories, Dübendorf.

7.1.2 MSW Input into Incinerator

Elemental Composition of Incinartor Input by Waste Types (kg/kg)

Substance	Wastes type: Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.32	0.49	0.02	0.45	0.25	0.47	0	0.49	0.46	0.33	0.36	0.41	0.5	0.28	4.8
H	0.05	0.052	0.15	0.065	0	0.063	0	0	0.063	0.073	0.067	0.06	0.053	0	0.69
C	0.41	0.41	0.8	0.48	0.3	0.46	0	0	0.46	0.53	0.52	0.53	0.42	0	5.3
S	0.0037	0.0007	0.0016	0.0017	0	0.00082	0	0.0024	0.00081	0.0016	0.0037	0.00083	0.0047	0	0.023
N	0.01	0.001	0.003	0.0016	0	0.0018	0	0	0.0018	0.0024	0.041	0.0029	0.013	0.07	0.15
P	0.0028	0.00013	0	0	0	0	0	0	0	0	0	0	0	0.13	0.14
B	0.000026	0.00002	0	0	0	0	0	0	0	0	0	0	0	0	0.000046
Cl	0.01	0.0002	0.027	0.0024	0.011	0.0028	0	0.0002	0.0098	0.0064	0.0036	0.0011	0.00012	0	0.075
Br	0.000015	0	0.000075	0	0	0	0	0	0	0.000002	0	0	0	0	0.000092
F	0.0005	0	0.000014	0.000048	0	0.000047	0	0	0	0.000003	0	0.000048	0	0	0.00066
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	0.000005	0.00000053	0	0.0000037	0	0	0	0	0	0.00000096	0	0	0.0000056	0	0.000016
Ba	0	0.00003	0	0.000052	0	0	0	0	0	0.000097	0	0	0.00026	0	0.00044
Cd	0	0.00001	0.00005	0.0000021	0	0.0000021	0.00004	0	0.00000093	0.000008	0	0.0000012	0.0000038	0.00000011	0.00012
Co	0.000012	0	0	0	0	0	0	0	0	0.0000011	0	0	0	0	0.000014
Cr	0.00002	0.000034	0.00005	0.000025	0	0	0.0098	0	0	0.00001	0	0	0.000055	0.00035	0.01
Cu	0.000045	0.00003	0.000075	0.000089	0	0.000046	0.021	0.00001	0.0000064	0.000038	0	0.000015	0.000075	0.000073	0.021
Hg	0	0.00000003	0.00000005	0.00000096	0	0.00000094	0.000005	0	0	0.00000026	0	0.0000006	0.0000015	0.000000028	0.0000093
Mn	0.000011	0.00005	0	0.00011	0	0	0	0	0	0.000085	0	0	0.00045	0.000028	0.00073
Mo	0.000001	0.0000079	0	0	0	0	0	0	0	0	0	0	0	0	0.0000089
Ni	0.000014	0.00001	0.000018	0.000027	0	0	0.003	0	0	0.000009	0	0	0.000022	0	0.0031
Pb	0.000046	0.00005	0.00009	0.000046	0	0.000033	0.016	0.00001	0.000013	0.00003	0	0.00037	0.00058	0.0000084	0.017
Sb	0	0.0000054	0	0	0	0	0.0009	0	0	0.0000021	0	0	0	0	0.00091
Se	0.0000012	0.000000085	0	0.0000035	0	0	0	0.000003	0	0.0000026	0	0	0.0000037	0	0.000014
Sn	0.00002	0.0000084	0	0	0	0	0.0015	0	0	0.0000064	0	0	0	0	0.0015
V	0.0000075	0	0	0	0	0	0	0	0	0.00046	0	0	0	0	0.00047
Zn	0.00015	0.0001	0.0007	0.000064	0	0.000028	0.014	0.000004	0.000032	0.00012	0	0.000085	0.00044	0.00014	0.016
Si	0.1	0.022	0	0	0.25	0	0	0.34	0	0	0	0	0	0	0.71
Fe	0.0015	0.0007	0.0039	0	0	0	0.8	0.001	0	0.00032	0	0	0	0.0067	0.82
Ca	0.054	0.004	0	0	0.17	0	0	0.042	0	0.00054	0	0	0	0.3	0.57
Al	0.025	0.013	0.0002	0	0.024	0	0.1	0.0079	0	0.055	0	0	0	0	0.22
K	0.0087	0.001	0	0	0	0	0	0.0002	0	0	0	0	0	0.028	0.038
Mg	0.007	0.005	0	0	0	0	0.03	0.0027	0	0.00002	0	0	0	0.084	0.13
Na	0.0037	0.0007	0	0	0	0	0	0.11	0	0	0	0	0	0.098	0.22
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14

7.1.3 Transfer coefficients

Transfer Coefficients Burnable Waste g/kg waste

Substance	Output Type						
	Slag	Boiler Ash	ESP Ash	Scrubber Sludge	Water Emissions	Air emissions	Total
water	0	0	0	0	0	1000	1000
O	69.8	2.04	10.2	1.02	0	916.94	1000
H	0	0	0	0	0	1000	1000
C	7.55	0	3.44	0.0101	0.0101	988.9898	1000
S	553.87	0	298	74.6	71.4	2.13	1000
N	10	0	0	0	1	989	1000
P	880	25	94	0	0	1	1000
B	383	0	166	180	151	120	1000
Cl	71.3	0	13	6.478	909.2112	0.0108	1000
Br	110	10	877	0	0	3	1000
F	614.5	0	308	21	56	0.5	1000
I	71.3	0	13	6.48	909.2092	0.0108	1000
Ag	614.5941	5.32	274	106	0.0729	0.013	1000
As	549.899990	30	381	39	0.1	0.0000102	1000
Ba	887	22	90	0	0	1	1000
Cd	3.27	0	369	627.2339	0.441	0.0551	1000
Co	849.989968	10	120	20	0.01	0.0000318	1000
Cr	455.209926	31.9	446	63.7	3.19	0.0000739	1000
Cu	800.19262	0	185	14.8	0	0.00738	1000
Hg	5.74	2.09	366	615.669966	10.5	0.0000345	1000
Mn	859.989995	10	120	10	0.01	0.00000545	1000
Mo	867	21	110	0	0	2	1000
Ni	900.999957	35.5	63.5	0	0	0.0000432	1000
Pb	66.4	0	848.1443	85.4	0.0186	0.0371	1000
Sb	16.1	18.2	821.518	144	0.182	0.00000389	1000
Se	80.3	130	718.881995	70.7	0.118	0.00000503	1000
Sn	495.9567	19.9	451	31.8	0.0133	1.33	1000
V	889.89	10	90	10	0.01	0.1	1000
Zn	3.29	0	816.5307	180	0.163	0.0163	1000
Si	918.57	25.6	53.5	0	0	2.33	1000
Fe	899.4516	0	93.5	6.68	0.334	0.0344	1000
Ca	861.63	36.7	100	0	0	1.67	1000
Al	853.54	35.9	109	0	0	1.56	1000
K	668.79	47.2	281	0	0	3.01	1000
Mg	917.32	20.7	60.6	0	0	1.38	1000
Na	614.49	94.1	282	0	0	9.41	1000

7.1.4 Output 1

Elemental Composition of Slag of Incinerated MSW by Waste Types (kg/kg)

Substance	Wastes type														
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.022	0.034	0.0014	0.031	0.017	0.033	0	0.49	0.032	0.023	0.025	0.029	0.035	0.019	0.79
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0.0031	0.0031	0.006	0.0036	0.0023	0.0035	0	0	0.0035	0.004	0.0039	0.004	0.0032	0	0.04
S	0.0021	0.00039	0.00089	0.00094	0	0.00045	0	0.0013	0.00045	0.00086	0.0021	0.00046	0.0026	0	0.012
N	0.0001	0.00001	0.00003	0.000016	0	0.000018	0	0	0.000018	0.000024	0.00041	0.000029	0.00013	0.0007	0.0015
P	0.0025	0.00011	0	0	0	0	0	0	0	0	0	0	0	0.12	0.12
B	0.0000098	0.0000077	0	0	0	0	0	0	0	0	0	0	0	0	0.000017
Cl	0.00071	0.000014	0.0019	0.00017	0.00078	0.0002	0	0.000014	0.0007	0.00046	0.00026	0.000076	0.0000087	0	0.0053
Br	0.0000016	0	0.0000083	0	0	0	0	0	0	0.00000022	0	0	0	0	0.00001
F	0.00031	0	0.0000086	0.000029	0	0.000029	0	0	0	0.0000019	0	0.000029	0	0	0.0004
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	0.0000027	0.00000029	0	0.000002	0	0	0	0	0	0.00000053	0	0	0.0000031	0	0.0000087
Ba	0	0.000027	0	0.000046	0	0	0	0	0	0.000086	0	0	0.00023	0	0.00039
Cd	0	0.000000033	0.00000016	0.000000007	0	6.9E-09	0.00000013	0	0.000000003	0.000000026	0	3.9E-09	0.000000012	3.7E-10	0.00000039
Co	0.000011	0	0	0	0	0	0	0	0	0.00000094	0	0	0	0	0.000012
Cr	0.0000091	0.000015	0.000023	0.000011	0	0	0.0045	0	0	0.0000047	0	0	0.000025	0.00016	0.0047
Cu	0.000036	0.000024	0.00006	0.000072	0	0.000037	0.017	0.000008	0.0000051	0.00003	0	0.000012	0.00006	0.000058	0.017
Hg	0	1.7E-10	2.9E-10	5.5E-09	0	5.4E-09	0.000000029	0	0	1.5E-09	0	3.4E-09	8.4E-09	1.6E-10	0.000000054
Mn	0.0000092	0.000043	0	0.000093	0	0	0	0	0	0.000073	0	0	0.00039	0.000024	0.00063
Mo	0.00000086	0.0000068	0	0	0	0	0	0	0	0	0	0	0	0	0.0000077
Ni	0.000012	0.000009	0.000016	0.000024	0	0	0.0027	0	0	0.0000081	0	0	0.00002	0	0.0028
Pb	0.0000031	0.0000033	0.000006	0.000003	0	0.0000022	0.001	0.00000067	0.00000089	0.000002	0	0.000024	0.000039	0.00000056	0.0011
Sb	0	0.000000088	0	0	0	0	0.000014	0	0	0.000000034	0	0	0	0	0.000015
Se	0.0000001	6.8E-09	0	0.00000028	0	0	0	0.00000024	0	0.00000021	0	0	0.0000003	0	0.0000011
Sn	0.0000099	0.0000042	0	0	0	0	0.00074	0	0	0.0000032	0	0	0	0	0.00076
V	0.0000067	0	0	0	0	0	0	0	0	0.00041	0	0	0	0	0.00042
Zn	0.00000048	0.00000033	0.0000023	0.00000021	0	0.000000093	0.000046	0.000000013	0.00000011	0.00000041	0	0.00000028	0.0000015	0.00000046	0.000052
Si	0.092	0.02	0	0	0.23	0	0	0.31	0	0	0	0	0	0	0.65
Fe	0.0013	0.00063	0.0035	0	0	0	0.72	0.0009	0	0.00029	0	0	0	0.0061	0.74
Ca	0.047	0.0034	0	0	0.15	0	0	0.036	0	0.00047	0	0	0	0.26	0.49
Al	0.021	0.011	0.00017	0	0.02	0	0.085	0.0068	0	0.047	0	0	0	0	0.19
K	0.0058	0.00067	0	0	0	0	0	0.00013	0	0	0	0	0	0.019	0.025
Mg	0.0065	0.0046	0	0	0	0	0.028	0.0025	0	0.000018	0	0	0	0.077	0.12
Na	0.0023	0.00043	0	0	0	0	0	0.071	0	0	0	0	0	0.06	0.13
Total	0.21	0.079	0.014	0.036	0.41	0.037	0.86	0.92	0.037	0.077	0.032	0.033	0.042	0.56	3.3

7.1.5 Output 2

Elemental Composition of Boiler Ash of Incinerated MSW by Waste Types (kg/kg)

Substance	Wastes type														
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.00065	0.001	0.000041	0.00091	0.00051	0.00095	0	0.001	0.00095	0.00068	0.00074	0.00084	0.001	0.00056	0.0098
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0.00007	0.0000033	0	0	0	0	0	0	0	0	0	0	0	0.0033	0.0034
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Br	0.00000015	0	0.00000075	0	0	0	0	0	0	0.00000002	0	0	0	0	0.00000092
F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	0.00000015	0.000000016	0	0.00000011	0	0	0	0	0	0.000000029	0	0	0.00000017	0	0.00000048
Ba	0	0.00000066	0	0.0000011	0	0	0	0	0	0.0000021	0	0	0.0000057	0	0.0000096
Cd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co	0.00000012	0	0	0	0	0	0	0	0	0.000000011	0	0	0	0	0.00000014
Cr	0.00000064	0.0000011	0.0000016	0.00000079	0	0	0.00031	0	0	0.00000033	0	0	0.0000017	0.000011	0.00033
Cu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hg	0	6.3E-11	1E-10	0.000000002	0	0.000000002	0.00000001	0	0	5.4E-10	0	1.2E-09	3.1E-09	5.9E-11	0.00000002
Mn	0.00000011	0.0000005	0	0.0000011	0	0	0	0	0	0.00000085	0	0	0.0000045	0.00000028	0.0000073
Mo	0.000000021	0.00000017	0	0	0	0	0	0	0	0	0	0	0	0	0.00000019
Ni	0.00000048	0.00000036	0.00000064	0.00000096	0	0	0.00011	0	0	0.00000032	0	0	0.00000077	0	0.00011
Pb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sb	0	0.000000099	0	0	0	0	0.000016	0	0	0.000000038	0	0	0	0	0.000017
Se	0.00000016	0.000000011	0	0.00000046	0	0	0	0.00000039	0	0.00000033	0	0	0.00000048	0	0.0000018
Sn	0.0000004	0.00000017	0	0	0	0	0.00003	0	0	0.00000013	0	0	0	0	0.000031
V	0.000000075	0	0	0	0	0	0	0	0	0.0000046	0	0	0	0	0.0000047
Zn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Si	0.0026	0.00057	0	0	0.0063	0	0	0.0087	0	0	0	0	0	0	0.018
Fe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ca	0.002	0.00015	0	0	0.0062	0	0	0.0015	0	0.00002	0	0	0	0.011	0.021
Al	0.00089	0.00047	0.0000072	0	0.00086	0	0.0036	0.00028	0	0.002	0	0	0	0	0.0081
K	0.00041	0.000047	0	0	0	0	0	0.0000094	0	0	0	0	0	0.0013	0.0018
Mg	0.00015	0.0001	0	0	0	0	0.00062	0.000056	0	0.00000042	0	0	0	0.0017	0.0027
Na	0.00035	0.000066	0	0	0	0	0	0.011	0	0	0	0	0	0.0093	0.02
Total	0.0071	0.0024	0.000051	0.00092	0.014	0.00095	0.0047	0.022	0.00095	0.0027	0.00074	0.00084	0.001	0.027	0.086

7.1.6 Output 3

Elemental Composition of ESP Ash of Incinerated MSW by Waste Types (kg/kg)

Substance	Wastes type													
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.0032	0.005	0.0002	0.0046	0.0026	0.0048	0	0.005	0.0047	0.0034	0.0037	0.0042	0.0051	0.0028	0.049
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0.0014	0.0014	0.0027	0.0017	0.001	0.0016	0	0	0.0016	0.0018	0.0018	0.0018	0.0015	0	0.018
S	0.0011	0.00021	0.00048	0.00051	0	0.00024	0	0.00072	0.00024	0.00046	0.0011	0.00025	0.0014	0	0.0067
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0.00026	0.000012	0	0	0	0	0	0	0	0	0	0	0	0.013	0.013
B	0.0000042	0.0000033	0	0	0	0	0	0	0	0	0	0	0	0	0.0000076
Cl	0.00013	0.0000026	0.00035	0.000032	0.00014	0.000036	0	0.0000026	0.00013	0.000083	0.000047	0.000014	0.0000016	0	0.00097
Br	0.000013	0	0.000066	0	0	0	0	0	0	0.0000018	0	0	0	0	0.000081
F	0.00015	0	0.0000043	0.000015	0	0.000015	0	0	0	0.00000093	0	0.000015	0	0	0.0002
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	0.0000019	0.0000002	0	0.0000014	0	0	0	0	0	0.00000037	0	0	0.0000021	0	0.000006
Ba	0	0.0000027	0	0.0000047	0	0	0	0	0	0.0000088	0	0	0.000023	0	0.000039
Cd	0	0.0000037	0.000018	0.00000079	0	0.00000077	0.000015	0	0.00000034	0.000003	0	0.00000044	0.0000014	0.000000041	0.000044
Co	0.0000015	0	0	0	0	0	0	0	0	0.00000013	0	0	0	0	0.0000016
Cr	0.0000089	0.000015	0.000022	0.000011	0	0	0.0044	0	0	0.0000046	0	0	0.000024	0.00016	0.0046
Cu	0.0000083	0.0000056	0.000014	0.000017	0	0.0000085	0.0038	0.0000019	0.0000012	0.000007	0	0.0000029	0.000014	0.000014	0.0039
Hg	0	0.000000011	0.000000018	0.00000035	0	0.00000035	0.0000018	0	0	0.000000094	0	0.00000022	0.00000054	0.0000001	0.0000034
Mn	0.0000013	0.000006	0	0.000013	0	0	0	0	0	0.00001	0	0	0.000054	0.0000034	0.000088
Mo	0.00000011	0.00000087	0	0	0	0	0	0	0	0	0	0	0	0	0.00000098
Ni	0.00000086	0.00000064	0.0000011	0.0000017	0	0	0.00019	0	0	0.00000057	0	0	0.0000014	0	0.0002
Pb	0.000039	0.000042	0.000076	0.000039	0	0.000028	0.013	0.0000085	0.000011	0.000025	0	0.00031	0.00049	0.0000072	0.014
Sb	0	0.0000045	0	0	0	0	0.00074	0	0	0.0000017	0	0	0	0	0.00075
Se	0.0000009	0.000000061	0	0.0000025	0	0	0	0.0000022	0	0.0000018	0	0	0.0000026	0	0.00001
Sn	0.000009	0.0000038	0	0	0	0	0.00068	0	0	0.0000029	0	0	0	0	0.00069
V	0.00000067	0	0	0	0	0	0	0	0	0.000042	0	0	0	0	0.000042
Zn	0.00012	0.000082	0.00057	0.000052	0	0.000023	0.011	0.0000033	0.000026	0.0001	0	0.000069	0.00036	0.00011	0.013
Si	0.0053	0.0012	0	0	0.013	0	0	0.018	0	0	0	0	0	0	0.038
Fe	0.00014	0.000065	0.00036	0	0	0	0.075	0.000094	0	0.00003	0	0	0	0.00063	0.077
Ca	0.0054	0.0004	0	0	0.017	0	0	0.0042	0	0.000054	0	0	0	0.03	0.057
Al	0.0027	0.0014	0.000022	0	0.0026	0	0.011	0.00086	0	0.006	0	0	0	0	0.024
K	0.0025	0.00028	0	0	0	0	0	0.000056	0	0	0	0	0	0.0079	0.011
Mg	0.00043	0.0003	0	0	0	0	0.0018	0.00016	0	0.0000012	0	0	0	0.0051	0.0078
Na	0.0011	0.0002	0	0	0	0	0	0.032	0	0	0	0	0	0.028	0.061
Total	0.024	0.011	0.0049	0.0069	0.036	0.0067	0.12	0.061	0.0067	0.012	0.0066	0.0066	0.009	0.087	0.4

7.1.7 Output 4

Elemental Composition of Scrubber Sludge of Incinerated MSW by Waste Types (kg/kg)

Substance	Wastes type														
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.00032	0.0005	0.00002	0.00046	0.00026	0.00048	0	0.0005	0.00047	0.00034	0.00037	0.00042	0.00051	0.00028	0.0049
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0.0000041	0.0000041	0.0000081	0.0000049	0.000003	0.0000047	0	0	0.0000047	0.0000053	0.0000053	0.0000053	0.0000043	0	0.000054
S	0.00028	0.000052	0.00012	0.00013	0	0.000061	0	0.00018	0.000061	0.00012	0.00028	0.000062	0.00035	0	0.0017
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0.0000046	0.0000036	0	0	0	0	0	0	0	0	0	0	0	0	0.0000082
Cl	0.000065	0.0000013	0.00017	0.000016	0.000071	0.000018	0	0.0000013	0.000064	0.000041	0.000023	0.0000069	0.00000079	0	0.00048
Br	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0.00001	0	0.00000029	0.000001	0	0.00000099	0	0	0	0.000000063	0	0.000001	0	0	0.000014
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	0.00000019	0.000000021	0	0.00000015	0	0	0	0	0	0.000000037	0	0	0.00000022	0	0.00000062
Ba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cd	0	0.0000063	0.000031	0.0000013	0	0.0000013	0.000025	0	0.00000058	0.000005	0	0.00000075	0.0000024	0.000000071	0.000074
Co	0.00000025	0	0	0	0	0	0	0	0	0.000000022	0	0	0	0	0.00000027
Cr	0.0000013	0.0000022	0.0000032	0.0000016	0	0	0.00062	0	0	0.00000065	0	0	0.0000035	0.000022	0.00066
Cu	0.00000066	0.00000044	0.0000011	0.0000013	0	0.00000068	0.00031	0.00000015	0.000000095	0.00000056	0	0.00000023	0.0000011	0.0000011	0.00032
Hg	0	0.000000018	0.000000031	0.00000059	0	0.00000058	0.0000031	0	0	0.00000016	0	0.00000037	0.00000091	0.000000017	0.0000057
Mn	0.00000011	0.0000005	0	0.0000011	0	0	0	0	0	0.00000085	0	0	0.0000045	0.00000028	0.0000073
Mo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb	0.000004	0.0000043	0.0000077	0.0000039	0	0.0000028	0.0013	0.00000085	0.0000012	0.0000025	0	0.000031	0.00005	0.0000072	0.0014
Sb	0	0.00000078	0	0	0	0	0.00013	0	0	0.0000003	0	0	0	0	0.00013
Se	0.000000088	0.000000006	0	0.00000025	0	0	0	0.00000021	0	0.00000018	0	0	0.00000026	0	0.000001
Sn	0.00000063	0.00000027	0	0	0	0	0.000048	0	0	0.0000002	0	0	0	0	0.000049
V	0.000000075	0	0	0	0	0	0	0	0	0.0000046	0	0	0	0	0.0000047
Zn	0.000026	0.000018	0.00013	0.000011	0	0.0000051	0.0025	0.00000072	0.0000058	0.000022	0	0.000015	0.000079	0.000025	0.0029
Si	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fe	0.00001	0.0000047	0.000026	0	0	0	0.0054	0.0000067	0	0.0000021	0	0	0	0.000045	0.0055
Ca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Na	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0.00073	0.0006	0.00052	0.00063	0.00033	0.00057	0.01	0.00069	0.00061	0.00054	0.00068	0.00054	0.001	0.00038	0.018

7.1.8 Output 5

Elemental Composition of Water Emissions of Incinerated MSW by Waste Types (kg/kg)

Substance	Wastes type														
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0.0000041	0.0000041	0.0000081	0.0000049	0.000003	0.0000047	0	0	0.0000047	0.0000053	0.0000053	0.0000053	0.0000043	0	0.000054
S	0.00027	0.00005	0.00011	0.00012	0	0.000059	0	0.00017	0.000058	0.00011	0.00027	0.000059	0.00033	0	0.0016
N	0.00001	0.000001	0.000003	0.0000016	0	0.0000018	0	0	0.0000018	0.0000024	0.000041	0.0000029	0.000013	0.00007	0.00015
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0.0000039	0.000003	0	0	0	0	0	0	0	0	0	0	0	0	0.0000069
Cl	0.0091	0.00018	0.025	0.0022	0.01	0.0025	0	0.00018	0.0089	0.0058	0.0033	0.00097	0.00011	0	0.068
Br	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0.000028	0	0.00000078	0.0000027	0	0.0000026	0	0	0	0.00000017	0	0.0000027	0	0	0.000037
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	5E-10	5.3E-11	0	3.7E-10	0	0	0	0	0	9.6E-11	0	0	5.6E-10	0	1.6E-09
Ba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cd	0	4.4E-09	0.000000022	9.4E-10	0	9.3E-10	0.000000018	0	4.1E-10	3.5E-09	0	5.2E-10	1.7E-09	5E-11	0.000000052
Co	1.2E-10	0	0	0	0	0	0	0	0	1.1E-11	0	0	0	0	1.4E-10
Cr	0.000000064	0.00000011	0.00000016	0.000000079	0	0	0.000031	0	0	0.000000033	0	0	0.00000017	0.0000011	0.000033
Cu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hg	0	3.2E-10	5.3E-10	0.00000001	0	9.9E-09	0.000000052	0	0	2.7E-09	0	6.2E-09	0.000000015	3E-10	0.000000098
Mn	1.1E-10	5E-10	0	1.1E-09	0	0	0	0	0	8.5E-10	0	0	4.5E-09	2.8E-10	7.3E-09
Mo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb	8.6E-10	9.3E-10	1.7E-09	8.5E-10	0	6.2E-10	0.00000029	1.9E-10	2.5E-10	5.5E-10	0	6.8E-09	0.000000011	1.6E-10	0.00000031
Sb	0	9.9E-10	0	0	0	0	0.00000016	0	0	3.8E-10	0	0	0	0	0.00000017
Se	1.5E-10	1E-11	0	4.1E-10	0	0	0	3.5E-10	0	3E-10	0	0	4.3E-10	0	1.7E-09
Sn	2.7E-10	1.1E-10	0	0	0	0	0.00000002	0	0	8.5E-11	0	0	0	0	0.00000002
V	7.5E-11	0	0	0	0	0	0	0	0	4.6E-09	0	0	0	0	4.7E-09
Zn	0.000000024	0.000000016	0.00000011	0.00000001	0	4.6E-09	0.0000023	6.5E-10	5.2E-09	0.00000002	0	0.000000014	0.000000072	0.000000023	0.0000026
Si	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fe	0.0000005	0.00000023	0.0000013	0	0	0	0.00027	0.00000033	0	0.00000011	0	0	0	0.0000023	0.00027
Ca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Na	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0.0094	0.00024	0.025	0.0024	0.01	0.0026	0.0003	0.00035	0.009	0.0059	0.0036	0.001	0.00046	0.000074	0.07

7.1.9 Output 6

Elemental Composition of Air Emissions of Incinerated MSW by Waste Types (kg/kg)

Substance	Wastes type														
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.29	0.45	0.018	0.41	0.23	0.43	0	0	0.42	0.3	0.33	0.38	0.46	0.25	4
H	0.05	0.052	0.15	0.065	0	0.063	0	0	0.063	0.073	0.067	0.06	0.053	0	0.69
C	0.4	0.41	0.79	0.48	0.3	0.46	0	0	0.46	0.52	0.52	0.52	0.42	0	5.3
S	0.000008	0.0000015	0.0000034	0.0000036	0	0.0000017	0	0	0.0000017	0.0000033	0.000008	0.0000018	0.0000099	0	0.000043
N	0.0099	0.00099	0.003	0.0016	0	0.0018	0	0	0.0018	0.0024	0.041	0.0028	0.013	0.069	0.15
P	0.0000028	0.00000013	0	0	0	0	0	0	0	0	0	0	0	0.00013	0.00014
B	0.0000031	0.0000024	0	0	0	0	0	0	0	0	0	0	0	0	0.0000055
Cl	0.00000011	2.2E-09	0.00000029	0.000000026	0.00000012	0.00000003	0	0	0.00000011	0.000000069	0.000000039	0.000000012	1.3E-09	0	0.0000008
Br	0.000000045	0	0.00000023	0	0	0	0	0	0	0.000000006	0	0	0	0	0.00000028
F	0.00000025	0	0.000000007	0.000000024	0	0.000000024	0	0	0	1.5E-09	0	0.000000024	0	0	0.00000033
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	5.1E-14	5.4E-15	0	3.8E-14	0	0	0	0	0	9.8E-15	0	0	5.7E-14	0	1.6E-13
Ba	0	0.00000003	0	0.000000052	0	0	0	0	0	0.000000097	0	0	0.00000026	0	0.00000044
Cd	0	5.5E-10	2.8E-09	1.2E-10	0	1.2E-10	2.2E-09	0	5.1E-11	4.4E-10	0	6.6E-11	2.1E-10	6.2E-12	6.5E-09
Co	4E-13	0	0	0	0	0	0	0	0	3.5E-14	0	0	0	0	4.3E-13
Cr	1.5E-12	2.5E-12	3.7E-12	1.8E-12	0	0	7.2E-10	0	0	7.6E-13	0	0	4E-12	2.6E-11	7.6E-10
Cu	3.3E-10	2.2E-10	5.5E-10	6.6E-10	0	3.4E-10	0.0000015	0	4.7E-11	2.8E-10	0	1.1E-10	5.6E-10	5.4E-10	0.0000016
Hg	0	1E-15	1.7E-15	3.3E-14	0	3.3E-14	1.7E-13	0	0	8.9E-15	0	2.1E-14	5.1E-14	9.7E-16	3.2E-13
Mn	5.8E-14	2.7E-13	0	5.9E-13	0	0	0	0	0	4.6E-13	0	0	2.5E-12	1.5E-13	4E-12
Mo	0.000000002	0.000000016	0	0	0	0	0	0	0	0	0	0	0	0	0.000000018
Ni	5.8E-13	4.3E-13	7.8E-13	1.2E-12	0	0	1.3E-10	0	0	3.9E-13	0	0	9.4E-13	0	1.3E-10
Pb	1.7E-09	1.9E-09	3.3E-09	1.7E-09	0	1.2E-09	0.0000058	0	5E-10	1.1E-09	0	0.000000014	0.000000022	3.1E-10	0.0000063
Sb	0	2.1E-14	0	0	0	0	3.5E-12	0	0	8.2E-15	0	0	0	0	3.5E-12
Se	6.3E-15	4.3E-16	0	1.8E-14	0	0	0	0	0	1.3E-14	0	0	1.8E-14	0	5.6E-14
Sn	0.000000027	0.000000011	0	0	0	0	0.000002	0	0	8.5E-09	0	0	0	0	0.000002
V	7.5E-10	0	0	0	0	0	0	0	0	0.000000046	0	0	0	0	0.000000047
Zn	2.4E-09	1.6E-09	0.000000011	0.000000001	0	4.6E-10	0.00000023	0	5.2E-10	0.000000002	0	1.4E-09	7.2E-09	2.3E-09	0.00000026
Si	0.00023	0.000052	0	0	0.00057	0	0	0	0	0	0	0	0	0	0.00086
Fe	0.000000051	0.000000024	0.00000013	0	0	0	0.000028	0	0	0.000000011	0	0	0	0.00000023	0.000028
Ca	0.000091	0.0000067	0	0	0.00028	0	0	0	0	0.00000091	0	0	0	0.0005	0.00089
Al	0.000039	0.00002	0.00000031	0	0.000037	0	0.00016	0	0	0.000085	0	0	0	0	0.00034
K	0.000026	0.000003	0	0	0	0	0	0	0	0	0	0	0	0.000085	0.00011
Mg	0.0000097	0.0000069	0	0	0	0	0.000041	0	0	0.000000028	0	0	0	0.00012	0.00017
Na	0.000035	0.0000066	0	0	0	0	0	0	0	0	0	0	0	0.00093	0.00097
Total	0.75	0.91	0.96	0.95	0.53	0.95	0.00023	0	0.95	0.9	0.96	0.96	0.95	0.32	10

7.1.10 Balance

Balance Elemental Compositions Incineration MSW

Description	Wastes type													
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones
Input														
Dry Waste	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Out-put														
Slag	0.21	0.079	0.014	0.036	0.41	0.037	0.86	0.92	0.037	0.077	0.032	0.033	0.042	0.56
Boiler Ash	0.0071	0.0024	0.000051	0.00092	0.014	0.00095	0.0047	0.022	0.00095	0.0027	0.00074	0.00084	0.001	0.027
ESP Ash	0.024	0.011	0.0049	0.0069	0.036	0.0067	0.12	0.061	0.0067	0.012	0.0066	0.0066	0.009	0.087
Scrubber Sludge	0.00073	0.0006	0.00052	0.00063	0.00033	0.00057	0.01	0.00069	0.00061	0.00054	0.00068	0.00054	0.001	0.00038
Water Emissions	0.0094	0.00024	0.025	0.0024	0.01	0.0026	0.0003	0.00035	0.009	0.0059	0.0036	0.001	0.00046	0.000074
Air emissions	0.75	0.91	0.96	0.95	0.53	0.95	0.00023	0	0.95	0.9	0.96	0.96	0.95	0.32
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1

7.1.11 Emission factors

Fuel, Electricity and other Consumption for MSW incineration

Utility Type	Unit	Total	Actual	Actual Consu														
		(kg-1 MSW)1	(kg-1 MSW)1	Food	Paper	Plastics	Cardboard	Minerals	Plastic coat	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biom	Bones	Total
Natural gas	kg	0.016	0.0160	0.01400	0.01100	0.04300	0.01600	0.00560	0.01500	0.00000	0.00000	0.01500	0.02000	0.01900	0.01700	0.01200	0.00000	0.19000
Electricity	kWh	0.090	0.0900	0.07500	0.06100	0.24000	0.08700	0.03000	0.08000	0.00000	0.00000	0.08000	0.11000	0.10000	0.09500	0.06300	0.00000	1.00000
Heat	kWh	0.025	0.0250	0.02100	0.01700	0.06600	0.02400	0.00850	0.02200	0.00000	0.00000	0.02200	0.03100	0.02900	0.02600	0.01700	0.00000	0.28000
CaCO3	kg	0.0026	0.0026	0.00220	0.00180	0.00680	0.00250	0.00088	0.00230	0.00000	0.00000	0.00230	0.00320	0.00300	0.00270	0.00180	0.00000	0.03000
NaOH solution, 30%	kg	0.00240	0.00072	0.00060	0.00049	0.00190	0.00069	0.00024	0.00064	0.00000	0.00000	0.00064	0.00089	0.00083	0.00076	0.00050	0.00000	0.00820
NH3 solution, 25%	kg	0.0030	0.00075	0.00063	0.00051	0.00200	0.00072	0.00025	0.00067	0.00000	0.00000	0.00067	0.00093	0.00086	0.00079	0.00052	0.00000	0.00850
Precipitation agents	kg	0.0002	0.00020	0.00017	0.00014	0.00053	0.00019	0.00007	0.00018	0.00000	0.00000	0.00018	0.00025	0.00023	0.00021	0.00014	0.00000	0.00230

1Spittelau the Thermal Waste Treatment Plant accessed fr

Emission, Electricity and other Produ

Utility Type	Unit	Total Production	Actual Production	Actual Produ														
		(kg-1 MSW)1	(kg-1 MSW)1	Food	Paper	Plastics	Cardboard	Minerals	Plastic coat	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biom	Bones	Total
Refined petroleum products and fuels	kg	0.000	0.000	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Electricity	kWh	0.034	0.034	2.800E-02	2.300E-02	8.900E-02	3.300E-02	1.100E-02	3.000E-02	0.000E+00	0.000E+00	3.000E-02	4.200E-02	3.900E-02	3.600E-02	2.400E-02	0.000E+00	3.900E-01
Heat	kWh	1.900	1.900	1.600E+00	1.300E+00	5.000E+00	1.800E+00	6.400E-01	1.700E+00	0.000E+00	0.000E+00	1.700E+00	2.300E+00	2.200E+00	2.000E+00	1.300E+00	0.000E+00	2.200E+01

1Spittelau the Thermal Waste Treatment Plant accessed fr

7.1.12 Results Emissions from Waste

Unit:

NACE No.	Product No.	Activity No. / Activities / Products	1 Incineration Food Waste	2 Incineration Paper	3 Incineration Plastics	4 Incineration Cardboard	5 Incineration Minerals	6 Incineration Plastic coated paper	7 Incineration Metals	8 Incineration Glass	9 Incineration Diapers	10 Incineration Tetra pack	11 Incineration Textiles	12 Incineration Wood	13 Incineration Other biomass	15 Incineration Bones
Emissions Distribution, emissions from residuals (-Gw)																
Air	1	Ammonia														
Air	2	Arsenic	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	3	Cadmium	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	4	Carbon dioxide, fibre carbon		0.11296		0.13306	0.08275	0.12813	0.00000	0.00000	0.12724	0.14388	0.14420	0.14490	0.11694	0.00000
Air	5	Carbon dioxide, food carbon	0.11171													
Air	6	Carbon dioxide, coal carbon														
Air	7	Carbon dioxide, crude oil and natural gas carbon			0.32017											
Air	8	Carbon dioxide, carbonate														
Air	9	Carbon monoxide	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	10	Chromium	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	11	Copper	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	12	Dinitrogen monoxide														
Air	13	Hydrogen chloride														
Air	14	Hydrogen fluoride														
Air	15	Lead	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	16	Mercury	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	17	Methane	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	18	Nickel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	19	Nitric acid														
Air	20	Nitrogen dioxide	0.00004	0.00000	0.00001	0.00001	0.00000	0.00001	0.00000	0.00000	0.00001	0.00001	0.00010	0.00001	0.00006	0.00014
Air	21	NMVOC														
Air	22	ODP														
Air	23	PAH, measured as Benzo(a)pyrene														
Air	24	Particulates, < 10 um														
Air	25	Phosphorus	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00013
Air	26	Selenium	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	27	Sulfur dioxide	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00001	0.00000
Air	28	Vanadium	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	29	Zinc	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
water	30	Copper														
water	31	Nitrogen, total														
water	32	Phosphorus														
Soil	33	Antimony														
Soil	34	Arsenic														
Soil	35	Barium														
Soil	36	Cadmium														
Soil	37	Chromium														
Soil	38	Cobalt														
Soil	39	Copper														
Soil	40	Lead														
Soil	41	Mercury														
Soil	42	Nickel														
Soil	43	Phosphorus														
Soil	44	Selenium														
Soil	45	Zinc														
	46	Aluminium	0.00004	0.00002	0.00000	0.00000	0.00004	0.00000	0.00016	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	47	Carbon, biomass, unspecified														
	48	Carbon, fossil, unspecified														
	49	Clay and soil														
	50	Iron	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	51	Metals n.e.c.	0.00013	0.00002	0.00000	0.00000	0.00028	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02143
	52	Minerals n.e.c.	0.42867	0.4272	0.87776	0.50729	0.27411	0.48958	0.00024	0.00000	0.48517	0.55861	0.56596	0.54214	0.45304	0.06870
	53	Oxygen	0.29134	0.44871	0.01834	0.40929	0.22824	0.42784	0.00000	0.00000	0.42488	0.30788	0.33144	0.37548	0.46175	0.25290
	54	Sand, gravel and stone	0.00023	0.00000	0.00000	0.00000	0.00057	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		Total from Emissions Distribution (-Gw)	0.75209	0.90682	0.95575	0.95298	0.52682	0.95237	0.00023	0.00000	0.94573	0.90234	0.95644	0.95775	0.94670	0.32425

Balance Check (g-g)

	1	2	3	4	5	6	7	8	9	10	11	12	13	15
Residual Input	0.75209	0.90682	0.95575	0.95298	0.52682	0.95237	0.00023	0.00000	0.94573	0.90234	0.95644	0.95775	0.94670	0.32425
Emmission	0.75209	0.90682	0.95575	0.95298	0.52682	0.95237	0.00023	0.00000	0.94573	0.90234	0.95644	0.95775	0.94670	0.32425
Balance Check	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

7.1.13 Results Emissions from Material and Energy Use

Unit:

NACE No.	Product No.	Activity No. / Products \ Activities	1 Incineration Food Waste	2 Incineration Paper	3 Incineration Plastics	4 Incineration Cardboard	5 Incineration Minerals	6 Incineration Plastic coated paper	7 Incineration Metals	8 Incineration Glass	9 Incineration Diapers	10 Incineration Tetra pack	11 Incineration Textiles	12 Incineration Wood	13 Incineration Other biomass	15 Incineration Bones
kg		**Emissions Distribution, emissions from products (-Gc)**														
Air	1	Ammonia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	2	Arsenic														
Air	3	Cadmium														
Air	4	Carbon dioxide, fibre carbon														
Air	5	Carbon dioxide, food carbon														
Air	6	Carbon dioxide, coal carbon														
Air	7	Carbon dioxide, crude oil and natural gas carbon	0.03642	0.02945	0.11427	0.04196	0.01470	0.03885	0.00000	0.00000	0.03858	0.05347	0.05003	0.04575	0.03037	0.00000
Air	8	Carbon dioxide, carbonate														
Air	9	Carbon monoxide	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	10	Chromium														
Air	11	Copper														
Air	12	Dinitrogen monoxide	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	13	Hydrogen chloride														
Air	14	Hydrogen fluoride														
Air	15	Lead														
Air	16	Mercury														
Air	17	Methane	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	18	Nickel														
Air	19	Nitric acid														
Air	20	Nitrogen dioxide	0.00003	0.00002	0.00009	0.00002	0.00001	0.00003	0.00000	0.00000	0.00003	0.00004	0.00004	0.00002	0.00002	0.00000
Air	21	NMVOC	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	22	ODP														
Air	23	PAH, measured as Benzo(a)pyrene														
Air	24	Particulates, < 10 um	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	25	Phosphorus														
Air	26	Selenium														
Air	27	Sulfur dioxide	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	28	Vanadium														
Air	29	Zinc														
water	30	Copper														
water	31	Nitrogen, total														
water	32	Phosphorus														
Soil	33	Antimony														
Soil	34	Arsenic														
Soil	35	Barium														
Soil	36	Cadmium														
Soil	37	Chromium														
Soil	38	Cobalt														
Soil	39	Copper														
Soil	40	Lead														
Soil	41	Mercury														
Soil	42	Nickel														
Soil	43	Phosphorus														
Soil	44	Selenium														
Soil	45	Zinc														
	46	Aluminium														
	47	Carbon, biomass, unspecified														
	48	Carbon, fossil, unspecified														
	49	Clay and soil														
	50	Iron														
	51	Metals n.e.c.														
	52	Minerals n.e.c.	0.00088	0.00312	0.01211	0.00444	0.00136	0.00412	0.00000	0.00000	0.00409	0.00571	0.00530	0.00481	0.00322	0.00000
	53	Oxygen														
	54	Sand, gravel and stone														
		Total from Emissions Distribution (-GC)	**0.01379**	**0.01116**	**0.04328**	**0.01587**	**0.00557**	**0.01472**	0.00000	0.00000	**0.01461**	**0.02041**	**0.01895**	**0.01733**	**0.01150**	0.00000
kg		**Balance Check (g-g)**														
		Product Input	0.01379	0.01116	0.04328	0.01587	0.00557	0.01471	0.00000	0.00000	0.01461	0.02041	0.01895	0.01733	0.01150	0.00000
		Emission	0.01379	0.01116	0.04328	0.01587	0.00557	0.01472	0.00000	0.00000	0.01461	0.02041	0.01895	0.01733	0.01150	0.00000
		Balance Check	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

7.2 Landfilling module

7.2.1 Elemental composition of landfill gas

Elemental Composition of Landfill Gas by Waste Types (kg/kg)

Substance	Wates Type Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.1906365	0.1320768	0.0002000	0.1448010	0.0000000	0.0840805	0.0000000	0.0000000	0.0556011	0.0596772	0.0433760	0.0135137	0.0100717	0.0000000	0.7340346
H	0.0299272	0.0140316	0.0014500	0.0210708	0.0000000	0.0114017	0.0000000	0.0000000	0.0075397	0.0131970	0.0080320	0.0019760	0.0010537	0.0000000	0.1096798
C	0.2430092	0.1105348	0.0079823	0.1565109	0.0000000	0.0837109	0.0000000	0.0000000	0.0553567	0.0952897	0.0627360	0.0173361	0.0084789	0.0000000	0.8409454
S	0.0022434	0.0001890	0.0000160	0.0005527	0.0000000	0.0001478	0.0000000	0.0000000	0.0000978	0.0002796	0.0004480	0.0000275	0.0000931	0.0000000	0.0040949
N	0.0059854	0.0002700	0.0000300	0.0005181	0.0000000	0.0003326	0.0000000	0.0000000	0.0002200	0.0004321	0.0049760	0.0000943	0.0002622	0.0000000	0.0131208
P	0.0016909	0.0000352	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0017261
B	0.0000153	0.0000054	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000207
Cl	0.0059854	0.0000541	0.0002700	0.0007945	0.0000000	0.0004979	0.0000000	0.0000000	0.0011785	0.0011530	0.0004320	0.0000354	0.0000025	0.0000000	0.0104032
Br	0.0000090	0.0000000	0.0000008	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000004	0.0000000	0.0000000	0.0000000	0.0000000	0.0000101
F	0.0002993	0.0000000	0.0000001	0.0000155	0.0000000	0.0000085	0.0000000	0.0000000	0.0000000	0.0000005	0.0000000	0.0000016	0.0000000	0.0000000	0.0003256
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000030	0.0000001	0.0000000	0.0000012	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000002	0.0000000	0.0000000	0.0000001	0.0000000	0.0000046
Ba	0.0000000	0.0000081	0.0000000	0.0000168	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000175	0.0000000	0.0000000	0.0000051	0.0000000	0.0000476
Cd	0.0000000	0.0000027	0.0000005	0.0000007	0.0000000	0.0000004	0.0000200	0.0000000	0.0000001	0.0000014	0.0000000	0.0000000	0.0000001	0.0000000	0.0000259
Co	0.0000075	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000002	0.0000000	0.0000000	0.0000000	0.0000000	0.0000077
Cr	0.0000120	0.0000092	0.0000005	0.0000080	0.0000000	0.0000000	0.0049000	0.0000000	0.0000000	0.0000018	0.0000000	0.0000000	0.0000011	0.0000000	0.0049325
Cu	0.0000269	0.0000081	0.0000008	0.0000290	0.0000000	0.0000083	0.0103924	0.0000000	0.0000008	0.0000068	0.0000000	0.0000005	0.0000015	0.0000000	0.0104751
Hg	0.0000000	0.0000000	0.0000000	0.0000003	0.0000000	0.0000002	0.0000025	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000031
Mn	0.0000064	0.0000135	0.0000000	0.0000349	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000153	0.0000000	0.0000000	0.0000090	0.0000000	0.0000791
Mo	0.0000006	0.0000021	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000027
Ni	0.0000081	0.0000027	0.0000002	0.0000088	0.0000000	0.0000000	0.0015000	0.0000000	0.0000000	0.0000016	0.0000000	0.0000000	0.0000004	0.0000000	0.0015218
Pb	0.0000278	0.0000135	0.0000009	0.0000149	0.0000000	0.0000060	0.0077899	0.0000000	0.0000016	0.0000053	0.0000000	0.0000121	0.0000116	0.0000000	0.0078836
Sb	0.0000000	0.0000015	0.0000000	0.0000000	0.0000000	0.0000000	0.0004500	0.0000000	0.0000000	0.0000004	0.0000000	0.0000000	0.0000000	0.0000000	0.0004518
Se	0.0000007	0.0000000	0.0000000	0.0000011	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000005	0.0000000	0.0000000	0.0000001	0.0000000	0.0000024
Sn	0.0000120	0.0000023	0.0000000	0.0000000	0.0000000	0.0000000	0.0007500	0.0000000	0.0000000	0.0000011	0.0000000	0.0000000	0.0000000	0.0000000	0.0007654
V	0.0000045	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000832	0.0000000	0.0000000	0.0000000	0.0000000	0.0000877
Zn	0.0000871	0.0000270	0.0000070	0.0000207	0.0000000	0.0000051	0.0069999	0.0000000	0.0000039	0.0000225	0.0000000	0.0000028	0.0000088	0.0000000	0.0071849
Si	0.0598252	0.0060136	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0658388
Fe	0.0008978	0.0001890	0.0000390	0.0000000	0.0000000	0.0000000	0.4021960	0.0000000	0.0000000	0.0000579	0.0000000	0.0000000	0.0000000	0.0000000	0.4033797
Ca	0.0326207	0.0010796	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000978	0.0000000	0.0000000	0.0000000	0.0000000	0.0337981
Al	0.0149563	0.0035222	0.0000020	0.0000000	0.0000000	0.0000000	0.0499995	0.0000000	0.0000000	0.0098533	0.0000000	0.0000000	0.0000000	0.0000000	0.0783333
K	0.0052373	0.0002700	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0055073
Mg	0.0042197	0.0013488	0.0000000	0.0000000	0.0000000	0.0000000	0.0149999	0.0000000	0.0000000	0.0000036	0.0000000	0.0000000	0.0000000	0.0000000	0.0205720
Na	0.0022445	0.0001890	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0024335
	0.60000	0.26990	0.01000	0.32440	0.00000	0.18020	0.50000	0.00000	0.12000	0.18020	0.12000	0.03300	0.02000	0.00000	**2.36**

Elemental Composition of Landfill Gas by Waste Types (kg/kg)

Substance	Wates Type Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O															0.0000000
H	0.0134673	0.0063142	0.0006525	0.0094818	0.0000000	0.0051308	0.0000000	0.0000000	0.0033929	0.0059386	0.0036144	0.0008892	0.0004742	0.0000000	0.0493559
C	0.0404018	0.0189427	0.0019575	0.0284455	0.0000000	0.0153923	0.0000000	0.0000000	0.0101787	0.0178159	0.0108432	0.0026676	0.0014225	0.0000000	0.1480677
	0.05387	0.02526	0.00261	0.03793	0.00000	0.02052	0.00000	0.00000	0.01357	0.02375	0.01446	0.00356	0.00190	0.00000	**0.20**

7.2.2 Elemental composition of leachate

Elemental Composition of Leachate by Waste Types (kg/kg)

Substance	Wates Type														
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.1906365	0.1320768	0.0002000	0.1448010	0.0000000	0.0840805	0.0000000	0.0000000	0.0556011	0.0596772	0.0433760	0.0135137	0.0100717	0.0000000	0.7340346
H	0.0164600	0.0077174	0.0007975	0.0115889	0.0000000	0.0062709	0.0000000	0.0000000	0.0041469	0.0072583	0.0044176	0.0010868	0.0005796	0.0000000	0.0603239
C	0.2026074	0.0915921	0.0060247	0.1280653	0.0000000	0.0683187	0.0000000	0.0000000	0.0451780	0.0774737	0.0518928	0.0146685	0.0070563	0.0000000	0.6928777
S	0.0022434	0.0001890	0.0000160	0.0005527	0.0000000	0.0001478	0.0000000	0.0000000	0.0000978	0.0002796	0.0004480	0.0000275	0.0000931	0.0000000	0.0040949
N	0.0059854	0.0002700	0.0000300	0.0005181	0.0000000	0.0003326	0.0000000	0.0000000	0.0002200	0.0004321	0.0049760	0.0000943	0.0002622	0.0000000	0.0131208
P	0.0016909	0.0000352	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0017261
B	0.0000153	0.0000054	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000207
Cl	0.0059854	0.0000541	0.0002700	0.0007945	0.0000000	0.0004979	0.0000000	0.0000000	0.0011785	0.0011530	0.0004320	0.0000354	0.0000025	0.0000000	0.0104032
Br	0.0000090	0.0000000	0.0000008	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000004	0.0000000	0.0000000	0.0000000	0.0000000	0.0000101
F	0.0002993	0.0000000	0.0000001	0.0000155	0.0000000	0.0000085	0.0000000	0.0000000	0.0000000	0.0000005	0.0000000	0.0000016	0.0000000	0.0000000	0.0003256
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000030	0.0000001	0.0000000	0.0000012	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000002	0.0000000	0.0000000	0.0000001	0.0000000	0.0000046
Ba	0.0000000	0.0000081	0.0000000	0.0000168	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000175	0.0000000	0.0000000	0.0000051	0.0000000	0.0000476
Cd	0.0000000	0.0000027	0.0000005	0.0000007	0.0000000	0.0000004	0.0000200	0.0000000	0.0000001	0.0000014	0.0000000	0.0000000	0.0000001	0.0000000	0.0000259
Co	0.0000075	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000002	0.0000000	0.0000000	0.0000000	0.0000000	0.0000077
Cr	0.0000120	0.0000092	0.0000005	0.0000080	0.0000000	0.0000000	0.0049000	0.0000000	0.0000000	0.0000018	0.0000000	0.0000000	0.0000011	0.0000000	0.0049325
Cu	0.0000269	0.0000081	0.0000008	0.0000290	0.0000000	0.0000083	0.0103924	0.0000000	0.0000008	0.0000068	0.0000000	0.0000005	0.0000015	0.0000000	0.0104751
Hg	0.0000000	0.0000000	0.0000000	0.0000003	0.0000000	0.0000002	0.0000025	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000031
Mn	0.0000064	0.0000135	0.0000000	0.0000349	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000153	0.0000000	0.0000000	0.0000090	0.0000000	0.0000791
Mo	0.0000006	0.0000021	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000027
Ni	0.0000081	0.0000027	0.0000002	0.0000088	0.0000000	0.0000000	0.0015000	0.0000000	0.0000000	0.0000016	0.0000000	0.0000000	0.0000004	0.0000000	0.0015218
Pb	0.0000278	0.0000135	0.0000009	0.0000149	0.0000000	0.0000060	0.0077899	0.0000000	0.0000016	0.0000053	0.0000000	0.0000121	0.0000116	0.0000000	0.0078836
Sb	0.0000000	0.0000015	0.0000000	0.0000000	0.0000000	0.0000000	0.0004500	0.0000000	0.0000000	0.0000004	0.0000000	0.0000000	0.0000000	0.0000000	0.0004518
Se	0.0000007	0.0000000	0.0000000	0.0000011	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000005	0.0000000	0.0000000	0.0000001	0.0000000	0.0000024
Sn	0.0000120	0.0000023	0.0000000	0.0000000	0.0000000	0.0000000	0.0007500	0.0000000	0.0000000	0.0000011	0.0000000	0.0000000	0.0000000	0.0000000	0.0007654
V	0.0000045	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000832	0.0000000	0.0000000	0.0000000	0.0000000	0.0000877
Zn	0.0000871	0.0000270	0.0000070	0.0000207	0.0000000	0.0000051	0.0069999	0.0000000	0.0000039	0.0000225	0.0000000	0.0000028	0.0000088	0.0000000	0.0071849
Si	0.0598252	0.0060136	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0658388
Fe	0.0008978	0.0001890	0.0000390	0.0000000	0.0000000	0.0000000	0.4021960	0.0000000	0.0000000	0.0000579	0.0000000	0.0000000	0.0000000	0.0000000	0.4033797
Ca	0.0326207	0.0010796	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000978	0.0000000	0.0000000	0.0000000	0.0000000	0.0337981
Al	0.0149563	0.0035222	0.0000020	0.0000000	0.0000000	0.0000000	0.0499995	0.0000000	0.0000000	0.0098533	0.0000000	0.0000000	0.0000000	0.0000000	0.0783333
K	0.0052373	0.0002700	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0055073
Mg	0.0042197	0.0013488	0.0000000	0.0000000	0.0000000	0.0000000	0.0149999	0.0000000	0.0000000	0.0000036	0.0000000	0.0000000	0.0000000	0.0000000	0.0205720
Na	0.0022445	0.0001890	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0024335
	0.54613	0.24464	0.00739	0.28647	0.00000	0.15968	0.50000	0.00000	0.10643	0.15645	0.10554	0.02944	0.01810	0.00000	**2.16**

7.2.3 Composition remaining material in landfill

Elemental Composition of Residue Waste in Landfill by Waste Types (kg/kg)

Substance	Wates Type														
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
O	0.1270910	0.3572778	0.0198002	0.3015647	0.2500000	0.3825151	0.0000000	0.4919882	0.4077411	0.2714947	0.3180907	0.3959933	0.4935135	0.2759055	4.0929756
H	0.0199515	0.0379566	0.1435511	0.0438823	0.0000000	0.0518707	0.0000000	0.0000000	0.0552915	0.0600383	0.0589013	0.0579025	0.0516328	0.0000000	0.5809786
C	0.1620061	0.2990051	0.7902441	0.3259517	0.3000000	0.3808337	0.0000000	0.0000000	0.4059488	0.4335099	0.4600640	0.5079995	0.4154639	0.0000000	4.4810269
S	0.0014956	0.0005113	0.0015840	0.0011510	0.0000000	0.0006726	0.0000000	0.0024023	0.0007169	0.0012720	0.0032853	0.0008058	0.0045629	0.0000000	0.0184597
N	0.0039903	0.0007305	0.0029700	0.0010791	0.0000000	0.0015132	0.0000000	0.0000000	0.0016130	0.0019656	0.0364907	0.0027627	0.0128482	0.0702693	0.1362326
P	0.0011273	0.0000953	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.1335117	0.1347342
B	0.0000102	0.0000146	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000249
Cl	0.0039903	0.0001464	0.0267302	0.0016546	0.0110000	0.0022652	0.0000000	0.0002002	0.0086421	0.0052455	0.0031680	0.0010360	0.0001201	0.0000000	0.0641986
Br	0.0000060	0.0000000	0.0000743	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000016	0.0000000	0.0000000	0.0000000	0.0000000	0.0000819
F	0.0001995	0.0000000	0.0000139	0.0000324	0.0000000	0.0000387	0.0000000	0.0000000	0.0000000	0.0000025	0.0000000	0.0000460	0.0000000	0.0000000	0.0003330
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000020	0.0000004	0.0000000	0.0000025	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000008	0.0000000	0.0000000	0.0000055	0.0000000	0.0000112
Ba	0.0000000	0.0000219	0.0000000	0.0000350	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000798	0.0000000	0.0000000	0.0002522	0.0000000	0.0003889
Cd	0.0000000	0.0000073	0.0000495	0.0000014	0.0000000	0.0000017	0.0000200	0.0000000	0.0000008	0.0000066	0.0000000	0.0000012	0.0000037	0.0000001	0.0000923
Co	0.0000050	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000009	0.0000000	0.0000000	0.0000000	0.0000000	0.0000059
Cr	0.0000080	0.0000248	0.0000495	0.0000167	0.0000000	0.0000000	0.0049000	0.0000000	0.0000000	0.0000084	0.0000000	0.0000000	0.0000534	0.0003513	0.0054121
Cu	0.0000180	0.0000219	0.0000743	0.0000604	0.0000000	0.0000379	0.0103924	0.0000100	0.0000056	0.0000311	0.0000000	0.0000150	0.0000737	0.0000731	0.0108133
Hg	0.0000000	0.0000000	0.0000000	0.0000006	0.0000000	0.0000008	0.0000025	0.0000000	0.0000000	0.0000002	0.0000000	0.0000006	0.0000014	0.0000000	0.0000062
Mn	0.0000043	0.0000365	0.0000000	0.0000727	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000694	0.0000000	0.0000000	0.0004410	0.0000281	0.0006520
Mo	0.0000004	0.0000057	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000061
Ni	0.0000054	0.0000073	0.0000178	0.0000183	0.0000000	0.0000000	0.0015000	0.0000000	0.0000000	0.0000073	0.0000000	0.0000000	0.0000213	0.0000000	0.0015775
Pb	0.0000185	0.0000365	0.0000891	0.0000309	0.0000000	0.0000272	0.0077899	0.0000100	0.0000119	0.0000242	0.0000000	0.0003557	0.0005705	0.0000084	0.0089729
Sb	0.0000000	0.0000040	0.0000000	0.0000000	0.0000000	0.0000000	0.0004500	0.0000000	0.0000000	0.0000017	0.0000000	0.0000000	0.0000000	0.0000000	0.0004557
Se	0.0000005	0.0000001	0.0000000	0.0000024	0.0000000	0.0000000	0.0000000	0.0000030	0.0000000	0.0000021	0.0000000	0.0000000	0.0000036	0.0000000	0.0000116
Sn	0.0000080	0.0000061	0.0000000	0.0000000	0.0000000	0.0000000	0.0007500	0.0000000	0.0000000	0.0000052	0.0000000	0.0000000	0.0000000	0.0000000	0.0007693
V	0.0000030	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0003787	0.0000000	0.0000000	0.0000000	0.0000000	0.0003817
Zn	0.0000581	0.0000730	0.0006930	0.0000432	0.0000000	0.0000232	0.0069999	0.0000040	0.0000282	0.0001024	0.0000000	0.0000817	0.0004323	0.0001405	0.0086796
Si	0.0398835	0.0162671	0.0000000	0.0000000	0.2450000	0.0000000	0.0000000	0.3382228	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.6393733
Fe	0.0005985	0.0005113	0.0038610	0.0000000	0.0000000	0.0000000	0.4021960	0.0010010	0.0000000	0.0002636	0.0000000	0.0000000	0.0000000	0.0067459	0.4151772
Ca	0.0217471	0.0029203	0.0000000	0.0000000	0.1700000	0.0000000	0.0000000	0.0420401	0.0000000	0.0004448	0.0000000	0.0000000	0.0000000	0.3021581	0.5393105
Al	0.0099709	0.0095279	0.0001980	0.0000000	0.0240000	0.0000000	0.0499995	0.0079075	0.0000000	0.0448263	0.0000000	0.0000000	0.0000000	0.0000000	0.1464301
K	0.0034915	0.0007305	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0002002	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0281077	0.0325299
Mg	0.0028132	0.0036485	0.0000000	0.0000000	0.0000000	0.0000000	0.0149999	0.0027026	0.0000000	0.0000165	0.0000000	0.0000000	0.0000000	0.0843232	0.1085037
Na	0.0014964	0.0005113	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.1133081	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0983770	0.2136928
	0.40000	0.73010	0.99000	0.67560	1.00000	0.81980	0.50000	1.00000	0.88000	0.81980	0.88000	0.96700	0.98000	1.00000	11.64

7.2.4 Balance of elements from landfill residuals, gaseous and liquid emissions and DOC

Balance Elemental Compositions Landfilling MSW

Description	Wates Type													
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones
Input														
Dry Waste	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000
Total	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000
Out-put														
LFG	0.0538690	0.0252569	0.0026100	0.0379274	0.0000000	0.0205230	0.0000000	0.0000000	0.0135715	0.0237546	0.0144576	0.0035568	0.0018967	0.0000000
Residual	0.5461310	0.2446431	0.0073900	0.2864726	0.0000000	0.1596770	0.5000000	0.0000000	0.1064285	0.1564454	0.1055424	0.0294432	0.0181033	0.0000000
Remain	0.4000000	0.7301000	0.9900000	0.6756000	1.0000000	0.8198000	0.5000000	1.0000000	0.8800000	0.8198000	0.8800000	0.9670000	0.9800000	1.0000000
Total	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000
Balance	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000

Degradable Organic Carbon of Dry MWS by Waste Types (kg/kg)[1]

Substance	Wates Type														
	Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
DOC	0.063182	0.023212	0.001197	0.012521	0.000000	0.003348	0.000000	0.000000	0.001661	0.001906	0.001255	0.000347	0.000127	0.000000	0.109
Share in Dry Waste	58.1%	21.3%	1.1%	11.5%	0.0%	3.1%	0.0%	0.0%	1.5%	1.8%	1.2%	0.3%	0.1%	0.0%	**1.0**

[1] Own estimate based on IPCC 2006

7.2.5 Emission factors used

Fuel, Electricity and other Consumption for Landfilling of MSW

Utility Type	Unit	Actual Consumption by Waste Type (kg^{-1} Dry Waste) Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
Landfill Gas	kg	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Electricity	kWh	2.972E-05	1.352E-05	9.762E-07	1.914E-05	0.000E+00	1.024E-05	0.000E+00	0.000E+00	6.770E-06	1.165E-05	7.672E-06	2.120E-06	1.037E-06	0.000E+00	1.028E-04
Heat	kWh	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

[1] Doka, G., 2003, Life Cycle Inventories of Waste Treatment Srvices, Ecoinvent Report No. 13, Part III Landfills-Undergraound Depositsa-Landfarming, Swiss Centre for Life Cycle Inventories, Dübendorf.

Emission, Electricity and other Products of MSW Landfilling

Utility Type	Unit	Actual Production by Waste Type (kg^{-1} Dry Waste) Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Total
Landfill Gas	kg	5.387E-02	2.526E-02	2.610E-03	3.793E-02	0.000E+00	2.052E-02	0.000E+00	0.000E+00	1.357E-02	2.375E-02	1.446E-02	3.557E-03	1.897E-03	0.000E+00	1.9742E-01
Electricity	kWh	7.347E-01	3.445E-01	3.560E-02	5.173E-01	0.000E+00	2.799E-01	0.000E+00	0.000E+00	1.851E-01	3.240E-01	1.972E-01	4.851E-02	2.587E-02	0.000E+00	2.693E+00
Heat	kWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000E+00

[1] Own estimate

Landfill Gas Composition

Gas Type	Unit	Landfill Gas Composition (% vol)[1]	(% vol)[2]	(% vol)[3]	(% vol)[4]	(% vol)[5]	Remark
Carbon Dioxide (CO_2)	kg	37.14	45.00	34.00	37.00	40.86	
Carbon monoxide (CO)	kg						
Methane (CH_4)	kg	55.63	55.00	64.00	47.00	59.14	
Nitrogen Oxide (NO_x)	kg						
Dinitrogen Oxides (N_2O)	kg						
Ammonia	kg						
NMVOC	kg						
PM	kg						
SO2	kg						

[1] Bart Eklund, B., Anderson, E., Walker, B. and Don B . Burrows, 1998, Characterization of Landfill Gas Composition at the Fresh Kills Municipal Solid Waste Landfill, Environ. Sci. Technol. vol. 32, pp. 2233 – 2237.
[2] US EPA, 2000, Facts About Landfill Gas.
[3] Riley, R., 2003, The Monitoring of Landfill Gas, Gas Detection Magazine, issue June 20
[4] Doka, G., 2003, Life Cycle Inventories of Waste Treatment Srvices, Ecoinvent Report No. 13, Part III Landfills Swiss Centre for Life Cycle Inventories, Dübendorf.
[5] This module

Emission Factor

Gas Type	Unit	Waste Derived Emission Food	Paper	Plastics	Cardboard	Minerals	Plastic coated paper	Metals	Glass	Diapers	Tetrapack	Textiles	Wood	Other biomass	Bones	Remark
Carbon Dioxide (CO_2)	kg	4.89E-02	2.29E-02	2.37E-03	3.44E-02	0.00E+00	1.86E-02	0.00E+00	0.00E+00	1.23E-02	2.15E-02	1.31E-02	3.23E-03	1.72E-03	0.00E+00	
Carbon monoxide (CO)	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Methane (CH_4)	kg	6.58E-02	3.09E-02	3.19E-03	4.64E-02	0.00E+00	2.51E-02	0.00E+00	0.00E+00	1.66E-02	2.90E-02	1.77E-02	4.35E-03	2.32E-03	0.00E+00	
Nitrogen Oxide (NO_x)	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Dinitrogen Oxides (N_2O)	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Ammonia	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
NMVOC	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
PM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SO2	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Emission Factor[1]

Gas Type	Unit	Fuels Derived Emission (MJ^{-1}) Natural Gas	Diesel Oils	Landfill Gas	Remark
Carbon Dioxide (CO_2)	kg	5.50E-02	1.34E+02	5.45E-02	
Carbon monoxide (CO)	kg	5.00E-06	4.89E-01	5.00E-06	
Methane (CH_4)	kg	2.00E-06	6.89E-03	2.00E-06	
Nitrogen Oxide (NO_x)	kg	4.10E-05	1.89E+00	4.10E-05	
Dinitrogen Oxides (N_2O)	kg	1.00E-06	5.15E-03	1.00E-06	
Ammonia	kg	0.00E+00	8.58E-04	0.00E+00	
NMVOC	kg	0.00E+00	2.22E-01	0.00E+00	
PM	kg	0.00E+00	0.00E+00	0.00E+00	
SO2	kg	1.00E-06	4.34E-02	1.00E-06	

[1] FORWAST Deliverable 2-2

Net Calorific Value

Fuel Type	Unit	Net Ccalorific Value	Remark
Natural Gas	MJ kg^{-1}	48.00	
Diesel Oils	MJ kg^{-1}	42.70	
Crude Oils	MJ kg^{-1}	42.30	
Lubricating Oils	MJ kg^{-1}	40.20	
Waste Oils	MJ kg^{-1}	40.20	
Landfill Gas	MJ kg^{-1}	50.40	

[1] IPCC 2006

7.2.6 Emissions regarding waste

Unit: kg

NACE No.	Product No.	Activity No. / Activities / Products	1 Landfilling of Food Waste	2 Incineration Paper	3 Incineration Plastics	4 Incineration Cardboard	5 Incineration Minerals	6 Incineration Plastic coated paper	7 Incineration Metals	8 Incineration Glass	9 Incineration Diapers	10 Incineration Tetra pack	11 Incineration Textiles	12 Incineration Wood	13 Incineration Other biomass	14 Incineration Bones
Emissions Distribution, emissions from residuals (-Gw)																
Air	1	Ammonia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	2	Arsenic	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	3	Cadmium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	4	Carbon dioxide, fibre carbon		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	5	Carbon dioxide, fossil carbon	[illegible]													
Air	6	Carbon dioxide, coal carbon														
Air	7	Carbon dioxide, crude oil and natural gas carbon			[illegible]											
Air	8	Carbon dioxide, carbonate														
Air	9	Carbon monoxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	10	Chromium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	11	Copper	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	12	Dinitrogen monoxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	13	Hydrogen chloride														
Air	14	Hydrogen fluoride														
Air	15	Lead	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	16	Mercury	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	17	Methane	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	18	Nickel	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	19	Nitric acid														
Air	20	Nitrogen dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	21	NMVOC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	22	ODP														
Air	23	PAH, measured as Benzo(a)pyrene														
Air	24	Particulates, < 10 um	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	25	Phosphorus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	26	Selenium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	27	Sulfur dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	28	Vanadium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Air	29	Zinc	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
water	30	Copper														
water	31	Nitrogen, total														
water	32	Phosphorus														
Soil	33	Antimony														
Soil	34	Arsenic														
Soil	35	Barium														
Soil	36	Cadmium														
Soil	37	Chromium														
Soil	38	Cobalt														
Soil	39	Copper														
Soil	40	Lead														
Soil	41	Mercury														
Soil	42	Nickel														
Soil	43	Phosphorus														
Soil	44	Selenium														
Soil	45	Zinc														
	46	Aluminium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	47	Carbon, biomass, unspecified														
	48	Carbon, fossil, unspecified														
	49	Clay and soil														
	50	Iron	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	51	Metals n.e.c.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	52	Minerals n.e.c.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	53	Oxygen	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	54	Sand, gravel and stone	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Total from Emissions Distribution (-Gw)	0.54613	0.24484	0.00739	0.28647	0.00000	0.10988	0.00000	0.00000	0.10643	0.10648	0.10684	0.02944	0.01810	0.00000

Balance Check (g-g)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Residual Input	0.54613	0.24484	0.00739	0.28647	0.00000	0.10988	0.00000	0.00000	0.10643	0.10648	0.10684	0.02944	0.01810	0.00000
Emmission	0.54613	0.24484	0.00739	0.28647	0.00000	0.10988	0.00000	0.00000	0.10643	0.10648	0.10684	0.02944	0.01810	0.00000
Balance Check	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

7.2.7 Emissions regarding fuel

Unit: kg

NACE No.	Product No.	Activity No. / Products \ Activities	1 Landfilling of Food Waste	2 Incineration Paper	3 Incineration Plastics	4 Incineration Cardboard	5 Incineration Minerals	6 Incineration Plastic coated paper	7 Incineration Metals	8 Incineration Glass	9 Incineration Diapers	10 Incineration Tetra pack	11 Incineration Textiles	12 Incineration Wood	13 Incineration Other biomass	14 Incineration Bones
Emissions Distribution, emissions from products (-Gc)																
Air	1	Ammonia	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	2	Arsenic														
Air	3	Cadmium														
Air	4	Carbon dioxide, fibre carbon														
Air	5	Carbon dioxide, food carbon														
Air	6	Carbon dioxide, coal carbon														
Air	7	Carbon dioxide, crude oil and natural gas carbon	0.14797	0.09038	0.00717	0.10418	0.00000	0.05637	0.00000	0.00000	0.03726	0.00525	0.03971	0.00977	0.00521	0.00000
Air	8	Carbon dioxide, carbonate														
Air	9	Carbon monoxide	0.00001	0.00001	0.00000	0.00001	0.00000	0.00001	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000
Air	10	Chromium														
Air	11	Copper														
Air	12	Dinitrogen monoxide	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	13	Hydrogen chloride														
Air	14	Hydrogen fluoride														
Air	15	Lead														
Air	16	Mercury														
Air	17	Methane	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	18	Nickel														
Air	19	Nitric acid														
Air	20	Nitrogen dioxide	0.00011	0.00000	0.00001	0.00009	0.00000	0.00004	0.00000	0.00000	0.00003	0.00005	0.00000	0.00001	0.00000	0.00000
Air	21	NMVOC	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	22	ODP														
Air	23	PAH, measured as Benzo(a)pyrene														
Air	24	Particulates, < 10 um	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	25	Phosphorus														
Air	26	Selenium														
Air	27	Sulfur dioxide	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Air	28	Vanadium														
Air	29	Zinc														
water	30	Copper														
water	31	Nitrogen, total														
water	32	Phosphorus														
Soil	33	Antimony														
Soil	34	Arsenic														
Soil	35	Barium														
Soil	36	Cadmium														
Soil	37	Chromium														
Soil	38	Cobalt														
Soil	39	Copper														
Soil	40	Lead														
Soil	41	Mercury														
Soil	42	Nickel														
Soil	43	Phosphorus														
Soil	44	Selenium														
Soil	45	Zinc														
	46	Aluminium														
	47	Carbon, biomass, unspecified														
	48	Carbon, fossil, unspecified														
	49	Clay and soil														
	50	Iron														
	51	Metals n.e.c.														
	52	Minerals n.e.c.	0.01390	0.00033	0.00065	0.00851	0.00000	0.00514	0.00000	0.00000	0.00340	0.00595	0.00382	0.00069	0.00048	0.00000
	53	Oxygen														
	54	Sand, gravel and stone														
		Total from Emissions Distribution (-GC)	**0.05387**	**0.02526**	**0.00261**	**0.03793**	0.00000	**0.02052**	0.00000	0.00000	**0.01357**	**0.02376**	**0.01446**	**0.00356**	**0.00190**	0.00000

Balance Check (g-g) (kg)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Product Input	0.05387	0.02526	0.00261	0.03793	0.00000	0.02052	0.00000	0.00000	0.01357	0.02375	0.01446	0.00356	0.00190	0.00000
Emmission	0.05387	0.02526	0.00261	0.03793	0.00000	0.02052	0.00000	0.00000	0.01357	0.02376	0.01446	0.00356	0.00190	0.00000
Balance Check	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

7.3 Composting of Food Waste

7.3.1 Elemental composition food waste

Substance	Wates Type		
	Food wet	Food dry	Remark
Water	59.9417092		
O	12.7276229	0.0826092	
H	1.9980570	0.0129685	
C	16.2242226	0.1053040	
S	0.1497810	0.0009722	
N	0.3996114	0.0025937	
P	0.1128902	0.0007327	
B	0.0010230	0.0000066	
Cl	0.3996114	0.0025937	
Br	0.0005994	0.0000039	
F	0.0199806	0.0001297	
I	0.0000000	0.0000000	
Ag	0.0000000	0.0000000	
As	0.0001998	0.0000013	
Ba	0.0000000	0.0000000	
Cd	0.0000000	0.0000000	
Co	0.0004995	0.0000032	
Cr	0.0007992	0.0000052	
Cu	0.0017983	0.0000117	
Hg	0.0000000	0.0000000	
Mn	0.0004296	0.0000028	
Mo	0.0000400	0.0000003	
Ni	0.0005415	0.0000035	
Pb	0.0018542	0.0000120	
Sb	0.0000000	0.0000000	
Se	0.0000499	0.0000003	
Sn	0.0007988	0.0000052	
V	0.0002996	0.0000019	
Zn	0.0058183	0.0000378	
Si	3.9941588	0.0259243	
Fe	0.0599417	0.0003891	
Ca	2.1778821	0.0141356	
Al	0.9985397	0.0064811	
K	0.3496600	0.0022695	
Mg	0.2817260	0.0018286	
Na	0.1498543	0.0009726	
Total	100.00	0.26000	Soure: Doka 2003

7.3.2 Elemental composition of dry food waste per kg; composition of emission and compost per kg dry food waste input

Substance	Good in g/kg dry food waste input		
	Food waste dry	Emission	Composition Compost
Degradability	29.00%		
O	0.3177276	0.1112046	0.2065229
H	0.0498787	0.0174576	0.0324212
C	0.4050153	0.1417554	0.2632600
S	0.0037391	0.0003739	0.0033652
N	0.0099757	0.0009976	0.0089782
P	0.0028181	0.0002818	0.0025363
B	0.0000255	0.0000026	0.0000230
Cl	0.0099757	0.0009976	0.0089782
Br	0.0000150	0.0000015	0.0000135
F	0.0004988	0.0000499	0.0004489
I	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000
As	0.0000050	0.0000005	0.0000045
Ba	0.0000000	0.0000000	0.0000000
Cd	0.0000000	0.0000000	0.0000000
Co	0.0000125	0.0000012	0.0000112
Cr	0.0000200	0.0000020	0.0000180
Cu	0.0000449	0.0000045	0.0000404
Hg	0.0000000	0.0000000	0.0000000
Mn	0.0000107	0.0000011	0.0000097
Mo	0.0000010	0.0000001	0.0000009
Ni	0.0000135	0.0000014	0.0000122
Pb	0.0000463	0.0000046	0.0000417
Sb	0.0000000	0.0000000	0.0000000
Se	0.0000012	0.0000001	0.0000011
Sn	0.0000199	0.0000020	0.0000179
V	0.0000075	0.0000007	0.0000067
Zn	0.0001452	0.0000145	0.0001307
Si	0.0997087	0.0099709	0.0897378
Fe	0.0014964	0.0001496	0.0013467
Ca	0.0543678	0.0054368	0.0489310
Al	0.0249272	0.0024927	0.0224345
K	0.0087288	0.0008729	0.0078559
Mg	0.0070329	0.0007033	0.0063296
Na	0.0037409	0.0003741	0.0033668
Total	1.00	0.29	0.71

Source: Doka 2003; removal of elements except O, H, C about 10%

7.3.3 Emission factors used

Fuel and Electricity Use for Composting Plant

Utility Type	Unit	Total Consumption (kg^{-1} Compost)[1]	(kg^{-1} Food Waste)[1]	(kg^{-1} Dry Food Waste)[2]	Remark
Diesel Oils	kg	0.00720	0.00530	0.00530	
Electricity	kWh	0.01180	0.00868	0.00868	
Heat	kWh	0.00000	0.00000	0.00000	

[1]Ecoinvent Report No. 15
[2]Our own calculation   0.00268

Fuel and Electricity Production from Composting Plant

Utility Type	Unit	Total Consumption (kg^{-1} Compost)[1]	(kg^{-1} Food Waste)[1]	(kg^{-1} Dry Food Waste)[2]	Remark
Refined petroleum products and fuels	kg	0.00000	0.00000	0.00000	
Electricity	kWh	0.00000	0.00000	0.00000	
Heat	kWh	0.00000	0.00000	0.00000	

[1]Ecoinvent Report No. 15
[2]Our own calculation

Emission Factor

Gas Type	Unit	Waste Derived Emission (kg^{-1} compost)[1]	(kg^{-1} Biowaste)[2]	(kg^{-1} Food Waste)[3]	Remark
Carbon Dioxie (CO_2)	kg	0.52000		0.38254	
Carbon monoxide (CO)	kg				
Methane (CH_4)	kg	0.01010	0.01000	0.00743	
Nitrogen Oxide (NO_X)	kg				
Dinitrogen Oxides (N_2O)	kg	0.00028	0.00060	0.00021	
Ammonia	kg				
NMVOC	kg				
PM	kg				
SO2	kg				

[1]Ecoinvent Report No. 15
[2]IPCC 2006
[3]This Module

Emission Factor[1]

Gas Type	Unit	Fuele Derived Emission (MJ^{-1}) Natural Gas	Diesel Oils	Landfill Gas	Remark
Carbon Dioxie (CO_2)	kg	5.50E-02	1.34E+02	5.45E-02	
Carbon monoxide (CO)	kg	5.00E-06	4.89E-01	5.00E-06	
Methane (CH_4)	kg	2.00E-06	6.89E-03	2.00E-06	
Nitrogen Oxide (NO_X)	kg	4.10E-05	1.89E+00	4.10E-05	
Dinitrogen Oxides (N_2O)	kg	1.00E-06	5.15E-03	1.00E-06	
Ammonia	kg	0.00E+00	8.58E-04	0.00E+00	
NMVOC	kg	0.00E+00	2.22E-01	0.00E+00	
PM	kg	0.00E+00	0.00E+00	0.00E+00	
SO2	kg	1.00E-06	4.34E-02	1.00E-06	

[1]FORWAST Deliverable 2-2

Net Calorific Value[1]

Fuel Type	Unit	Net Ccalorific Value	Remark
Natural Gas	MJ kg^{-1}	48.00	
Diesel Oils	MJ kg^{-1}	43.00	
Crude Oils	MJ kg^{-1}	42.30	
Lubricating Oils	MJ kg^{-1}	40.20	
Waste Oils	MJ kg^{-1}	40.20	
Landfill Gas	MJ kg^{-1}	50.40	

[1]IPCC 2006

7.3.4 Emissions regarding waste

Unit:		Activity No.	1
NACE No.	Product No.	Activities / Products	Composting Food Waste
kg		**Emissions Distribution, emissions from residuals (-Gw)**	
Air	1	Ammonia	0.00000
Air	2	Arsenic	0.00000
Air	3	Cadmium	0.00000
Air	4	Carbon dioxide, fibre carbon	
Air	5	Carbon dioxide, food carbon	0.38254
Air	6	Carbon dioxide, coal carbon	
Air	7	Carbon dioxide, crude oil and natural gas carbon	
Air	8	Carbon dioxide, carbonate	
Air	9	Carbon monoxide	0.00000
Air	10	Chromium	0.00000
Air	11	Copper	0.00000
Air	12	Dinitrogen monoxide	0.00021
Air	13	Hydrogen chloride	
Air	14	Hydrogen fluoride	
Air	15	Lead	0.00000
Air	16	Mercury	0.00000
Air	17	Methane	0.00743
Air	18	Nickel	0.00000
Air	19	Nitric acid	
Air	20	Nitrogen dioxide	0.00000
Air	21	NMVOC	
Air	22	ODP	
Air	23	PAH, measured as Benzo(a)pyrene	
Air	24	Particulates, < 10 um	
Air	25	Phosphorus	0.00028
Air	26	Selenium	0.00000
Air	27	Sulfur dioxide	0.00000
Air	28	Vanadium	0.00000
Air	29	Zinc	0.00001
water	30	Copper	
water	31	Nitrogen, total	
water	32	Phosphorus	
Soil	33	Antimony	
Soil	34	Arsenic	
Soil	35	Barium	
Soil	36	Cadmium	
Soil	37	Chromium	
Soil	38	Cobalt	
Soil	39	Copper	
Soil	40	Lead	
Soil	41	Mercury	
Soil	42	Nickel	
Soil	43	Phosphorus	
Soil	44	Selenium	
Soil	45	Zinc	
	46	Aluminium	0.00249
	47	Carbon, biomass, unspecified	
	48	Carbon, fossil, unspecified	
	49	Clay and soil	
	50	Iron	0.00015
	51	Metals n.e.c.	0.00587
	52	Minerals n.e.c.	0.05140
	53	Oxygen	0.11120
	54	Sand, gravel and stone	0.00997
		Total from Emissions Distribution (-Gw)	**0.29316**

kg **Balance Check (g-g)**

Biowaste Input	**0.29316**
Emmission	**0.29316**
Balance Check	**0.00000**

7.3.5 Emissions regarding fuel

Unit:

	NACE No.	Product No.	Activity No. / Activities / Products	1 Composting Food Waste
kg	Emissions Distribution, emissions from products (-Gc)			
	Air	1	Ammonia	0.00020
	Air	2	Arsenic	
	Air	3	Cadmium	
	Air	4	Carbon dioxide, fibre carbon	
	Air	5	Carbon dioxide, food carbon	
	Air	6	Carbon dioxide, coal carbon	
	Air	7	Carbon dioxide, crude oil and natural gas carbon	30.55302
	Air	8	Carbon dioxide, carbonate	
	Air	9	Carbon monoxide	0.11133
	Air	10	Chromium	
	Air	11	Copper	
	Air	12	Dinitrogen monoxide	0.00117
	Air	13	Hydrogen chloride	
	Air	14	Hydrogen fluoride	
	Air	15	Lead	
	Air	16	Mercury	
	Air	17	Methane	0.00157
	Air	18	Nickel	
	Air	19	Nitric acid	
	Air	20	Nitrogen dioxide	0.43109
	Air	21	NMVOC	0.05064
	Air	22	ODP	
	Air	23	PAH, measured as Benzo(a)pyrene	
	Air	24	Particulates, < 10 um	0.00000
	Air	25	Phosphorus	
	Air	26	Selenium	
	Air	27	Sulfur dioxide	0.00988
	Air	28	Vanadium	
	Air	29	Zinc	
	water	30	Copper	
	water	31	Nitrogen, total	
	water	32	Phosphorus	
	Soil	33	Antimony	
	Soil	34	Arsenic	
	Soil	35	Barium	
	Soil	36	Cadmium	
	Soil	37	Chromium	
	Soil	38	Cobalt	
	Soil	39	Copper	
	Soil	40	Lead	
	Soil	41	Mercury	
	Soil	42	Nickel	
	Soil	43	Phosphorus	
	Soil	44	Selenium	
	Soil	45	Zinc	
		46	Aluminium	
		47	Carbon, biomass, unspecified	
		48	Carbon, fossil, unspecified	
		49	Clay and soil	
		50	Iron	
		51	Metals n.e.c.	
		52	Minerals n.e.c.	
		53	Oxygen	
		54	Sand, gravel and stone	
			Total from Emissions Distribution (-GC)	8.43770
kg	Balance Check (g-g)			
			Product Input	0.00530
			Emmission	8.43770
			Balance Check	-8.43240

The balance checked did not work due to a failure in the module.

7.4 Biogasification

7.4.1 Composition of wet wastes to biogas plant

Elemental Compositions MSW by Wate Type (fraction)[1]

Substance	Waste Type					
	Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Remark
Water	60	58.6	88.4	90.0	95.0	
O	12.73	6.917	2.201	0.127	1.386	
H	2	0.617	0.294	0.043	0.332	
C	16.22	22.595	8.506	4.880	2.263	
S	0.149780955	0.25917	0.03456	0.01032	0.03815	
N	0.4	3.168	0.09799	0.08707	0.193	
P	0.113	1.789	0.056150	0.334	0.092	
B	0.001023	0.001319	0.000130	0.000848	0.003180	
Cl	0.4	0.968	0.017676	0.0	0.004400	
Br	0.0006	0.0	0.0	0.0	0.000171	
F	0.02	0.0	0.000151	0.0	0.002359	
I		0.0	0.0	0.0	0.000231	
Ag		0.0	0.0	0.0	0.0	
As	0.0002	0.002183	0.000276	0.000141	0.002884	
Ba		0.001310	0.003672	0.0	0.016687	
Cd		0.000097	0.000	0.000019	0.003631	
Co	0.0005	0.000151	0.000262	0.000278	0.002500	
Cr	0.0008	0.000914	0.000659	0.000354	0.158	
Cu	0.0018	0.006187	0.000317	0.006200	0.020361	
Hg		0.0	0.0	0.0	0.033702	
Mn	0.00043	0.022821	0.002363	0.002353	0.008951	
Mo	0.00004	0.000143	0.000530	0.000433	0.003183	
Ni	0.000541	0.000933	0.000408	0.0	0.014959	
Pb	0.001854	0.000712	0.000098	0.000250	0.027874	
Sb		0.0	0.000	0.0	0.000086	
Se	0.0000499	0.0	0.008342	0.0	0.000067	
Sn	0.0007988	0.0	0.000120	0.0	0.002353	
V	0.0002996	0.000391	0.000119	0.0	0.000727	
Zn	0.005818	0.026516	0.001635	0.006334	0.041887	
Si	3.994158808	0.069987	0.166	0.0	0.0	
Fe	0.06	0.105051	0.013026	0.029648	0.037686	
Ca	2.18	2.8626632	0.043000	2.347	0.029886	
Al	0.998539702	0.048543	0.001123	0.0	0.214	
K	0.35	1.370	0.113284	0.258	0.034655	
Mg	0.282	0.315211	0.029458	0.470	0.022892	
Na	0.15	0.261516	0.007167	1.396	0.008902	
	100	100	100	100	100	

1Subtracted from MSW Composition provides by Doka, G., 2003, Life Cycle Inventories of Waste Treatment Srvices, Ecoinvent Report No. 13,

7.4.2 Composition of dry waste to biogas plant

Elemental Composition of Dry MWS by Waste Types (kg)

Substance	Wates Type					
	Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Total
O	0.3177276	0.1670337	0.1897454	0.0127229	0.2772415	0.9644711
H	0.0498787	0.0149047	0.0253528	0.0042929	0.0663006	0.1607297
C	0.4050153	0.5456448	0.7332789	0.4879918	0.4526159	2.6245467
S	0.0037391	0.0062586	0.0029792	0.0010319	0.0076305	0.0216392
N	0.0099757	0.0765062	0.0084475	0.0087067	0.0386930	0.1423292
P	0.0028181	0.0431921	0.0048405	0.0334067	0.0183132	0.1025707
B	0.0000255	0.0000319	0.0000112	0.0000848	0.0006360	0.0007895
Cl	0.0099757	0.0233796	0.0015238	0.0000000	0.0008801	0.0357591
Br	0.0000150	0.0000000	0.0000000	0.0000000	0.0000342	0.0000492
F	0.0004988	0.0000000	0.0000130	0.0000000	0.0004718	0.0009836
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000462	0.0000462
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000050	0.0000527	0.0000238	0.0000141	0.0005768	0.0006724
Ba	0.0000000	0.0000316	0.0003165	0.0000000	0.0033374	0.0036855
Cd	0.0000000	0.0000024	0.0000005	0.0000019	0.0007262	0.0007309
Co	0.0000125	0.0000036	0.0000226	0.0000278	0.0004999	0.0005664
Cr	0.0000200	0.0000221	0.0000568	0.0000354	0.0315049	0.0316391
Cu	0.0000449	0.0001494	0.0000273	0.0006200	0.0040721	0.0049137
Hg	0.0000000	0.0000000	0.0000001	0.0000000	0.0067403	0.0067404
Mn	0.0000107	0.0005511	0.0002037	0.0002353	0.0017901	0.0027909
Mo	0.0000010	0.0000035	0.0000457	0.0000433	0.0006365	0.0007300
Ni	0.0000135	0.0000225	0.0000352	0.0000000	0.0029917	0.0030630
Pb	0.0000463	0.0000172	0.0000084	0.0000250	0.0055749	0.0056718
Sb	0.0000000	0.0000000	0.0000005	0.0000000	0.0000171	0.0000176
Se	0.0000012	0.0000000	0.0007191	0.0000000	0.0000134	0.0007337
Sn	0.0000199	0.0000000	0.0000103	0.0000000	0.0004705	0.0005008
V	0.0000075	0.0000095	0.0000102	0.0000000	0.0001455	0.0001727
Zn	0.0001452	0.0006403	0.0001409	0.0006334	0.0083774	0.0099373
Si	0.0997087	0.0016901	0.0143361	0.0000000	0.0000000	0.1157348
Fe	0.0014964	0.0025369	0.0011229	0.0029648	0.0075372	0.0156582
Ca	0.0543678	0.0691303	0.0037069	0.2347175	0.0059772	0.3678997
Al	0.0249272	0.0011723	0.0000968	0.0000000	0.0428580	0.0690542
K	0.0087288	0.0330858	0.0097659	0.0258239	0.0069310	0.0843354
Mg	0.0070329	0.0076120	0.0025395	0.0469894	0.0045783	0.0687521
Na	0.0037409	0.0063153	0.0006178	0.1396305	0.0017805	0.1520850
Total	1.00	1.00	1.00	1.00	1.00	**5.00**

7.4.3 Composition of dry waste to biogas plant incl. degradation rate

Elemental Composition of Dry MWS by Waste Types (kg)

Substance	Wates Type					
	Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Total
Decomposition Rate	**60.0%**	**55.0%**	**29.0%**	**49.0%**	**45.0%**	
O	0.3177276	0.1670337	0.1897454	0.0127229	0.2772415	0.9644711
H	0.0498787	0.0149047	0.0253528	0.0042929	0.0663006	0.1607297
C	0.4050153	0.5456448	0.7332789	0.4879918	0.4526159	2.6245467
S	0.0037391	0.0062586	0.0029792	0.0010319	0.0076305	0.0216392
N	0.0099757	0.0765062	0.0084475	0.0087067	0.0386930	0.1423292
P	0.0028181	0.0431921	0.0048405	0.0334067	0.0183132	0.1025707
B	0.0000255	0.0000319	0.0000112	0.0000848	0.0006360	0.0007895
Cl	0.0099757	0.0233796	0.0015238	0.0000000	0.0008801	0.0357591
Br	0.0000150	0.0000000	0.0000000	0.0000000	0.0000342	0.0000492
F	0.0004988	0.0000000	0.0000130	0.0000000	0.0004718	0.0009836
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000462	0.0000462
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000050	0.0000527	0.0000238	0.0000141	0.0005768	0.0006724
Ba	0.0000000	0.0000316	0.0003165	0.0000000	0.0033374	0.0036855
Cd	0.0000000	0.0000024	0.0000005	0.0000019	0.0007262	0.0007309
Co	0.0000125	0.0000036	0.0000226	0.0000278	0.0004999	0.0005664
Cr	0.0000200	0.0000221	0.0000568	0.0000354	0.0315049	0.0316391
Cu	0.0000449	0.0001494	0.0000273	0.0006200	0.0040721	0.0049137
Hg	0.0000000	0.0000000	0.0000001	0.0000000	0.0067403	0.0067404
Mn	0.0000107	0.0005511	0.0002037	0.0002353	0.0017901	0.0027909
Mo	0.0000010	0.0000035	0.0000457	0.0000433	0.0006365	0.0007300
Ni	0.0000135	0.0000225	0.0000352	0.0000000	0.0029917	0.0030630
Pb	0.0000463	0.0000172	0.0000084	0.0000250	0.0055749	0.0056718
Sb	0.0000000	0.0000000	0.0000005	0.0000000	0.0000171	0.0000176
Se	0.0000012	0.0000000	0.0007191	0.0000000	0.0000134	0.0007337
Sn	0.0000199	0.0000000	0.0000103	0.0000000	0.0004705	0.0005008
V	0.0000075	0.0000095	0.0000102	0.0000000	0.0001455	0.0001727
Zn	0.0001452	0.0008403	0.0001409	0.0006334	0.0083774	0.0099373
Si	0.0997087	0.0016901	0.0143361	0.0000000	0.0000000	0.1157348
Fe	0.0014964	0.0025369	0.0011229	0.0029648	0.0075372	0.0156582
Ca	0.0543678	0.0691303	0.0037069	0.2347175	0.0059772	0.3678997
Al	0.0249272	0.0011723	0.0000968	0.0000000	0.0428580	0.0690542
K	0.0087288	0.0330858	0.0097659	0.0258239	0.0069310	0.0843354
Mg	0.0070329	0.0076120	0.0025395	0.0469894	0.0045783	0.0687521
Na	0.0037409	0.0063153	0.0006178	0.1396305	0.0017805	0.1520850
Total	1.00	1.00	1.00	1.00	1.00	**5.00**

7.4.4 Composition of degraded waste in kg/kg dry matter input

Substance	Wates Type					
	Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Total
O	0.2255866	0.1252753	0.0569236	0.0115778	0.1885242	0.6078875
H	0.0354139	0.0111785	0.0076058	0.0039065	0.0450844	0.1031892
C	0.2875609	0.4092336	0.2199837	0.4440725	0.3077788	1.6686295
S	0.0026547	0.0046939	0.0008938	0.0009390	0.0051887	0.0143702
N	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
P	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
B	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cl	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Br	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
F	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ba	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cd	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Co	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cr	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cu	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Hg	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mo	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ni	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Pb	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Sb	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Se	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Sn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
V	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Zn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Si	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Fe	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ca	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Al	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
K	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mg	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Na	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	0.55000	0.55000	0.29000	0.49000	0.55000	**2.39**

7.4.5 Composition of Biogas in kg/kg dry matter input

Elemental Composition of Biogas by Waste Types (kg)

Substance	Wates Type					
	Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Total
O	0.0750775	0.0236984	0.0161244	0.0082818	0.0955789	0.2187610
H	0.0099159	0.0031300	0.0021296	0.0010938	0.0126236	0.0288930
C	0.0566622	0.0178856	0.0121693	0.0062505	0.0721350	0.1651027
S	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
N						0.0000000
P						0.0000000
B						0.0000000
Cl						0.0000000
Br						0.0000000
F						0.0000000
I						0.0000000
Ag						0.0000000
As						0.0000000
Ba						0.0000000
Cd						0.0000000
Co						0.0000000
Cr						0.0000000
Cu						0.0000000
Hg						0.0000000
Mn						0.0000000
Mo						0.0000000
Ni						0.0000000
Pb						0.0000000
Sb						0.0000000
Se						0.0000000
Sn						0.0000000
V						0.0000000
Zn						0.0000000
Si						0.0000000
Fe						0.0000000
Ca						0.0000000
Al						0.0000000
K						0.0000000
Mg						0.0000000
Na						0.0000000
	0.14166	0.04471	0.03042	0.01563	0.18034	**0.41**

7.4.6 Composition of residuals from biogas plant in kg/kg dry matter input

Substance	Wates Type					
	Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Total
O	0.1505091	0.1015768	0.0407993	0.0032960	0.0929453	0.3891265
H	0.0254980	0.0080485	0.0054762	0.0028127	0.0324608	0.0742962
C	0.2308987	0.3913480	0.2078143	0.4378221	0.2356438	1.5035268
S	0.0026547	0.0046939	0.0008938	0.0009390	0.0051887	0.0143702
N	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
P	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
B	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cl	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Br	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
F	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ba	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cd	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Co	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cr	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cu	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Hg	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mo	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ni	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Pb	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Sb	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Se	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Sn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
V	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Zn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Si	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Fe	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ca	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Al	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
K	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mg	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Na	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	0.40956	0.50567	0.25498	0.44487	0.36624	**1.98**

7.4.7 Compositon of digested matter in kg/kg dry matter input

Substance	Wates Type					
	Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Total
O	0.0921410	0.0417584	0.1328218	0.0011451	0.0887173	0.3565836
H	0.0144648	0.0037262	0.0177469	0.0003864	0.0212162	0.0575405
C	0.1174545	0.1364112	0.5132952	0.0439193	0.1448371	0.9559172
S	0.0010843	0.0015646	0.0020854	0.0000929	0.0024418	0.0072690
N	0.0099757	0.0765062	0.0084475	0.0087067	0.0386930	0.1423292
P	0.0028181	0.0431921	0.0048405	0.0334067	0.0183132	0.1025707
B	0.0000255	0.0000319	0.0000112	0.0000848	0.0006360	0.0007895
Cl	0.0099757	0.0233796	0.0015238	0.0000000	0.0008801	0.0357591
Br	0.0000150	0.0000000	0.0000000	0.0000000	0.0000342	0.0000492
F	0.0004988	0.0000000	0.0000130	0.0000000	0.0004718	0.0009836
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000462	0.0000462
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000050	0.0000527	0.0000238	0.0000141	0.0005768	0.0006724
Ba	0.0000000	0.0000316	0.0003165	0.0000000	0.0033374	0.0036855
Cd	0.0000000	0.0000024	0.0000005	0.0000019	0.0007262	0.0007309
Co	0.0000125	0.0000036	0.0000226	0.0000278	0.0004999	0.0005664
Cr	0.0000200	0.0000221	0.0000568	0.0000354	0.0315049	0.0316391
Cu	0.0000449	0.0001494	0.0000273	0.0006200	0.0040721	0.0049137
Hg	0.0000000	0.0000000	0.0000001	0.0000000	0.0067403	0.0067404
Mn	0.0000107	0.0005511	0.0002037	0.0002353	0.0017901	0.0027909
Mo	0.0000010	0.0000035	0.0000457	0.0000433	0.0006365	0.0007300
Ni	0.0000135	0.0000225	0.0000352	0.0000000	0.0029917	0.0030630
Pb	0.0000463	0.0000172	0.0000084	0.0000250	0.0055749	0.0056718
Sb	0.0000000	0.0000000	0.0000005	0.0000000	0.0000171	0.0000176
Se	0.0000012	0.0000000	0.0007191	0.0000000	0.0000134	0.0007337
Sn	0.0000199	0.0000000	0.0000103	0.0000000	0.0004705	0.0005008
V	0.0000075	0.0000095	0.0000102	0.0000000	0.0001455	0.0001727
Zn	0.0001452	0.0006403	0.0001409	0.0006334	0.0083774	0.0099373
Si	0.0997087	0.0016901	0.0143361	0.0000000	0.0000000	0.1157348
Fe	0.0014964	0.0025369	0.0011229	0.0029648	0.0075372	0.0156582
Ca	0.0543678	0.0691303	0.0037069	0.2347175	0.0059772	0.3678997
Al	0.0249272	0.0011723	0.0000968	0.0000000	0.0428580	0.0690542
K	0.0087288	0.0330858	0.0097659	0.0258239	0.0069310	0.0843354
Mg	0.0070329	0.0076120	0.0025395	0.0469894	0.0045783	0.0687521
Na	0.0037409	0.0063153	0.0006178	0.1396305	0.0017805	0.1520850
	0.44878	0.44962	0.71459	0.53950	0.45342	**2.61**

7.4.8 Balance biogas plant

Balance Elemental Compositions Biogas in kg/kg dry matter

Description	Wates Type				
	Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge
Input					
Dry Waste	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000
Total	1.0000000	1.0000000	1.0000000	1.0000000	1.0000000
Out-put					
Biogas	0.14166	0.04471	0.03042	0.01563	0.18034
Residual	0.40956	0.50567	0.25498	0.44487	0.36624
Digested Matter	0.44878	0.44962	0.71459	0.53950	0.45342
Total	1.00000	1.00000	1.00000	1.00000	1.00000
Balance	0	0	0	0	0

7.4.9 Emission factors biogas

Fuel, Electricity and other Consumption for Biogasification

Utility Type	Unit	Actual Consumption by Waste Type					
		Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Remark
Landfill Gas	kg	0.00000	0.00000	0.00000	0.00000	0.00000	
Electricity	kWh	0.00999	0.00966	0.02749	0.03186	0.00032	
Heat	kWh	0.14828	0.14344	1.42087	1.62982	0.00504	

Emission, Electricity and other Products of Biogasification

Utility Type	Unit	Actual Consumption by Waste Type					
		Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Remark
Landfill Gas	kg	0.14166	0.04471	0.03042	0.01563	0.18034	
Electricity	kWh	1.90266	0.60058	0.40863	0.20988	2.42222	
Heat	kWh	2.24892	0.70988	0.48300	0.24808	2.86304	

Biogas Composition[1]

Gas Type	Unit	Waste Type					
		Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Remark
Carbon Dioxie (CO_2)	%	32.36	27.50	32.36	32.36	34.78	
Carbon monoxide (CO)	%						
Methane (CH_4)	%	67.64	72.50	67.64	67.64	65.22	
Nitrogen Oxide (NO_x)	%						
Dinitrogen Oxides (N_2O)	%						
Ammonia	%						
NMVOC	%						
PM	%						
SO2	%						

[1]Jungbluth, N. editor, 2007, Life Cycle Inventories of Bioenergy, Ecoinvent Report No. 17, Swiss Centre for Life Cycle Inventories, Dübendorf.

Emission Factor[1]

Gas Type	Unit	Waste Derived Emission (kg^{-1} Dry Waste Input)					
		Food Waste	Poultry Manure	Cattle Manure	Swine Manure	Sewage Sludge	Remark
Carbon Dioxie (CO_2)	kg	0.0728	0.0182	0.0156	0.0080	0.1033	
Carbon monoxide (CO)	kg	-	-	-	-	-	
Methane (CH_4)	kg	-	-	-	-	-	
Nitrogen Oxide (NO_x)	kg	-	-	-	-	-	
Dinitrogen Oxides (N_2O)	kg	-	-	-	-	-	
Ammonia	kg	-	-	-	-	-	
NMVOC	kg	-	-	-	-	-	
PM	kg	-	-	-	-	-	
SO2	kg	-	-	-	-	-	

[1]Jungbluth, N. editor, 2007, Life Cycle Inventories of Bioenergy, Ecoinvent Report No. 17, Swiss Centre for Life Cycle Inventories, Dübendorf.

Emission Factor[1]

Gas Type	Unit	Fuele Derived Emission (MJ^{-1})			
		Natural Gas	Diesel Oils	Landfill Gas	Remark
Carbon Dioxie (CO_2)	kg	5.50E-02	1.34E+02	5.45E-02	
Carbon monoxide (CO)	kg	5.00E-06	4.89E-01	5.00E-06	
Methane (CH_4)	kg	2.00E-06	6.89E-03	2.00E-06	
Nitrogen Oxide (NO_x)	kg	4.10E-05	1.89E+00	4.10E-05	
Dinitrogen Oxides (N_2O)	kg	1.00E-06	5.15E-03	1.00E-06	
Ammonia	kg	0.00E+00	8.58E-04	0.00E+00	
NMVOC	kg	0.00E+00	2.22E-01	0.00E+00	
PM	kg	0.00E+00	0.00E+00	0.00E+00	
SO2	kg	1.00E-06	4.34E-02	1.00E-06	

[1]FORWAST Deliverable 2-2

Net Calorific Value[1]

Fuel Type	Unit	Net Ccalorific Value	Remark
Natural Gas	$MJ\ kg^{-1}$	48.00	
Diesel Oils	$MJ\ kg^{-1}$	42.70	
Crude Oils	$MJ\ kg^{-1}$	42.30	
Lubricating Oils	$MJ\ kg^{-1}$	40.20	
Waste Oils	$MJ\ kg^{-1}$	40.20	
Landfill Gas	$MJ\ kg^{-1}$	50.40	

[1]IPCC 2006

7.4.10 Determination of emission factors

Determination Emission Factor (by using Solver)

Gas Type	Unit	C for CO2	C for CH4	Total C	Balance	CO2	CH4	CO2	CH4	Total
		(kg)	(kg)	(kg)		(kg)	(kg)	(%)	(%)	(%)
Food Waste		0.03300704	0.25455386	0.28756090	0.00000000	0.12102581	0.33940514	26.29%	73.71%	100.00%
Poultry Manure		0.03638259	0.37285100	0.40923360	0.00000000	0.13340284	0.49713467	21.16%	78.84%	100.00%
Cattle Manure		0.03150937	0.18847430	0.21998367	0.00000000	0.11553436	0.25129907	31.50%	68.50%	100.00%
Swine Manure		0.03543087	0.40864167	0.44407253	0.00000000	0.12991318	0.54485556	19.25%	80.75%	100.00%
Sewage Sludge		0.03308461	0.27469420	0.30777881	0.00000000	0.12131023	0.36625893	24.88%	75.12%	100.00%

Determination Fuel, Electricity and other Consumption for Biogasification

Gas Type	Unit	Crude petroleum & natural gas	Electricity	Heat	Potential Biogas Production	Dry Matter Content	Potential Biogas Production	Crude petroleum & natural gas	Electricity	Heat
		(MJ/Nm³ Biogas)	(kWh/Nm³ Biogas)	(MJ/Nm³ Biogas)	(Nm³ t⁻¹ Waste)	(t t⁻¹ Waste)	(Nm³ kg⁻¹ Dry Matter)	(MJ kg⁻¹ Dry Matter)	(kWh kg⁻¹ Dry Matter)	(MJ kg⁻¹ Dry Matter)
Food Waste			0.04000	0.59400	100.00	0.40	0.24964	0.00000E+00	9.98545E-03	1.48284E-01
Poultry Manure			0.04000	0.59400	100.00	0.41	0.24149	0.00000E+00	9.65957E-03	1.43445E-01
Cattle Manure			0.16000	8.27000	19.93	0.12	0.17181	0.00000E+00	2.74897E-02	1.42087E+00
Swine Manure			0.14800	7.57000	21.53	0.10	0.21530	0.00000E+00	3.18644E-02	1.62982E+00
Sewage Sludge			0.25200	4.02411	0.063	0.05	0.00125	0.00000E+00	3.15863E-04	5.04390E-03

7.4.11 Emissions from the waste treated in biogas plant

Unit:		Activity No.	1	2	3	4	5
NACE No.	Product No.	Activities / Products	Biogasification Food Waste	Biogasification Poultry Manure	Biogasification Cattle Manure	Biogasification Swine Manure	Biogasification Sewage Sludge
kg		**Emissions Distribution, emissions from residuals (-Gw)**					
Air	1	Ammonia	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	2	Arsenic	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	3	Cadmium	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	4	Carbon dioxide, fibre carbon		0.0182178	0.0156291	0.0080274	0.1032896
Air	5	Carbon dioxide, food carbon	0.0727712				
Air	6	Carbon dioxide, coal carbon					
Air	7	Carbon dioxide, crude oil and natural gas carbon					
Air	8	Carbon dioxide, carbonate					
Air	9	Carbon monoxide	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	10	Chromium	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	11	Copper	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	12	Dinitrogen monoxide	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	13	Hydrogen chloride					
Air	14	Hydrogen fluoride					
Air	15	Lead	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	16	Mercury	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	17	Methane	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	18	Nickel	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	19	Nitric acid					
Air	20	Nitrogen dioxide	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	21	NMVOC					
Air	22	ODP					
Air	23	PAH, measured as Benzo(a)pyrene					
Air	24	Particulates, < 10 um					
Air	25	Phosphorus	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	26	Selenium	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	27	Sulfur dioxide	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	28	Vanadium	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Air	29	Zinc	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
water	30	Copper					
water	31	Nitrogen, total					
water	32	Phosphorus					
Soil	33	Antimony					
Soil	34	Arsenic					
Soil	35	Barium					
Soil	36	Cadmium					
Soil	37	Chromium					
Soil	38	Cobalt					
Soil	39	Copper					
Soil	40	Lead					
Soil	41	Mercury					
Soil	42	Nickel					
Soil	43	Phosphorus					
Soil	44	Selenium					
Soil	45	Zinc					
	46	Aluminium	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	47	Carbon, biomass, unspecified					
	48	Carbon, fossil, unspecified					
	49	Clay and soil					
	50	Iron	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	51	Metals n.e.c.	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	52	Minerals n.e.c.	0.2392047	0.3991220	0.2099218	0.4393845	0.2451234
	53	Oxygen	0.1505091	0.1015768	0.0407993	0.0032960	0.0929453
	54	Sand, gravel and stone	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
		Total from Emissions Distribution (-Gw)	**0.40956**	**0.50567**	**0.25498**	**0.44487**	**0.36624**
kg		**Balance Check (g-g)**					
		Residual Input	**0.40956**	**0.50567**	**0.25498**	**0.44487**	**0.36624**
		Emmission	**0.40956**	**0.50567**	**0.25498**	**0.44487**	**0.36624**
		Balance Check	**0.00000**	**0.00000**	**0.00000**	**0.00000**	**0.00000**

7.4.12 Emissions from fuel

Unit:			Activity No.	1	2	3	4	5
	NACE No.	Product No.	Activities / Products	Biogasification Food Waste	Biogasification Poultry Manure	Biogasification Cattle Manure	Biogasification Swine Manure	Biogasification Sewage Sludge
kg	Emissions Distribution, emissions from products (-Gc)							
	Air	1	Ammonia	0.00000	0.00000	0.00000	0.00000	0.00000
	Air	2	Arsenic					
	Air	3	Cadmium					
	Air	4	Carbon dioxide, fibre carbon					
	Air	5	Carbon dioxide, food carbon					
	Air	6	Carbon dioxide, coal carbon					
	Air	7	Carbon dioxide, crude oil and natural gas carbon	0.38910	0.12282	0.08357	0.04292	0.49535
	Air	8	Carbon dioxide, carbonate					
	Air	9	Carbon monoxide	0.00004	0.00001	0.00001	0.00000	0.00005
	Air	10	Chromium					
	Air	11	Copper					
	Air	12	Dinitrogen monoxide	0.00001	0.00000	0.00000	0.00000	0.00001
	Air	13	Hydrogen chloride					
	Air	14	Hydrogen fluoride					
	Air	15	Lead					
	Air	16	Mercury					
	Air	17	Methane	0.00001	0.00000	0.00000	0.00000	0.00002
	Air	18	Nickel					
	Air	19	Nitric acid					
	Air	20	Nitrogen dioxide	0.00029	0.00009	0.00006	0.00003	0.00037
	Air	21	NMVOC	0.00000	0.00000	0.00000	0.00000	0.00000
	Air	22	ODP					
	Air	23	PAH, measured as Benzo(a)pyrene					
	Air	24	Particulates, < 10 um	0.00000	0.00000	0.00000	0.00000	0.00000
	Air	25	Phosphorus					
	Air	26	Selenium					
	Air	27	Sulfur dioxide	0.00001	0.00000	0.00000	0.00000	0.00001
	Air	28	Vanadium					
	Air	29	Zinc					
	water	30	Copper					
	water	31	Nitrogen, total					
	water	32	Phosphorus					
	Soil	33	Antimony					
	Soil	34	Arsenic					
	Soil	35	Barium					
	Soil	36	Cadmium					
	Soil	37	Chromium					
	Soil	38	Cobalt					
	Soil	39	Copper					
	Soil	40	Lead					
	Soil	41	Mercury					
	Soil	42	Nickel					
	Soil	43	Phosphorus					
	Soil	44	Selenium					
	Soil	45	Zinc					
		46	Aluminium					
		47	Carbon, biomass, unspecified					
		48	Carbon, fossil, unspecified					
		49	Clay and soil					
		50	Iron					
		51	Metals n.e.c.					
		52	Minerals n.e.c.	0.03551	0.01121	0.00763	0.00392	0.04520
		53	Oxygen					
		54	Sand, gravel and stone					
			Total from Emissions Distribution (-GC)	**0.14166**	**0.04472**	**0.03042**	**0.01563**	**0.18034**
kg	**Balance Check (g-g)**							
			Product Input	**0.14166**	**0.04471**	**0.03042**	**0.01563**	**0.18034**
			Emmission	**0.14166**	**0.04472**	**0.03042**	**0.01563**	**0.18034**
			Balance Check	**0.00000**	**0.00000**	**0.00000**	**0.00000**	**0.00000**

7.5 Manure application

7.5.1 Composition of manure in kg/kg dry matter input

Elemental Composition of Dry Matter by Manure Types (kg)

Substance	Waste Type				
	Food Waste Compost	Poultry Manure	Cattle Manure	Swine Manure	Total
Decomposition Rate	55.0%	55.0%	29.0%	49.0%	
O	0.3177276	0.1670337	0.1897454	0.1999928	0.5567719
H	0.0498787	0.0149047	0.0253528	0.0499982	0.0902556
C	0.4050153	0.5456448	0.7332789	0.4879741	1.7668978
S	0.0037391	0.0062586	0.0029792	0.0010318	0.0102696
N	0.0099757	0.0765062	0.0084475	0.0087064	0.0936601
P	0.0028181	0.0431921	0.0048405	0.0334055	0.0814381
B	0.0000255	0.0000319	0.0000112	0.0000848	0.0001279
Cl	0.0099757	0.0233796	0.0015238	0.0000000	0.0249034
Br	0.0000150	0.0000000	0.0000000	0.0000000	0.0000000
F	0.0004988	0.0000000	0.0000130	0.0000000	0.0000130
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000050	0.0000527	0.0000238	0.0000141	0.0000906
Ba	0.0000000	0.0000316	0.0003165	0.0000000	0.0003481
Cd	0.0000000	0.0000024	0.0000005	0.0000019	0.0000048
Co	0.0000125	0.0000036	0.0000226	0.0000278	0.0000541
Cr	0.0000200	0.0000221	0.0000568	0.0000354	0.0001143
Cu	0.0000449	0.0001494	0.0000273	0.0006200	0.0007967
Hg	0.0000000	0.0000000	0.0000001	0.0000000	0.0000001
Mn	0.0000107	0.0005511	0.0002037	0.0002352	0.0009901
Mo	0.0000010	0.0000035	0.0000457	0.0000433	0.0000925
Ni	0.0000135	0.0000225	0.0000352	0.0000000	0.0000577
Pb	0.0000463	0.0000172	0.0000084	0.0000250	0.0000506
Sb	0.0000000	0.0000000	0.0000005	0.0000000	0.0000005
Se	0.0000012	0.0000000	0.0007191	0.0000000	0.0007191
Sn	0.0000199	0.0000000	0.0000103	0.0000000	0.0000103
V	0.0000075	0.0000095	0.0000102	0.0000000	0.0000197
Zn	0.0001452	0.0006403	0.0001409	0.0006334	0.0014147
Si	0.0997087	0.0016901	0.0143361	0.0000000	0.0160262
Fe	0.0014964	0.0025369	0.0011229	0.0029647	0.0066245
Ca	0.0543678	0.0691303	0.0037069	0.0999964	0.1728335
Al	0.0249272	0.0011723	0.0000968	0.0000000	0.0012691
K	0.0087288	0.0330858	0.0097659	0.0258230	0.0686747
Mg	0.0070329	0.0076120	0.0025395	0.0469877	0.0571391
Na	0.0037409	0.0063153	0.0006178	0.0413985	0.0483317
Total	1.00	1.00	1.00	1.00	**4.00**

7.5.2 Composition of degraded matter in kg/kg dry matter

Elemental Composition of Degraded Dry Matter by Manure Types (kg)

Substance	Waste Type				
	Food Waste Compost	Poultry Manure	Cattle Manure	Swine Manure	Total
O	0.2255866	0.1269456	0.0588211	0.1359951	0.3217618
H	0.0354139	0.0113276	0.0078594	0.0339988	0.0531857
C	0.2875609	0.4146900	0.2273165	0.3318224	0.9738289
S	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
N	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
P	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
B	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cl	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Br	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
F	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ba	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cd	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Co	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cr	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Cu	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Hg	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mo	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ni	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Pb	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Sb	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Se	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Sn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
V	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Zn	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Si	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Fe	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ca	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Al	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
K	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Mg	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Na	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	0.55000	0.55000	0.29000	0.49000	**1.35**

7.5.3 Composition of residue in kg/kg dry matter input

Elemental Composition of Residual Dry Matter by Manure Types (kg)

Substance	Waste Type				
	Food Waste Compost	Poultry Manure	Cattle Manure	Swine Manure	Total
O	0.0921410	0.0400881	0.1309244	0.0639977	0.2350101
H	0.0144648	0.0035771	0.0174934	0.0159994	0.0370700
C	0.1174545	0.1309548	0.5059625	0.1561517	0.7930689
S	0.0037391	0.0062586	0.0029792	0.0010318	0.0102696
N	0.0099757	0.0765062	0.0084475	0.0087064	0.0936601
P	0.0028181	0.0431921	0.0048405	0.0334055	0.0814381
B	0.0000255	0.0000319	0.0000112	0.0000848	0.0001279
Cl	0.0099757	0.0233796	0.0015238	0.0000000	0.0249034
Br	0.0000150	0.0000000	0.0000000	0.0000000	0.0000000
F	0.0004988	0.0000000	0.0000130	0.0000000	0.0000130
I	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Ag	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
As	0.0000050	0.0000527	0.0000238	0.0000141	0.0000906
Ba	0.0000000	0.0000316	0.0003165	0.0000000	0.0003481
Cd	0.0000000	0.0000024	0.0000005	0.0000019	0.0000048
Co	0.0000125	0.0000036	0.0000226	0.0000278	0.0000541
Cr	0.0000200	0.0000221	0.0000568	0.0000354	0.0001143
Cu	0.0000449	0.0001494	0.0000273	0.0006200	0.0007967
Hg	0.0000000	0.0000000	0.0000001	0.0000000	0.0000001
Mn	0.0000107	0.0005511	0.0002037	0.0002352	0.0009901
Mo	0.0000010	0.0000035	0.0000457	0.0000433	0.0000925
Ni	0.0000135	0.0000225	0.0000352	0.0000000	0.0000577
Pb	0.0000463	0.0000172	0.0000084	0.0000250	0.0000506
Sb	0.0000000	0.0000000	0.0000005	0.0000000	0.0000005
Se	0.0000012	0.0000000	0.0007191	0.0000000	0.0007191
Sn	0.0000199	0.0000000	0.0000103	0.0000000	0.0000103
V	0.0000075	0.0000095	0.0000102	0.0000000	0.0000197
Zn	0.0001452	0.0006403	0.0001409	0.0006334	0.0014147
Si	0.0997087	0.0016901	0.0143361	0.0000000	0.0160262
Fe	0.0014964	0.0025369	0.0011229	0.0029647	0.0066245
Ca	0.0543678	0.0691303	0.0037069	0.0999964	0.1728335
Al	0.0249272	0.0011723	0.0000968	0.0000000	0.0012691
K	0.0087288	0.0330858	0.0097659	0.0258230	0.0686747
Mg	0.0070329	0.0076120	0.0025395	0.0469877	0.0571391
Na	0.0037409	0.0063153	0.0006178	0.0413985	0.0483317
	0.45144	0.44704	0.70600	0.49818	**1.65**

7.5.4 Balance

Balance Elemental Compositions Incineration MSW

Description	Waste Type			
	Food Waste Compost	Poultry Manure	Cattle Manure	Swine Manure
Input				
Dry Waste	1.0000000	1.0000000	1.0000000	1.0000000
Total	1.0000000	1.0000000	1.0000000	1.0000000
Out-put				
Degraded	0.55	0.55	0.29	0.49
Digested Matter	0.45	0.45	0.71	0.50
Total	1.00	1.00	1.00	1.00
Balance	0.00	0.00	0.00	0.0000000

7.5.5 Emission factors

Fuel, Electricity and other Consumption for Land Application

Utility Type	Unit	Actual Consumption by Waste Type				
		Food Waste Compost	Poultry Manure	Cattle Manure	Swine Manure	Remark
Conversion factor wet-dry	-	2.50	2.40	8.60	10.00	
Diesel Oils	kg	0.0013	0.0013	0.0046	0.0053	
Electricity	kWh	0.00	0.00	0.00	0.00	
Heat	kWh	0.00	0.00	0.00	0.00	

Diesel consumption Wet manure	0.000531	kg/kg wet

Emission, Electricity and other Product of Land Application

Utility Type	Unit	Actual Consumption by Waste Type				
		Food Waste Compost	Poultry Manure	Cattle Manure	Swine Manure	Remark
Diesel Oils	kg	0.00	0.00	0.00	0.00	
Electricity	kWh	0.00	0.00	0.00	0.00	
Heat	kWh	0.00	0.00	0.00	0.00	

Emission Factor of Land Application

Gas Type	Unit	Waste Derived Emission (kg^{-1} Dry Waste Input)				
		Biowaste Compost	Poultry Manure	Cattle Manure	Swine Manure	Remark
Carbon Dioxie (CO_2)	kg	1.038838	1.399543	1.880812	1.251621	
Carbon monoxide (CO)	kg	0.00	0.00	0.00	0.00	
Methane (CH_4)	kg	0.00	0.00	0.00	0.00	
Nitrogen Oxide (NO_X)	kg	0.000165	0.001262	0.000139	0.000144	0.21*N2O
Dinitrogen Oxides (N_2O)	kg	0.000784	0.006010	0.000664	0.000684	
Ammonia	kg	0.003032	0.023256	0.002568	0.002646	
NMVOC	kg					
PM	kg					
SO2	kg					

Emission Factor[1]

Gas Type	Unit	Fuels Derived Emission (MJ^{-1})			
		Natural Gas	Diesel Oils	Landfill Gas	Remark
Carbon Dioxie (CO_2)	kg	5.50E-02	1.34E+02	5.45E-02	
Carbon monoxide (CO)	kg	5.00E-06	4.89E-01	5.00E-06	
Methane (CH_4)	kg	2.00E-06	6.89E-03	2.00E-06	
Nitrogen Oxide (NO_X)	kg	4.10E-05	1.89E+00	4.10E-05	
Dinitrogen Oxides (N_2O)	kg	1.00E-06	5.15E-03	1.00E-06	
Ammonia	kg	0.00E+00	8.58E-04	0.00E+00	
NMVOC	kg	0.00E+00	2.22E-01	0.00E+00	
PM	kg	0.00E+00	0.00E+00	0.00E+00	
SO2	kg	1.00E-06	4.34E-02	1.00E-06	

[1]FORWAST Deliverable 2-2

Net Calorific Value[1]

Fuel Type	Unit	Net Ccalorific Value	Remark
Natural Gasses	MJ kg^{-1}	48.00	
Diesel Oils	MJ kg^{-1}	43.00	
Crude Oils	MJ kg^{-1}	42.30	
Lubricating Oils	MJ kg^{-1}	40.20	
Waste Oils	MJ kg^{-1}	40.20	
Landfill Gasses	MJ kg^{-1}	50.40	

[1]IPCC 2006

Fuel, Electricity and other Consumption for Land Application

Utility Type	Emission factor (kg/kg)	Actual Fuel Emission by Waste Type				
		Food Waste Compost	Poultry Manure	Cattle Manure	Swine Manure	Remark
Conversion factor wet-dry		2.50	2.40	8.60	10.00	
Diesel Oils (kg/kg waste)		0.0013	0.0013	0.0046	0.0053	
Carbon Dioxie (CO_2)	1.34E+02	1.78E-01	1.71E-01	6.13E-01	7.12E-01	
Carbon monoxide (CO)	4.89E-01	6.49E-04	6.23E-04	2.23E-03	2.60E-03	
Methane (CH_4)	6.89E-03	9.15E-06	8.78E-06	3.15E-05	3.66E-05	
Nitrogen Oxide (NO_X)	1.89E+00	2.51E-03	2.41E-03	8.64E-03	1.01E-02	
Dinitrogen Oxides (N_2O)	5.15E-03	6.83E-06	6.56E-06	2.35E-05	2.73E-05	
Ammonia	8.58E-04	1.14E-06	1.09E-06	3.92E-06	4.56E-06	
NMVOC	2.22E-01	2.95E-04	2.83E-04	1.02E-03	1.18E-03	
PM	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
SO2	4.34E-02	5.76E-05	5.53E-05	1.98E-04	2.30E-04	

7.5.6 Emissions from waste

Unit:		Activity No.	1	2	3	4
NACE No.	Product No.	Activities / Products	Application Food Waste Compost	Application Poultry Manure	Application Cattle Manure	Application Swine Manure
kg		**Emissions Distribution, emissions from residuals (-Gw)**				
Air	1	Ammonia	0.0030323	0.0232557	0.0025678	0.0026465
Air	2	Arsenic	0.0000000	0.0000000	0.0000000	0.0000000
Air	3	Cadmium	0.0000000	0.0000000	0.0000000	0.0000000
Air	4	Carbon dioxide, fibre carbon		1.3995428	1.8808119	1.2516213
Air	5	Carbon dioxide, food carbon	1.0388375			
Air	6	Carbon dioxide, coal carbon				
Air	7	Carbon dioxide, crude oil and natural gas carbon				
Air	8	Carbon dioxide, carbonate				
Air	9	Carbon monoxide	0.0000000	0.0000000	0.0000000	0.0000000
Air	10	Chromium	0.0000000	0.0000000	0.0000000	0.0000000
Air	11	Copper	0.0000000	0.0000000	0.0000000	0.0000000
Air	12	Dinitrogen monoxide	0.0007837	0.0060101	0.0006636	0.0006839
Air	13	Hydrogen chloride				
Air	14	Hydrogen fluoride				
Air	15	Lead	0.0000000	0.0000000	0.0000000	0.0000000
Air	16	Mercury	0.0000000	0.0000000	0.0000000	0.0000000
Air	17	Methane	0.0000000	0.0000000	0.0000000	0.0000000
Air	18	Nickel	0.0000000	0.0000000	0.0000000	0.0000000
Air	19	Nitric acid				
Air	20	Nitrogen dioxide	0.0001646	0.0012621	0.0001394	0.0001436
Air	21	NMVOC				
Air	22	ODP				
Air	23	PAH, measured as Benzo(a)pyrene				
Air	24	Particulates, < 10 um				
Air	25	Phosphorus	0.0000000	0.0000000	0.0000000	0.0000000
Air	26	Selenium	0.0000000	0.0000000	0.0000000	0.0000000
Air	27	Sulfur dioxide	0.0000000	0.0000000	0.0000000	0.0000000
Air	28	Vanadium	0.0000000	0.0000000	0.0000000	0.0000000
Air	29	Zinc	0.0000000	0.0000000	0.0000000	0.0000000
water	30	Copper				
water	31	Nitrogen, total				
water	32	Phosphorus				
Soil	33	Antimony				
Soil	34	Arsenic				
Soil	35	Barium				
Soil	36	Cadmium				
Soil	37	Chromium				
Soil	38	Cobalt				
Soil	39	Copper				
Soil	40	Lead				
Soil	41	Mercury				
Soil	42	Nickel				
Soil	43	Phosphorus				
Soil	44	Selenium				
Soil	45	Zinc				
	46	Aluminium	0.0000000	0.0000000	0.0000000	0.0000000
	47	Carbon, biomass, unspecified				
	48	Carbon, fossil, unspecified				
	49	Clay and soil				
	50	Iron	0.0000000	0.0000000	0.0000000	0.0000000
	51	Metals n.e.c.	0.0000000	0.0000000	0.0000000	0.0000000
	52	Minerals n.e.c.	0.0366231	0.0210685	-0.2803407	0.0218234
	53	Oxygen	0.2255866	0.1269456	0.0588211	0.1359951
	54	Sand, gravel and stone	0.0000000	0.0000000	0.0000000	0.0000000
		Total from Emissions Distribution (-Gw)	**0.55**	**0.55**	**0.29**	**0.50**

kg **Balance Check (g-g)**

Residual Input	**0.55000**	**0.55000**	**0.29000**	**0.49000**
Emmission	**0.55**	**0.55**	**0.29**	**0.50**
Balance Check	**0.0**	**0.0**	**0.0**	**0.0**

7.5.7 Emissions from fuel

Unit:			Activity No.	1	2	3	4
	NACE No.	Product No.	Activities / Products	Application Food Waste Compost	Application Poultry Manure	Application Cattle Manure	Application Swine Manure
kg	Emissions Distribution, emissions from products (-Gc)						
	Air	1	Ammonia	0.00000	0.00000	0.00000	0.00000
	Air	2	Arsenic				
	Air	3	Cadmium				
	Air	4	Carbon dioxide, fibre carbon				
	Air	5	Carbon dioxide, food carbon				
	Air	6	Carbon dioxide, coal carbon				
	Air	7	Carbon dioxide, crude oil and natural gas carbon	0.17806	0.17095	0.61259	0.71231
	Air	8	Carbon dioxide, carbonate				
	Air	9	Carbon monoxide	0.00065	0.00062	0.00223	0.00260
	Air	10	Chromium				
	Air	11	Copper				
	Air	12	Dinitrogen monoxide	0.00001	0.00001	0.00002	0.00003
	Air	13	Hydrogen chloride				
	Air	14	Hydrogen fluoride				
	Air	15	Lead				
	Air	16	Mercury				
	Air	17	Methane	0.00001	0.00001	0.00003	0.00004
	Air	18	Nickel				
	Air	19	Nitric acid				
	Air	20	Nitrogen dioxide	0.00251	0.00241	0.00864	0.01005
	Air	21	NMVOC	0.00030	0.00028	0.00102	0.00118
	Air	22	ODP				
	Air	23	PAH, measured as Benzo(a)pyrene				
	Air	24	Particulates, < 10 um	0.00000	0.00000	0.00000	0.00000
	Air	25	Phosphorus				
	Air	26	Selenium				
	Air	27	Sulfur dioxide	0.00006	0.00006	0.00020	0.00023
	Air	28	Vanadium				
	Air	29	Zinc				
	water	30	Copper				
	water	31	Nitrogen, total				
	water	32	Phosphorus				
	Soil	33	Antimony				
	Soil	34	Arsenic				
	Soil	35	Barium				
	Soil	36	Cadmium				
	Soil	37	Chromium				
	Soil	38	Cobalt				
	Soil	39	Copper				
	Soil	40	Lead				
	Soil	41	Mercury				
	Soil	42	Nickel				
	Soil	43	Phosphorus				
	Soil	44	Selenium				
	Soil	45	Zinc				
		46	Aluminium				
		47	Carbon, biomass, unspecified				
		48	Carbon, fossil, unspecified				
		49	Clay and soil				
		50	Iron				
		51	Metals n.e.c.				
		52	Minerals n.e.c.				
		53	Oxygen				
		54	Sand, gravel and stone				
			Total from Emissions Distribution (.GC)	0.04918	0.04721	0.16918	0.19672

kg **Balance Check (g-g)**

Product Input	0.00133	0.00127	0.00457	0.00531
Emmission	0.04918	0.04721	0.16918	0.19672
Balance Check	-0.04785	-0.04594	-0.16461	-0.19141

7.6 Manure storage

See text

7.7 Waste water treatment

See text

8 Data to calculated emissions

	Food	Paper	Plastics	Cardboard	Textiles	Wood	Other biomass	Compost waste	N Fertiliser	Other fertiliser	Sludge	Sand gravel and stone
water	0	0	0	0	0	0	0	0	0	0	0	0
O	31.7728	48.9355	2.0000	44.6366	36.1467	40.9507	50.3585	47.5804	0.3600	8.0000	40.8449	25.0000
H	4.9879	5.1988	14.5001	6.4953	6.6933	5.9878	5.2687	10.6164	0	0	3.9096	0
C	40.5015	40.9540	79.8226	48.2463	52.2800	52.5336	42.3943	19.0000	0.0400	24.1598	26.8657	30.0000
S	0.3739	0.0700	0.1600	0.1704	0.3733	0.0833	0.4656	0.6600	0.1413	7.0000	1.4686	0
N	0.9976	0.1001	0.3000	0.1597	4.1467	0.2857	1.3110	0.4800	31.0000	3.0000	3.4083	0
P	0.2818	0.0131	0	0	0	0	0	0.1546	0	4.0000	2.6471	0
B	0.0026	0.0020	0	0	0	0	0	0.0021	0	0	0.0080	0
Cl	0.9976	0.0201	2.7000	0.2449	0.3600	0.1071	0.0123	0.1400	0.0118	0.0067	0.1754	1.1000
Br	0.0015	0	0.0075	0	0	0	0	0.0003	0	0	0	0
F	0.0499	0	0.0014	0.0048	0	0.0048	0	0.0027	0	0	0.0020	0
I	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0
As	0.0005	0.0001	0	0.0004	0	0	0.0006	0.0003	0	0	0.0009	0
Ba	0	0.0030	0	0.0052	0	0	0.0257	0.0024	0	0	0.0401	0
Cd	0	0.0010	0.0050	0.0002	0	0.0001	0.0004	0.0130	0.0019	0.0011	0.0004	0
Co	0.0012	0	0	0	0	0	0	0.0007	0	0	0.0008	0
Cr	0.0020	0.0034	0.0050	0.0025	0	0	0.0055	0.0647	0.4771	0.2717	0.0085	0
Cu	0.0045	0.0030	0.0075	0.0089	0	0.0015	0.0075	0.1354	1.0087	0.5745	0.0286	0
Hg	0	0.0000	0.0000	0.0001	0	0.0001	0.0001	0.0000	0.0002	0.0001	0.0024	0
Mn	0.0011	0.0050	0	0.0108	0	0	0.0450	0.0050	0	0	0.0606	0
Mo	0.0001	0.0008	0	0	0	0	0	0.0003	0	0	0	0
Ni	0.0014	0.0010	0.0018	0.0027	0	0	0.0022	0.0206	0.1460	0.0832	0.0062	0
Pb	0.0046	0.0050	0.0090	0.0046	0	0.0368	0.0582	0.0410	0.7585	0.4319	0.0214	0
Sb	0	0.0005	0	0	0	0	0	0.0057	0.0438	0.0250	0.0005	0
Se	0.0001	0.0000	0	0.0004	0	0	0.0004	0.0001	0.0002	0.0001	0.0001	0
Sn	0.0020	0.0008	0	0	0	0	0	0.0106	0.0730	0.0416	0.0055	0
V	0.0007	0	0	0	0	0	0	0.0004	0.0000	0.0000	0.0022	0
Zn	0.0145	0.0100	0.0700	0.0064	0	0.0085	0.0441	0.2000	0.6816	0.3881	0.1063	0
Si	9.9709	2.2281	0	0	0	0	0	7.9137	19.8987	11.3323	6.8180	24.5000
Fe	0.1496	0.0700	0.3900	0	0	0	0	5.1074	20.7351	11.8086	4.2082	0
Ca	5.4368	0.4000	0	0	0	0	0	3.2608	2.4734	2.6000	4.8165	17.0000
Al	2.4927	1.3050	0.0200	0	0	0	0	2.4975	14.0102	7.9788	3.1847	2.4000
K	0.8729	0.1001	0	0	0	0	0	0.5011	0.0118	13.0000	0.5595	0
Mg	0.7033	0.4997	0	0	0	0	0	0.7506	1.4605	1.5000	0.6096	0
Na	0.3741	0.0700	0	0	0	0	0	0.8322	6.6663	3.7964	0.1893	0

Transfer coefficients for burnable waste in g/kg of waste (Source: Doka, 2003)
(File: Incineration2.xls; Sheet: Transfer coeff)

	slag	boiler ash	ESP ash	Scrubber sludge	Water emissions	air emissions
water	0	0	0	0	0	1000
O	69.8	2.04	10.2	1.02	0	916.94
H	0	0	0	0	0	1000
C	7.55	0	3.44	0.0101	0.0101	988.9898
S	553.87	0	298	74.6	71.4	2.13
N	10	0	0	0	1	989
P	880	25	94	0	0	1
B	383	0	166	180	151	120
Cl	71.3	0	13	6.478	909.2112	0.0108
Br	110	10	877	0	0	3
F	614.5	0	308	21	56	0.5
I	71.3	0	13	6.48	909.2092	0.0108
Ag	614.5941	5.32	274	106	0.0729	0.013
As	549.8999898	30	381	39	0.1	0.0000102
Ba	887	22	90	0	0	1
Cd	3.27	0	369	627.2339	0.441	0.0551
Co	849.9899682	10	120	20	0.01	0.0000318
Cr	455.2099261	31.9	446	63.7	3.19	0.0000739
Cu	800.19262	0	185	14.8	0	0.00738
Hg	5.74	2.09	366	615.6699655	10.5	0.0000345
Mn	859.9899946	10	120	10	0.01	0.00000545
Mo	867	21	110	0	0	2
Ni	900.9999568	35.5	63.5	0	0	0.0000432
Pb	66.4	0	848.1443	85.4	0.0186	0.0371
Sb	16.1	18.2	821.518	144	0.182	0.00000389
Se	80.3	130	718.881995	70.7	0.118	0.00000503
Sn	495.9567	19.9	451	31.8	0.0133	1.33
V	889.89	10	90	10	0.01	0.1
Zn	3.29	0	816.5307	180	0.163	0.0163
Si	918.57	25.6	53.5	0	0	2.33
Fe	899.4516	0	93.5	6.68	0.334	0.0344
Ca	861.63	36.7	100	0	0	1.67
Al	853.54	35.9	109	0	0	1.56
K	668.79	47.2	281	0	0	3.01
Mg	917.32	20.7	60.6	0	0	1.38
Na	614.49	94.1	282	0	0	9.41

Other data
(File: Incineration2.xls; Sheet: Annex 1)

	Water content of wet waste (%)	Heating value of dry waste (kcal/kg)
Food	0.599	3368
Paper	0.057	2724
Plastics	0	10567
Cardboard	0.061	3875
Textiles	0.250	4627
Wood	0.160	4231
Other biomass	0.184	2808
Sludge	0.063	1588
Minerals nec		4982

Release factors for average MSW (re%), percentage of emissions that are gaseous in average MSW (gas%), short and long term emissions of residual landfills and slag compartments (Source: Doka, 2003)
(File: Landfilling2.xls; Sheet: waste related emissions)

	MSW landfill		Residual Landfill		Slag Compartment	
	re %	gas (%)	Short Term	Long term	Short Term	Long Term
O	100	97.1	0.0001508	0.09051	0.004363	1
H	100	97.1	0.0001508	0.09051	0.004363	1
C	100	97.1	0.001079	0.6473	0.001798	0.4121
S	43.8	14.9	0.1073	1	0.09119	1
N	250	6.44	0.1888	1	0.1888	1
P	5.59	0	0.0003732	0.2239	0.00002204	0.005051
B	673	0	0.007835	0.9911	0.007835	0.8352
Cl	255	1.38	0.286	1	0.86378	1
Br	255	1.38	0.8033	1	1	1
F	45.2	83.8	0.05419	1	0.004988	0.6821
I	255	1.38	1	1	1	1
Ag	0.49	0.029	0.00006426	0.03856	0.00003472	0.007957
As	18	1.38	1	1	0.001504	0.3477
Ba	115	0.025	0.00001379	0.008274	0.0001533	0.03513
Cd	17.7	0.662	0.00001133	0.0068	0.0005145	0.1179
Co	32.2	0.025	0.0002854	0.1712	0.0001391	0.03188
Cr	1.14	0.025	0.06011	0.25	0.0000286	0.006469
Cu	0.49	0.029	0.00006426	0.03856	0.00003472	0.007957
Hg	9.59	28.6	0.0000788	0.04728	0.0262	1
Mn	115	0.025	0.00001379	0.008274	0.00005118	0.01173
Mo	10.5	0.025	0.9954	1	0.04659	1
Ni	5.82	0.025	0.0006044	0.3626	0.0006297	0.1443
Pb	0.59	0.033	0.00000866	0.005196	0.00001825	0.004183
Sb	10.5	0.025	0.3527	1	0.0006743	0.1432
Se	10.5	0.025	0.3527	1	0.0159	0.9746
Sn	0.59	0.025	0.00003163	0.01898	0.000016	0.003666
V	10.5	0.025	0.002454	0.7711	0.0004436	0.0967
Zn	4.74	0.022	0.00002046	0.01228	0.00002977	0.006822
Si	5	0.025	0.002249	1	0.0000639	0.008456
Fe	1.37	0.025	8.36E-06	0.00502	8.37E-06	0.001918
Ca	13	0.025	0.0001508	0.09051	0.004363	1
Al	5	0.025	0.0004956	0.2973	1.31E-05	0.003011
K	73.1	0.025	0.2819	1	0.1208	1
Mg	31.7	0.025	0.0001897	0.1138	0.003799	0.8707
Na	414	0.025	0.3753	1	0.122	1

Calculated leachate composition in the first 30 years (% of landfilled dry waste)
(File: Landfilling2.xls; Sheet: Tables)

	Food	Paper	Plastics	Carboard	Textiles	Wood	Other biomass	Rottereste	N-Fertilisers	Other Fertilisers	Sludge	Sand gravel stone
O	0.00248781	0.00383165	5.8E-06	0.00388338	0.0012579	0.00023751	0.0021906	3.952E-07	6.264E-05	0.001392	0.00592251	0
H	0.00039055	0.00040707	4.205E-05	0.00056509	0.00023293	3.473E-05	0.00022919	8.818E-08	0	0	0.00056689	0
C	0.00317127	0.0032067	0.00023149	0.00419742	0.00181934	0.00030469	0.00184415	1.1292E-06	6.96E-06	0.00420381	0.00389553	0
S	0.0003763	7.0473E-05	5.9639E-06	0.00019051	0.00016699	6.212E-06	0.00026032	0.00011446	0.00031608	0.015655	0.00273708	0
N	0.00629998	0.00063185	7.0171E-05	0.00112076	0.01163886	0.00013365	0.00459977	0.00016104	0.435054	0.042102	0.0398605	0
P	4.2534E-05	1.9697E-06	0	0	0	0	0	1.0958E-07	0	0.0013416	0.00073986	0
B	4.6405E-05	3.6438E-05	0	0	0	0	0	3.0839E-08	0	0	0.00026986	0
Cl	0.00677352	0.00013616	0.000679	0.00184767	0.0010864	5.3887E-05	4.622E-05	7.4999E-05	0.00017771	0.00010121	0.00220585	0
Br	1.016E-05	0	1.8861E-06	0	0	0	0	4.6402E-07	0	0	0	0
F	9.8613E-06	0	1.0251E-08	1.0526E-06	0	6.9734E-08	0	4.4521E-08	0	0	7.3404E-07	0
I	0	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0	0
As	2.3907E-07	2.5426E-08	0	1.9847E-07	0	0	1.5008E-07	6.5392E-07	0	0	8.1858E-07	0
Ba	0	9.3207E-06	0	1.7886E-05	0	0	4.4374E-05	6.3509E-11	0	0	0.00023051	0
Cd	0	4.7498E-07	8.7915E-08	1.1233E-07	0	4.1862E-09	1.0018E-07	2.779E-10	2.0543E-06	1.1699E-06	3.5252E-07	0
Co	1.0838E-06	0	0	0	0	0	0	3.5955E-10	0	0	1.2505E-06	0
Cr	6.1395E-08	1.0448E-07	5.6986E-09	8.4465E-08	0	0	9.3213E-08	7.3868E-06	3.2625E-05	1.858E-05	4.8557E-07	0
Cu	5.9373E-08	3.9713E-08	3.674E-09	1.3144E-07	0	1.5162E-09	5.5279E-08	1.652E-08	2.9648E-05	1.6885E-05	6.9976E-07	0
Hg	0	5.5511E-10	3.4237E-11	1.9686E-08	0	8.1512E-10	1.5102E-08	9.19E-13	1E-07	5.6951E-08	8.2712E-07	0
Mn	3.3289E-06	1.5513E-05	0	3.7131E-05	0	0	7.7613E-05	1.2967E-10	0	0	0.00034864	0
Mo	2.8274E-08	2.2313E-07	0	0	0	0	0	6.2981E-07	0	0	0	0
Ni	2.1236E-07	1.5718E-07	1.0473E-08	4.7396E-07	0	0	1.8928E-07	2.3592E-08	5.0987E-05	2.9037E-05	1.8082E-06	0
Pb	7.3712E-08	7.958E-08	5.3083E-09	8.1015E-08	0	4.3391E-08	5.1501E-07	6.7414E-10	2.6841E-05	1.5286E-05	6.3116E-07	0
Sb	0	1.5427E-07	0	0	0	0	0	3.8424E-06	2.7596E-05	1.5716E-05	2.8675E-07	0
Se	3.5325E-08	2.4057E-09	0	1.1066E-07	0	0	5.7879E-08	9.5389E-08	1.1127E-07	6.337E-08	2.6308E-08	0
Sn	3.1759E-08	1.3383E-08	0	0	0	0	0	6.3661E-10	2.5844E-06	1.4718E-06	1.6261E-07	0
V	2.1195E-07	0	0	0	0	0	0	1.8541E-09	0	0	1.1681E-06	0
Zn	1.8585E-06	1.2802E-06	3.3173E-07	9.0829E-07	0	8.0108E-08	3.1355E-06	7.7702E-09	0.00019379	0.00011036	2.5178E-05	0
Si	0.00134573	0.00030071	0	0	0	0	0	3.3795E-05	0.00596812	0.00339884	0.00170408	0
Fe	5.5337E-06	2.5896E-06	5.3417E-07	0	0	0	0	8.1076E-08	0.001704	0.00097043	0.00028819	0
Ca	0.00190783	0.00014036	0	0	0	0	0	9.337E-07	0.00192873	0.00202749	0.00312997	0
Al	0.00033643	0.00017613	9.9976E-08	0	0	0	0	2.3503E-06	0.004202	0.00239304	0.00079597	0
K	0.00172237	0.00019742	0	0	0	0	0	0.00026823	5.1645E-05	0.05700375	0.00204432	0
Mg	0.0006018	0.00042761	0	0	0	0	0	2.7035E-07	0.00277711	0.00285229	0.00096599	0
Na	0.00418054	0.00078254	0	0	0	0	0	0.00059306	0.1655487	0.09428	0.00391734	0

	Fe	Al	Cu	Glass	MSWI Slags	Metals nec	Other minerals nec	C_oil	C_fibre	C_food	C Carbonate
O	0	0	0	0	3.5528E-05	0	0	0	0	0	0
H	0	0	0	0	7.9272E-06	0	0	0	0	0	0
C	0	0	0	0	2.2524E-05	0	0	0.00029	0.00435	0.00783	0.00145
S	0	0	0	0	0.0001551	0	0	0	0	0	0
N	0	0	0	0	0.000905	0	0.000845432	0	0	0	0
P	0	0	0	0	2.0107E-08	0	9.22259E-06	0	0	0	0
B	0	0	0	0	9.5822E-08	0	2.65047E-06	0	0	0	0
Cl	0	0	0	0	0.00732776	0	9.33848E-06	0	0	0	0
Br	0	0	0	0	1.8687E-05	0	1.44687E-05	0	0	0	0
F	0	0	0	0	1.3257E-07	0	8.03511E-09	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0	0	0	0	0	0	0	0	0	0
As	0	0	0	0	3.0559E-09	0	0	0	0	0	0
Ba	0	0	0	0	2.1937E-09	0	0	0	0	0	0
Cd	0	0	0	0	6.8008E-09	4.6997E-05	0	0	0	0	0
Co	0	0	0	0	5.4451E-10	0	0	0	0	0	0
Cr	0	0	0	0	1.092E-08	0.00074636	0	0	0	0	0
Cu	0	0	0.00244929	0	2.7734E-08	0	0	0	0	0	0
Hg	0	0	0	0	5.7652E-09	2.2878E-06	0	0	0	0	0
Mn	0	0	0	0	1.4953E-09	0	0	0	0	0	0
Mo	0	0	0	0	9.1595E-08	0	0	0	0	0	0
Ni	0	0	0	0	7.6374E-08	0.00116643	0	0	0	0	0
Pb	0	0	0	0	1.1467E-08	0.00061404	0	0	0	0	0
Sb	0	0	0	0	2.2825E-08	0.00063132	0	0	0	0	0
Se	0	0	0	0	1.3361E-08	0	0	0	0	0	0
Sn	0	0	0	0	1.0006E-09	5.9123E-05	0	0	0	0	0
V	0	0	0	0	1.0414E-09	0	0	0	0	0	0
Zn	0	0	0	0	2.1491E-08	0.00443337	0	0	0	0	0
Si	0	0	0	0	2.9835E-06	0	0	0	0	0	0
Fe	0.00684829	0	0	0	2.5213E-07	0	0	0	0	0	0
Ca	0	0	0	0	8.3938E-05	0	0	0	0	0	0
Al	0	0.02499375	0	0	1.9362E-07	0	0	0	0	0	0
K	0	0	0	0	0.00035715	0	0	0	0	0	0
Mg	0	0	0	0	1.6823E-05	0.06353239	0	0	0	0	0
Na	0	0	0	0	0.00059902	0	0	0	0	0	0