MANUAL

SWM-GHG Calculator

TOOL FOR CALCULATING GREENHOUSE GASES (GHG) IN SOLID WASTE MANAGEMENT (SWM)

Developed by

ifeu

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Preliminary Note

This manual provides background information and additional explanations on the use of the SWM-GHG Calculator. However, it is by no means necessary to study the manual before using the SWM-GHG Calculator. The quickest way to learn how to utilise the tool is to start it and to follow the instructions provided.

Besides some explanatory instructions this manual provides additional background information and basic data. The main section titles in the manual refer to the different spreadsheets in the SWM-GHG Calculator.

The SWM-GHG Calculator was developed by IFEU Institute, sponsored by KfW Development Bank (German Financial Development Cooperation) in cooperation with GTZ (German Technical Development Cooperation) and financed with funds provided by the German Federal Ministry for Economic Cooperation and Development.

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Contents

1 Background and objective

Climate change is considered one of the greatest global challenges of the 21st century. A general consensus exists among the vast majority of climate experts that global warming is the result of rising concentrations of greenhouse gases in the Earth's atmosphere. Since industrialisation began, human activities have intensified the natural greenhouse effect, which is caused largely by water vapour, carbon dioxide, methane and ozone in the atmosphere, through anthropogenic emissions of greenhouse gases (GHG), resulting in global warming.

The waste management sector contributes to the anthropogenic greenhouse effect primarily through emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The IPCC's Fourth Assessment Report puts the contribution made by the solid waste and wastewater management sector to global greenhouse gas emissions at 2.7%, which might at first sight appear to be comparatively low. This figure, however, does not fully reflect the actual potential for reducing GHG emissions by the waste management sector. The IPCC calculations take into account only end-of-pipe solid waste management strategies, such as:

- Landfill/waste dumping
- Composting
- Waste incineration (in case the generated heat energy is not utilised)
- Sewage disposal

The positive impacts of reducing, re-using or recycling waste – the 3R's –, as well as waste-to-energy strategies, on climate protection are either attributed to other source categories – in particular to the energy sector and to industrial processes – or they are not accounted for at all in the GHG inventories reported to the United Nations Framework Convention on Climate Change (UNFCCC) under the Kyoto Protocol.

"Recycling" in GHG national inventories

The effects of material or energy recycling are not credited to the "Waste" sector in the GHG inventories, but are included in the "Energy" or "Industrial Processes" sectors for methodological reasons. For instance, scrap recycling is included in the industry sector under "Metal Production: Iron and Steel Production" using an emission factor for steel production in an electric arc furnace where most of the scrap is used. The resulting emissions are lower than those from other steel production methods where primary material is used. Additionally, because scrap is used for steel production less pig iron produced from iron ore is needed. Both these effects, the saved emissions due to the recycling process and the reduced emissions from substituting the extraction of iron ore and production of pig iron, are not stated separately in the GHG inventory and thus hide the contributions of the waste sector to these GHG reductions.

The same applies to the use of all solid waste fractions as secondary raw materials. Therefore, national inventories only partially reflect the contribution of waste management activities to GHG mitigation. Developing countries and emerging economies would not only considerably reduce their GHG emissions at comparably low costs, but would also significantly contribute to improving public health conditions and environmental protection if they were to put in place sustainable waste management systems. GHG emissions produced by the waste management sector in developing countries and emerging economies are highly relevant, in particular because of the high percentage of biodegradable components contained in the waste streams. The potential to reduce GHG emissions is significantly higher than the 2.7% figure in the IPCC statistics would lead us to assume. Over and above this, stepping up recycling could further reduce emissions, although it must be pointed out that the recyclable components of waste in developing countries and emerging economies are lower than in industrialised countries.

A study conducted on behalf of the Federal Ministry for Economic Cooperation and Development BMZ estimates that developing countries and emerging economies could reduce their national GHG emissions by around 5% merely by adopting municipal waste management systems (IFEU 2008). The authors reckon that if other waste types, especially waste containing high levels of biodegradable organic matter, in particular the residues of agricultural activities and the food industry or other, similar industrial wastes are included in the waste management system, the reduction of greenhouse gas emissions in these countries could be doubled, i.e. in the order of 10%. For comparison: the German waste management activities accounted for about 20% of the overall GHG reduction achieved over the period 1990 to 2005 by establishing what is called "closed-loop waste management" (Troge 2007).

The objective of this "Tool for Calculating GHG Emissions in Solid Waste Management" (SWM-GHG Calculator) is to aid in understanding the effects of proper waste management on GHG emissions. The SWM-GHG Calculator allows quantification and comparison of GHG emissions for different waste management strategies at an early stage in the decision making process. Default values allow approximations to be made even if basic data are not (yet) available. Additionally, the SWM-GHG Calculator provides guidance information on the costs associated with different waste management strategies.

The use of the SWM-GHG Calculator does not require profound professional experience in solid waste management. It can even be used by persons having only basic knowledge in the sector, e.g. by decision makers or mayors. Nevertheless, the SWM-GHG Calculator can be better used and the results are better understood the more experience users have.

2 Methodology

Basically, the calculation method used in the SWM-GHG Calculator follows the Life Cycle Assessment (LCA) method. Different waste management strategies can be compared by calculating the GHG emissions of the different recycled (typically glass, paper and cardboard, plastics, metals, organic waste) and disposed of waste fractions over their whole life cy
cle – from "cradle to grave", in a manner of speaking. The tool sums up the emissions of all residual waste or recycling streams respectively and calculates the total GHG emissions of all process stages in CO_2 equivalents. The emissions calculated also include all future emissions caused by a given quantity of treated waste. This means that when waste is sent to landfill, for example, the calculated GHG emissions, given in tonne CO_2 equivalents per tonne waste, include the cumulated emissions this waste amount will

generate during its degradation. This method corresponds to the "Tier 1" approach described in IPCC (1996, 2006).

Figure 2-1 shows a simplified example of an integrated waste management system. At every stage of the recycling and disposal chains GHG emissions occur for each single waste fraction. Recycling activities lead to secondary products ("secondary raw materials"), which substitute for primary raw materials or fossil fuels ("waste-to-energy"). The benefits from the substitution of primary raw materials or fossil fuels are calculated as credits according to the emissions avoided in the corresponding processes, pursuant to the LCA method. The accounting procedures applied for the use of secondary raw materials encompass every stage in the process, from the separation of waste to sorting and preparing waste, as well as transport emissions. Only the emissions from waste collection were neglected because it may be assumed that emissions generated by waste collection are more or less in the same range for each scenario, as can be seen in Figure 2-1.

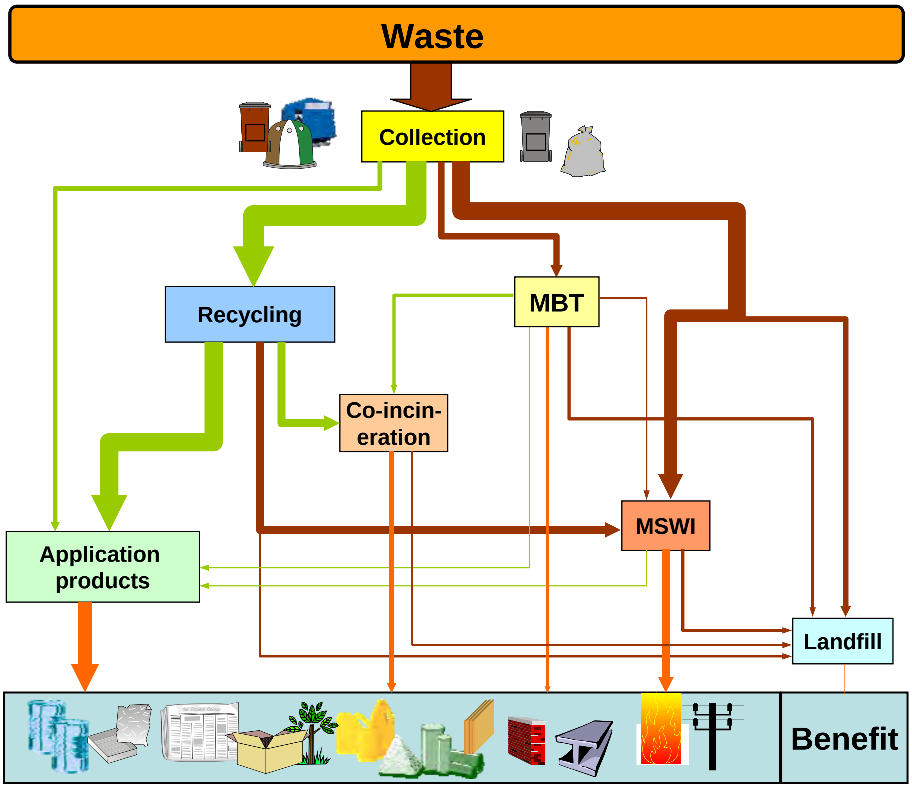


Figure 2-1 Flow diagram of an integrated solid waste management system

Up to four different waste management systems can be compared using the SWM-GHG Calculator; in addition to Status Quo, three user-definable scenarios can be analysed in one step. If users want to do calculations with different waste quantities or compositions, the SWM-GHG Calculator must be copied and saved under a different name.

For methodical and practical reasons it was necessary to design the tool by applying various simplifications. It must be emphasized that the SWM-GHG Calculator can by no means represent a fully-fledged Life Cycle Assessment (LCA). For example, most GHG calculations for the recycling chains are based on emission factors which account for specific treatment options in Germany and Europe. This is why the SWM-GHG Calculator delivers common results based on average data for recycling. Nevertheless, the variations are not serious or critical for decision making. Details of the main assumptions made are explained in this manual.

Furthermore, the SWM-GHG Calculator is not suited to calculating the anticipated quantity of Certified Emission Reductions (CER) in the framework of the Clean Development Mechanism (CDM)[1] or of Emission Reduction Units (ERU) in the framework of the Joint Implementation (JI). Firstly, the CDM and JI refer to individual projects and must take into account the theoretical generation of GHG that would occur during waste degradation if a CDM or JI project where not implemented ("baseline"). The SWM-GHG Calculator, on the other hand, compares different solid waste management systems or strategies. Secondly, the CERs and ERUs must be calculated and are compensated on an annual basis; i.e. only the GHG emissions caused by a given quantity of treated waste per year are considered – calculated in compliance with the "Tier 2" approach in (IPCC 1996, 2006) – and only a crediting period of either once ten years or three times seven years can be chosen. The CDM or JI crediting periods are therefore much shorter than the waste degradation period, which is 50 years or more. Thus only around 50% - 80% of the avoided GHG generation of a given quantity of waste is compensated by CDM resp. JI mechanisms (ANS/DWA 2009). Beyond that there are currently no methodologies available for recycling activities within the CDM.

The simplifications discussed above were necessary and had to be accepted for the benefit of better manageability of the SWM-GHG Calculator. Against the background of the tool's objective – to aid in understanding the consequences of waste management activities with respect to the related GHG emissions – it serves as a valuable orientation aid. The results deliver a sufficiently accurate quantitative approximation of the GHG impacts of different strategies as an important contribution to decision making.

Even if users have no access to complete data for the situation in their region or country they can use the proposed default values to achieve a best guess. Certainly, the better the databases – especially in terms of waste quantities and composition – the better and more reliable are the results. Nevertheless, in practice waste treatment options must be thoroughly assessed in any case before realising a new project. The results of the SWM-GHG Calculator can and should provide additional information for the decision making process only.

[1] Basic information according to the CDM procedure can be found e.g. in (UBA 2009)

3 Recommendations for defining scenarios

Some recommendations for defining scenarios are given, together with an example describing a possible Status Quo scenario and three waste management strategy scenarios. The exemplary scenarios are described briefly in Table 3-1.

1. All scenarios should refer to the same region, waste quantity and waste composition.
2. Describe the Status Quo as realistically as possible. Initially collect only easily accessible or available basic input data (population figures, waste quantities and compositions, present waste disposal practice). Don’t waste time on ambitious data research. If data are not easily available, use the default values provided.
3. Define Scenario 1 as the probable future business-as-usual development scenario, e.g. solutions in neighbouring regions, solutions discussed on political and professional levels. Try to estimate the quantities of waste already being recycled, in particular by the informal sector, as accurately as possible, but do not overestimate them! Keep in mind that even comprehensive informal recycling schemes do not recover more than about 50% of the generated recyclable waste components (paper, cardboard, plastics etc.).
4. Define Scenario 2 as a more advanced solid waste management system. For example, extension of waste collection services to as yet unconnected municipalities or city quarters; optimisation of recycling activities, e.g. by cooperation with the informal sector or supportive measures; introduction of composting for selected waste streams (garden, park, market waste); possible pre-treatment/biological stabilisation of residual waste before sending to landfill.
5. Define Scenario 3 as a modern solid waste management system according to the advanced standards and strategies of western European countries, e.g. closed-loop-recycling systems, waste-to-energy strategies, etc.; stay realistic with achievable recovery rates. Figures of more than 80% - 90% material recycling are not achievable even with very advanced strategies and technologies (see Table 6-1).

Last but not least and most important: **Play with the tool**! Try to identify what can be achieved in GHG mitigation by applying different visions for the organisation of solid waste management in your city, in your region or even in your country!

Table 3-1 Example of a Status Quo and definition of alternative scenarios

Status Quo	The Status Quo describes a typical situation in a developing country where no appropriate sanitary waste management currently takes place. Waste is partly recycled by the informal sector under difficult health conditions. Some neighbouring municipalities or districts are not yet covered by regular waste collection services. The majority of the waste is dumped on unmanaged disposal sites under anaerobic conditions producing methane; other parts are disposed of in low heaps ("scattered disposal") under aerobic conditions, producing mainly carbon dioxide. Half of the scattered waste is burned in open fires producing extreme air pollution.
Scenario 1: Improved recycling; disposal of residual waste to sanitary landfill	In this scenario it is assumed that a higher recycling rate can be realised and that garden and park waste is partly collected separately and composted. The remaining residual waste is mainly disposed of to sanitary landfill with a high-efficiency gas collection system (50%). The collected gas is used for electricity generation. 10% of the remaining residual waste is still scattered but no longer burned, assuming rural areas cannot be connected to the central landfill.
Scenario 2: Recycling as for Scenario 1; biological stabilisation of remaining residual waste	This scenario is similar to Scenario 1 with one important difference: it is assumed that the remaining residual waste is no longer sent to landfill directly, but is pre-treated in a stabilisation process before being discarded, thus significantly minimising the resulting methane emissions from landfill. Gas collection is therefore no longer needed. Recycling rates and connection rates to central facilities are identical to Scenario 1. In accordance with Scenario 1, 10% of the remaining residual waste is still scattered but not burned.
Scenario 3: Advanced solid waste management system	This scenario represents the most advanced solid waste management strategy. High recycling rates for dry recyclables are assumed as well as increased efficiency in the separate collection and composting of garden and park waste. The remaining residual waste is separated via mechanical-biological and/or mechanical-physical stabilisation producing a refuse-derived fuel (RDF) fraction that is used in a cement kiln and a metal fraction for recycling. Additionally, an inert fraction is separated for disposal and impurities for incineration in a MSWI plant. Rural areas are connected to the system – waste scattering no longer occurs.

The percentages for recycling rates, type of biological treatment, whereabouts of the remaining residual waste and data on disposal technologies for the above described scenarios in the example used in this manual are shown in Table 3-2 to Table 3-5. These tables correlate with the input boxes in the SWM-GHG Calculator where users should insert their own data for their Status Quo and the scenarios they would like to compare.

Table 3-2 Recycling rates – Example of a Status Quo and alternative scenarios

	Status Quo	Scenario 1	Scenario 2	Scenario 3
Paper, cardboard	30%	50%	50%	70%
Plastics	30%	50%	50%	70%
Glass	10%	30%	30%	50%
Ferrous metals	40%	60%	60%	70%
Aluminium	40%	60%	60%	70%
Textiles	10%	20%	20%	40%
Food waste	0%	0%	0%	0%
Garden and park waste	0%	20%	20%	40%

Table 3-3 Composting or digestion of separately collected organic waste – Example of a Status Quo and alternative scenarios

	Status Quo	Scenario 1	Scenario 2	Scenario 3
Composted	0%	100%	100%	100%
Digested	0%	0%	0%	0%

Table 3-4 Waste treatment and disposal of residual waste – Example of a Status Quo and alternative scenarios

	Status Quo	Scenario 1	Scenario 2	Scenario 3
Scattered waste not burned	10%	10%	10%	0%
Open burning of scattered waste	10%	0%	0%	0%
Wild dumps/unmanaged disposal site	80%	0%	0%	0%
Controlled dump/landfill without gas collection	0%	0%	0%	0%
Sanitary landfill with gas collection	0%	90%	0%	0%
BS + landfill	0%	0%	90%	0%
MBT + further treatment + landfill	0%	0%	0%	0%
MBS/MPS + co-processing cement kiln	0%	0%	0%	100%
Incineration	0%	0%	0%	0%

Table 3-5 Data on disposal technologies – Example of a Status Quo and alternative scenarios

	Status Quo	Scenario 1	Scenario 2	Scenario 3
Efficiency of gas collection	0%	50%	0%	0%
Treatment of collected landfill gas				
No treatment, ventilation only	0%	0%	0%	0%
Flare	0%	0%	0%	0%
Electricity generation	0%	100%	0%	0%
Energy efficiency of incineration				
Electricity	0%	0%	0%	0%
Thermal	0%	0%	0%	0%

4 Overview (Intro)

The SWM-GHG Calculator was financed by funds provided by the German Federal Ministry for Economic Cooperation and Development (BMZ) and designed on behalf of the KfW Entwicklungsbank (German Financial Cooperation / Development Bank), in cooperation with GTZ (German Technical Cooperation Agency). It is based on Excel as a very common spreadsheet application and implemented in a rather simple manner in order to allow users to quickly understand how the tool works. The tool contains brief instructions on what to do, at few points, where it may be a little more complex; alternatively, an assistant can be used. Principally, the ambition was to retain the Excel character as far as possible because most users are familiar with this software.

In addition to the instructions, further information can be found in the tool, e.g. in the reading text or in the Excel comments. Additionally, intermediate results are shown at a number of places; the respective areas in the tool can be recognised by boxes marked yellow.

The SWM-GHG Calculator comprises the following sheets:

Intro: Brief outline of the SWM-GHG Calculator, contact persons.

Start: Specification of waste amount, waste composition, waste characteristics and country-specific electricity grid.

Recycling: Specifications for waste recycling, up to 4 scenarios can be compared.

Disposal: Specifications for waste treatment and disposal, up to 4 scenarios can be compared.

Costs: Specification of costs for waste recycling, and waste treatment and disposal.

Result sheets:
Results SQ: Results of the Status Quo scenario
Results Sc1: Results of Scenario 1
Results Sc2: Results of Scenario 2
Results Sc3: Results of Scenario 3

Results all: Summary comparison of the results of up to four scenarios.

Results costs all: Summary comparison of the absolute costs of up to four scenarios and mitigation costs per tonne of GHG of the scenarios 1 to 3 compared to the Status Quo

The sheets are explained in more detail in the following sections.

Basically, to work with the tool, data must be entered into the green cells.

5 "Start"

Some basic data must be entered to start calculations.

On the first worksheet, "Start", these are:

- Total waste amount
- Waste composition in percentages of wet weight
- Waste characteristics
- Country-specific GHG emission factor for generation of electricity

5.1 Total waste amount

The total waste amount can be entered either as:

a) Total waste amount in tonnes per year (tonnes/yr), or
b) Specific waste quantity in kilogrammes per capita and year (kg/cap/yr) combined with number of inhabitants, or
c) Specific waste quantity in kilogrammes per capita and day (kg/cap/day) combined with number of inhabitants calculated for 365 days/year.

Please note that only one option (a, b or c) may be used!

Please note that **1 kg/cap/day = 365 kg/cap/yr** is generally used as a conversion factor.

If users are not sure of what to enter in this step they can alternatively use an assistant by clicking the respective button:

Assistant

If no data are available on the specific waste quantity, either the recommended default values for low income (LIE) or middle income (MIE) economies given in the tool may be selected or data from the IPCC guidelines 2006 used (see annex, Table 0-1).

Table 0-2 in the annex shows data on the number of inhabitants in low, lower middle and upper middle income economies and the degree of urbanisation (DSW 2007).

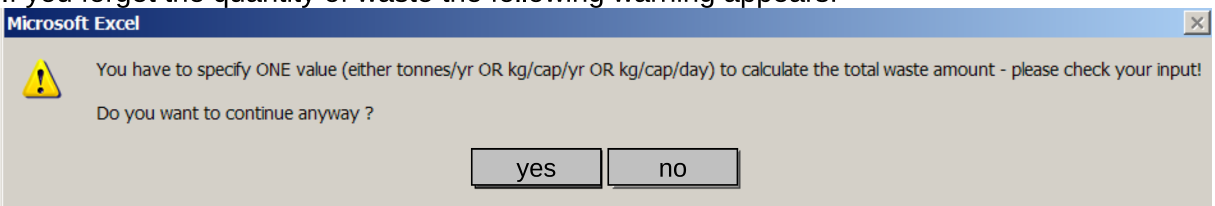
The result of your entry is shown in the yellow box for your information.

View before data entry		View after data entry	
Intermediate result / information		**Intermediate result / information**	
Your input results in a total waste amount of		Your input results in a total waste amount of	
Result - total waste amount		**Result - total waste amount**	
tonnes/yr	1.350.000	tonnes/yr	1.350.000
kg/cap/yr	insert inhabitants in green cell	kg/cap/yr	270
kg/cap/day	insert inhabitants in green cell	kg/cap/day	0,74

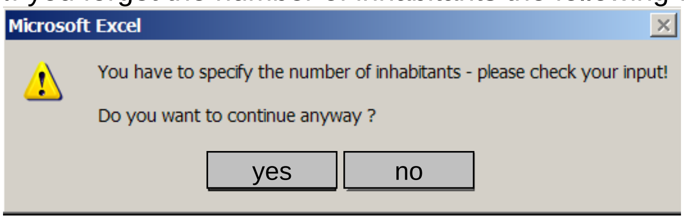
If you still see "insert inhabitants in green cell", you must insert the number of inhabitants in the green cell.
If you see "0", you must specify a value for the quantity of waste.
If you are not sure what to do use of the assistant is recommended.

In general, if users forget any data needed in the green cells on a worksheet, they will be reminded when they try to move to a different worksheet.

If you forget the quantity of waste the following warning appears:



If you forget the number of inhabitants the following warning appears:



In order to properly utilise the SWM-GHG Calculator, please do not continue anyway (click "no") but return to the previous worksheet and fill in the missing data in the green cells as advised or use the Assistant.

5.2 Waste composition

Waste composition is one of the main factors influencing GHG emissions from solid waste treatment, because different waste fractions contain different amounts of regenerative and/or degradable organic carbon (DOC) and fossil carbon. DOC is crucial for landfill gas generation, while only fossil carbon contributes to climate change in case of incineration. CO_2 from organic carbon is considered neutral to the climate because it originates from plants that bonded atmospheric CO_2. Another important aspect is the calorific value, which varies as a function of waste composition. For example, usually, the higher the organic waste content in municipal solid waste (MSW); the lower the calorific value is caused by the typically higher water content of the waste.

The calculations in the SWM-GHG Calculator are based on the total waste amount. This is necessary to assess possible waste management scenarios properly. The total waste amount is defined as the sum of waste for disposal and waste for recycling. Recycling includes activities from the informal sector.

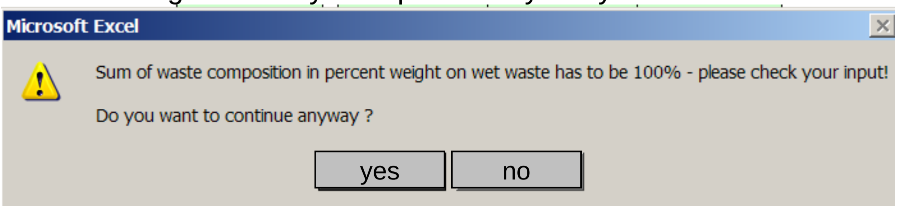
The waste composition must be entered in percentages of wet weight. The relation to weight is more reliable than a relation to volume. It is recommended to carry out a sorting analysis whenever possible to acquire the necessary data. If no data can be provided, choose from the recommended default values for low income (LIE) or middle income (MIE) economies (Table 5-1) that are also given in the tool. Alternatively, data from the IPCC guidelines 2006 can be used (see annex, Table 0-3) but these do not provide data for garden and park waste, ferrous metals, aluminium, nappies and mineral waste; see the recommendations below for these data.

Table 5-1 Default values for waste composition for low (LIE) and middle income economies (MIE)

Components	Default LIE	Default MIE
Food waste	55.4%	41.9%
Garden and park waste	9.2%	14.0%
Paper, cardboard	3.7%	9.3%
Plastics	2.8%	6.5%
Glass	1.2%	1.9%
Ferrous Metals	1.4%	1.9%
Aluminium	0.2%	0.5%
Textiles	1.4%	3.3%
Rubber, leather	1.4%	1.9%
Nappies (disposable diapers)	0%	4.0%
Wood	3.5%	6.0%
Mineral waste	6.0%	3.0%
Others	13.8%	5.8%
Total (must be 100%)	100.0%	100.0%

Source: (KfW 2008) supplemented by assessed shares of aluminium, nappies, wood and minerals and adjusting the "Others" fraction.

The total percentages entered must equal 100%. Otherwise, you will be reminded by an Excel warning to check your input when you try to move to another worksheet:



Explanations and recommendations:

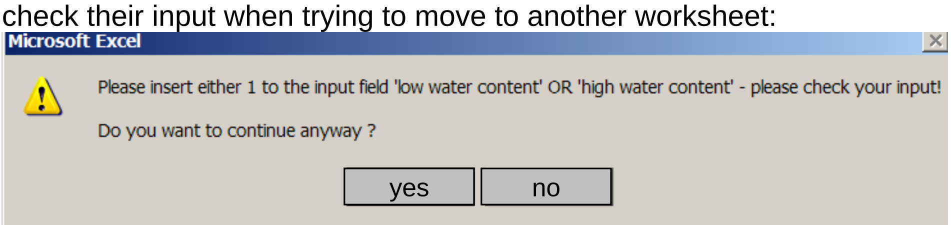
- Food waste is waste from kitchens before (waste from preparation) and after (scraps, leftovers) consumption; this includes smaller quantities of animal waste.
- If no information is available to distinguish between food waste and garden & park waste it is recommended to allocate the known percentage of organic waste as 50% food waste and 50% garden and park waste.
- If information is available on quantities of cardboard composites or cardboard packaging it may be added to the waste fraction "Paper, cardboard".
- Plastics include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS) and polyvinyl chloride (PVC).
- Aluminium is the only non-ferrous metal regarded separately here; other non-ferrous metals are of minor importance and should be included in "Others"; if only a percentage is known for "metals", it is recommended to split this percentage to 15% aluminium and 85% ferrous metals.
- "Others" includes all waste fractions not mentioned specifically, such as "fine fraction", "electronic scrap", "miscellaneous" or "carcasses and bones", etc.

5.3 Waste characteristics – water content

The water content of waste, and consequently the calorific value, can differ significantly, having an important impact on the results when waste is incinerated. The SWM-GHG Calculator respects this dependency and users must distinguish between waste with low or high water content.

Insert "1" for either low or high water content into the green cells. Alternatively, use the assistant by clicking the respective button:

If users forget to define the water content they will be reminded by an Excel warning to check their input when trying to move to another worksheet:



Even though "high" and "low" water content is a rather arbitrary distinction, it aids more precise calculations such that it can be assumed that the deviation due to simplification is probably no greater than the general uncertainty of the results. On the other hand, the effort required to determine the water content is relatively high and may not be possible in many developing countries.

Table 5-2 shows some indices to help judge if the waste in question has a low or high water content.

As a very rough rule of thumb a water content below 40% can be considered as low and a water content above 40% as high.

Table 5-2 Indices for low and high water content

Low water content	High water content
- The waste looks dry	- The waste is sludgy, water is oozing out
- The waste has a high ash content, e.g. in regions where people heat and cook on coal-burning stoves	- The waste has a high level of food waste caused by regional eating habits and lack of livestock to feed scraps to
- The waste has a low level of garden waste or waste from plants, e.g. in arid regions	- The waste has a high level of wet/non-ligneous garden waste or waste from plants, e.g. in humid areas
- The waste is stored under dry conditions	- The waste is stored openly, precipitation adds to the water content

5.4 Calculation of waste parameters – intermediate result

Based on the defined waste composition and the indication of low or high water content the regenerative carbon content, fossil carbon content and calorific value parameters are calculated by taking the respective carbon content and calorific value of each waste fraction and multiplying with the percentage of each waste fraction. The low and high water content are considered for the organic fraction and the non-specified fraction (others, especially fine fraction), because these two fractions usually vary most in water content. Other waste fractions such as paper/cardboard, plastics, glass, metals and textiles usually have a fairly stable water content and can be specified with fixed calorific value.

All calculation processes are shown transparently on the "Calculation" worksheet in the SWM-GHG Calculator.

Table 5-3 Carbon content waste fractions - Total and fossil carbon (IPCC 2006)

	C total	**C fossil**	
Food waste	15.2%	0%	% wet waste
Garden and park waste	19.6%	0%	% wet waste
Paper, cardboard	41.4%	1%	% wet waste
Plastics	75.0%	100%	% wet waste
Glass	0%	0%	% wet waste
Ferrous metals	0%	0%	% wet waste
Aluminium	0%	0%	% wet waste
Textiles	40.0%	20%	% wet waste
Rubber, leather	56.3%	20%	% wet waste
Nappies (diapers)	28.0%	10%	% wet waste
Wood	42.5%	0%	% wet waste
Mineral waste	0.0%	0%	% wet waste
Others	2.7%	100%	% wet waste

Table 5-3 shows the percentages used for total and fossil carbon content of the waste fractions according to (IPCC 2006). Table 5-4 shows the calorific values of the waste fractions used in the calculations. The table also shows the estimated water content of organic waste and non-specified waste ("Others") in case of a low or high water content.

Table 5-4 Calorific value waste fractions

Fraction	Calorific value	
Organic waste low water content	4	MJ/kg wet waste
Organic waste high water content	2	MJ/kg wet waste
Paper	11.5	MJ/kg wet waste
Plastics	31.5	MJ/kg wet waste
Glass	0	MJ/kg wet waste
Metals	0	MJ/kg wet waste
Textiles, rubber, leather	14.6	MJ/kg wet waste
Wood	15	MJ/kg wet waste
Mineral waste	0	MJ/kg wet waste
Others low water content	8.4	MJ/kg wet waste
Others high water content	5	MJ/kg wet waste

Source: (AEA 2001); wood IFEU estimate

The results of the calculations for calorific values and regenerative and fossil carbon content are shown in the tool for information. They are shown in the yellow box.

Intermediate result / information

The waste composition and water content you defined
leads to the following physical properties of the total waste

Result - calorific value and carbon content of total waste

Calorific value	in MJ/kg	6,8
Total carbon content	in % wet waste	24,0%
Fossil carbon content	in % wet waste	5,6%
Regenerative carbon content	in % wet waste	18,4%

If the cell for the calorific value indicates "wrong", please check that the question on water content was answered correctly. You will be reminded to do so anyway when you try to move to another worksheet.

Carbon content and calorific value are important parameters in many ways. As explained in Section 5.2, the organic and fossil carbon content influence the GHG emissions results. The calorific value is an important indicator for the combustibility of the waste. However, the results calculated and shown in the SWM-GHG Calculator are never reliable or representative enough to decide whether waste is appropriate for incineration or for waste management strategy decisions. More precise information acquired by detailed analysis of the waste is needed for decision making. The most important parameters that must be known are combustible matter, ash and water contents. Based on these three parameters the calorific value can be assessed with the help of what is called the fuel triangle (Figure 5-1). The triangle combines the three parameters in a graph that shows whether a waste is capable of self-sustaining incineration (red area) and indicates the respective calorific value.

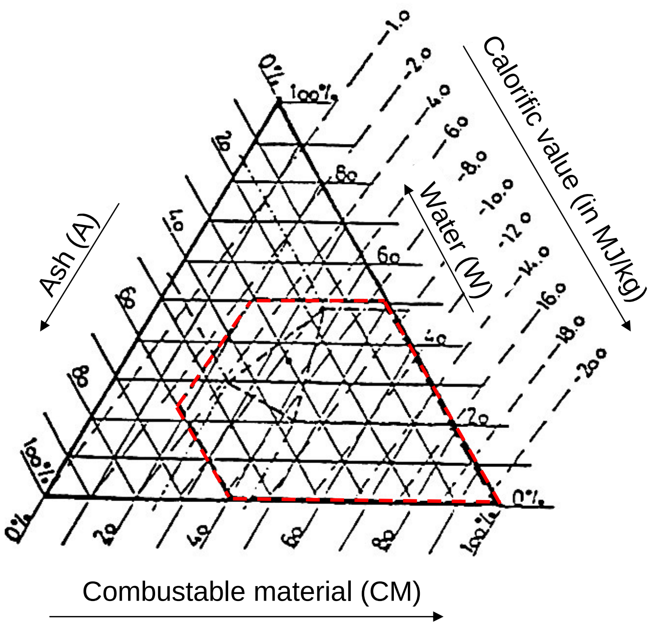


Figure 5-1 Fuel triangle

As a rough rule of thumb it can be assumed that self-sustaining incineration is difficult or no longer possible if the calorific value of a waste is < 6 MJ/kg. As discussed above, in practice waste should be thoroughly tested for incineration suitability.

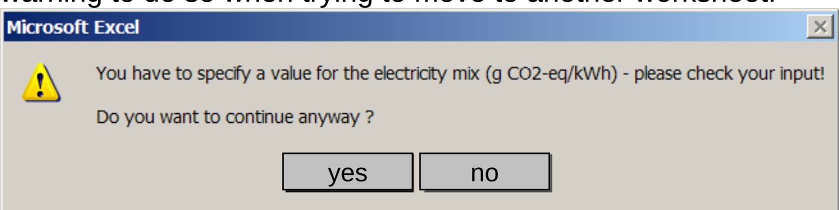
Furthermore, the heavy metal, sulphur and halogen contents in particular have a considerable impact on flue gas cleaning requirements and incineration costs. Determination of these parameters requires in-depth surveys of waste composition, and physical and chemical analyses.

5.5 Country-specific GHG emission factor for generation of electricity

Electricity generation produces GHG emissions. Usually, these are direct emissions from fuel combustion (mainly CO_2 from oxidation of the fossil carbon in the fuel) and indirect emissions from the supply of fuels, e.g. methane emissions from the mine during coal mining. Overall, the specific quantity of GHG emissions per kilowatt hour electricity depends on the energy carriers or mix of energy carriers used for electricity generation. The highest GHG emissions result from coal and oil as they have the highest fossil carbon content relative to energy content. The lowest GHG emissions from fossil fuels result from natural gas because natural gas has a low carbon content relative to energy content. Almost no GHG emissions at all result from such renewable energy sources as wind or water and from nuclear power plants, as in these cases no fossil carbon is burned.

The tool provides some examples for country-specific CO_2 emissions from electricity generation, which are shown in Table 5-5. More values for countries worldwide can be found in Table 0-4 in the annex. These emission factors only refer to direct CO_2 emissions from fuel combustion. Worldwide data on GHG emissions from electricity generation, including indirect emissions, are not available. Nevertheless, the underestimation by disregarding indirect GHG emissions for electricity production is not too significant in relation to the importance of methane emissions from landfill. On this note it is also not absolutely necessary to enter the correct emission factor for a specific country. If users know the specific emission factor for electricity production in their country then of course it is best to use that value (in g CO_2-eq/kWh electricity). But otherwise, a value can be chosen from the default values given in Table 5-5. If you are not sure what to choose please do not hesitate to make a best guess or try two different values to see the difference in the results.

If users forget to insert a figure for the electricity mix they are reminded by an Excel warning to do so when trying to move to another worksheet:



The CO_2 emission factors for electricity production are not only used to calculate the GHG emissions from electricity demand, but also to calculate the benefit from electricity generated by a waste treatment technology (e.g. incineration).

Table 5-5 Examples of country-specific GHG emissions for electricity production

Electricity grid	Default choices	
Brazil (90% renewable)	51	g CO2-eq/kWh
China (80% fossil, 18% renewable)	1009	g CO2-eq/kWh
India (75% fossil, 18% renewable)	886	g CO2-eq/kWh
Mexico (63% fossil, 27% renewable)	607	g CO2-eq/kWh
South Africa (95% fossil)	819	g CO2-eq/kWh
Ukraine (63% fossil, 32% nuclear)	276	g CO2-eq/kWh

Source: EIA Energy Information Administration: official energy statistics from the U.S. government
World total net electricity generation 2005 and CO_2 emissions from power plants worldwide using data from Carma (www.carma.org)

6 "Recycling"

On the "Recycling" worksheet you are asked for the recycling rates of different waste fractions and additionally for the type of treatment in the case of organic waste:

- Recycling rates for dry materials
- Recycling rates for organic waste (food waste, garden and park waste)
- Share of composting and digestion of recycled organic waste

6.1 Dry materials

Dry waste fractions that are considered in the SWM-GHG Calculator are

- Paper, cardboard
- Plastics
- Glass
- Ferrous metals
- Aluminium
- Textiles

The recycling rate asked for in the SWM-GHG Calculator corresponds to the amount of each waste fraction in the total waste (Figure 6-1).

Example – recycling rate for paper, cardboard:

The total waste in a region is 1,000,000 tonnes per year The share of paper and cardboard in the total waste quantity is 10% = 100,000 tonnes per year The recycling rate defines how much of these 100,000 tonnes of paper and cardboard in the total waste is recycled

➔ If 30,000 tonnes of paper, cardboard are recycled per year, then the recycling rate is 30,000/100,000 = 30% and this value must be entered into the green cells.

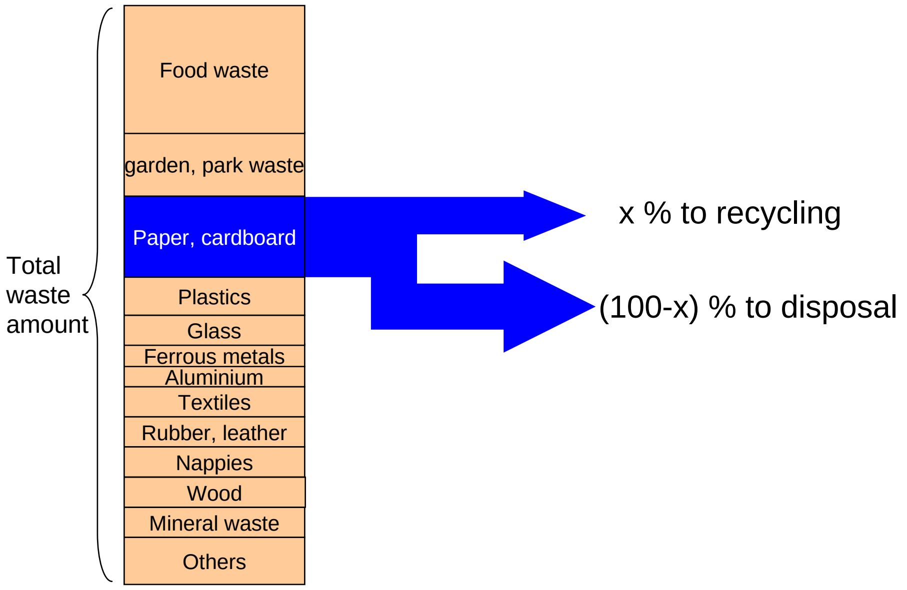


Figure 6-1 Example recycling rate for paper, cardboard

The recycling rate should include the activities of the informal sector. Therefore, the waste quantity that is already separated by the informal sector must be included in the calculation.

Recycling rates vary from country to country and it is not possible to provide default values. Usually, countries with integrated waste management systems have high recycling rates. Table 5-5 shows the recycling rates for waste fractions in the EU 27 (Prognos/IFEU/INFU 2008), for Germany as assessed in (IFEU/Öko-Institut 2009) in 2006 and for Mexico in 2004 (SEMARNAT/INE 2006).

Table 6-1 Recycling rates in the EU 27 and in Germany

	EU 27[1)]	**Germany**[2)]	**Mexico**
	Prognos/IFEU/ INFU 2008	Öko-Institut/ IFEU 2009	SEMARNAT/ INE 2006
Glass	50%	63%	13%
Paper, cardboard	56%	78%	16%
Plastics	35%	57%	8%
Ferrous metals	76%		80%
Aluminium	66%		
Textiles	32%		
Organic waste	37%	63%	3%

6.2 Organic waste composting and/or digestion

Organic waste considered in the SWM-GHG Calculator is:

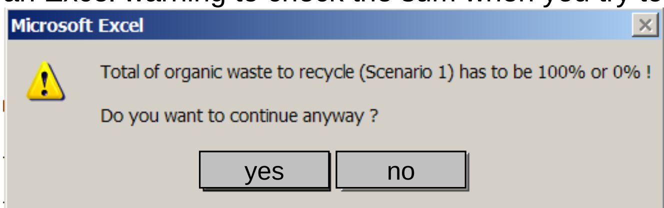
- Food waste
- Garden and park waste

The recycling rate for organic waste must be entered analogous to dry material. The SWM-GHG Calculator calculates two treatment options for organic waste: composting and digestion. The next step therefore asks how much of the recycled organic waste is either composted or digested. The reference value here is the amount of food waste, and garden & park waste in the total waste; as a simplification these two organic waste fractions are not distinguished further.

Example – recycling rate and type of treatment organic waste

The total waste amount in a region is 1,000,000 tonnes per year The share of food waste in the total waste is 40% = 400,000 tonnes per year The share of garden and park waste in the total waste is 15% = 150,000 tonnes per year The recycling rate for food waste is 20% = 80,000 tonnes per year The recycling rate for garden and park waste is 50% = 75,000 tonnes per year ➔ In total 155,000 tonnes of organic waste are recycled per year The next step asks how much of the 155,000 tonnes of organic waste is either composted or digested ➔ If 15,500 tonnes of the organic waste are digested and the rest is composted, then 15,500/155,000 = 10% must be entered into the green cells for digestion and 90% for composting.

If organic waste is recycled the sum of organic waste digested and/or composted must be 100% in any case. If no recycling of organic waste is planned the green cells must not be filled in. If you forget to fill in the respective green cells correctly you will be reminded by an Excel warning to check the sum when you try to move to a different worksheet:



6.3 Intermediate results – waste parameters of remaining residual waste

The recycling rates defined change the composition of the remaining residual waste and consequently the waste characteristics. For your information, the corresponding calorific values and regenerative and fossil carbon content of the remaining residual waste are now presented as intermediate results, which are shown in the yellow box.

Intermediate result / information
Separate collection changes the original waste composition, the recycling rates you inserted lead to the following physical properties for the remaining residual waste

Result - carbon content of total waste		Status Quo	Scenario 1	Scenario 2	Scenario 3
Calorific value	in MJ/kg	6,2	5,8	5,8	5,4
Total carbon content	in % wet waste	22,7%	21,7%	21,7%	20,5%
Fossil carbon content	in % wet waste	4,4%	3,6%	3,6%	2,6%
Regenerative carbon content	in % wet waste	18,3%	18,1%	18,1%	17,9%

Further calculations for disposal are in terms of this elementary composition of the remaining residual waste.

6.4 Recycling – treatment processes and GHG emission factors

GHG emissions for the recycled waste fractions defined in this step are calculated based on the mass of waste recycled and a GHG emission factor. The GHG emission factors used are shown in the annex. They correspond to the European level, and are described briefly in the annex.

7 "Disposal"

On the "Disposal" worksheet you are asked for the type of disposal of the remaining residual waste, and some data on disposal technology.

- Options for waste treatment and disposal
- Data on disposal technologies – landfill
- Data on disposal technologies – MSW Incineration

The remaining residual waste is the waste that remains after recycling material has been extracted from the total waste either by the informal sector or by separate collection (see Figure 6-1 "(100-x)% to disposal").

Example – remaining residual waste

> The total waste amount in a region is 1,000,000 tonnes per year
> The total waste recycled is 300,000 tonnes per year (sum of paper, cardboard, plastics, glass, ferrous metals, aluminium, textiles, food waste, garden and park waste to recycling)
> ➔ The resulting remaining residual waste is 1,000,000 - 300,000 = 700,000 tonnes per year.

You must indicate the type of treatment for this amount of remaining residual waste on the "disposal" worksheet.

7.1 Options for waste treatment and disposal

Manifold treatment types and technologies exist. Some should be avoided at all costs as they pose health hazards to the population and damage the environment, some are very simple but at least less hazardous, and finally there are sophisticated or advanced treatment technologies. The treatment technologies represented in the SWM-GHG Calculator are listed below.

The first group includes common present practices that should be avoided at all costs. They affect waste which is not regularly collected but usually scattered or delivered to a wild dump site. Additionally, scattered waste is sometimes burned in the open (including directly at households), producing huge amounts of extremely toxic substances (in particular dioxins, furanes, aromatic hydrocarbons ...).

1) Scattered waste not burned
2) Open burning of scattered waste
3) Wild dumps/unmanaged disposal site

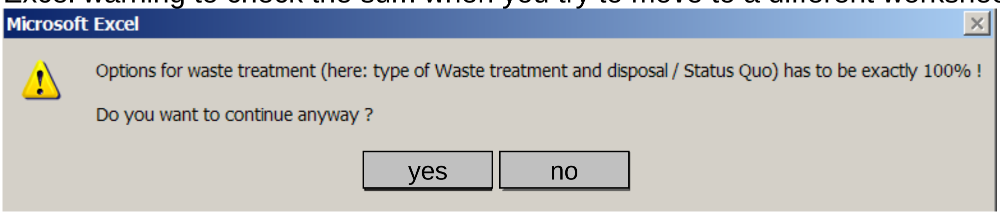
The second group is that of simple treatment and disposal technologies. Apart from disposal to controlled landfills this includes simple biological stabilisation (BS) before disposal whereby methane emissions are reduced.

4) Controlled dump/landfill without gas collection
5) Sanitary landfill with gas collection
6) BS[2] + landfill

The third group includes advanced technologies. Apart from waste incineration this includes treatment options with the purpose of separating recyclable fractions out of the residual waste before stabilising the remaining waste biologically prior to sending to landfill or to produce a refuse-derived fuel that may be co-incinerated, e.g. in cement kilns.

7) MBT[3] + further treatment + landfill
8) MBS/MPS[4] + co-processing cement kiln
9) Incineration

The total of the percentages of waste treatment and disposal options entered must equal 100%. If you forget to fill in the respective green cells correctly you will be reminded by an Excel warning to check the sum when you try to move to a different worksheet:



All treatment types and technologies mentioned are described briefly in the annex.

[2] Biological stabilisation
[3] Mechanical-biological treatment
[4] Mechanical-biological stabilisation / mechanical-physical stabilisation

7.2 Data on disposal technologies

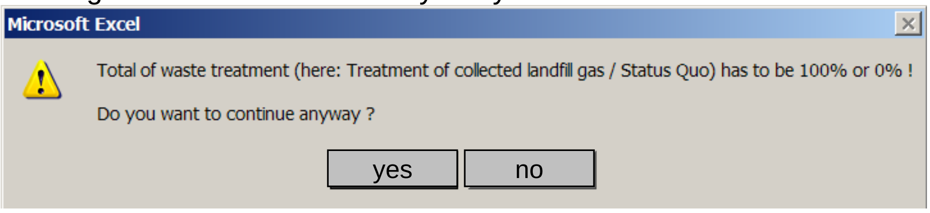
The tool requires some important parameters to be defined:

a) related to landfill:
- Efficiency of gas collection
- Treatment of collected landfill gas

b) related to incineration plants
- Net efficiency of energy utilisation

Efficiency of gas collection in this context means the share of all potential methane generated from a given quantity of waste that can be captured, or in other words the ratio of collected landfill gas to the total generated landfill gas from a given quantity of waste.

Treatment options for collected landfill gas are: no treatment, flaring or electricity generation. The total of the percentages of gas treatment you entered must equal 100%. If you forget to fill in the respective green cells correctly you will be reminded by an Excel warning to check the sum when you try to move to a different worksheet:



Further information on the net efficiency of energy utilisation through waste incineration and the efficiency of gas collection and treatment of collected landfill gas is given in the annex.

8 "Costs"

Typical default cost figures for the different activities have been deduced here from literature, data and empiricism. User-figures may be entered if available. The values represent average total costs (dynamic prime costs) and may vary considerably according to national and local conditions. The level of technology also has an important influence on the total cost.

The costs of establishing collection systems are also assumed to be required in each scenario and are not taken into account.

Costs for recycling are the effective costs from the point of view of the municipality. It is assumed that the collection and treatment costs are covered by revenues, irrespective of who is responsible for collection and treatment. The costs for municipalities mainly consist of public relations costs, the provision of bins and/or bags for the collection of recyclables, administration costs, etc.

Table 8-1 shows a range of minimum and maximum costs per tonne of waste for the different treatment options included in the SWM-GHG Calculator. The values can also be found in the SWM-GHG Calculator. They are based on data from (eunomia).

Table 8-1 Dynamic prime costs (DPC) – Default values for treatment options

Costs in euros/t waste	Min.	Max.
Controlled dump/landfill without gas collection	3	5
Sanitary landfill with gas collection	12	20
BS + landfill	15	25
MBT + further treatment + landfill	40	60
MBS/MPS + co-processing cement kiln	50	80
Incineration	90	150
Recycling of dry waste	0	5
Composting [1)]	20	40
Digestion	60	90

Source: KfW estimates

1) The default values correspond to open, simple composting plants, costs for advanced composting technologies of a similar magnitude to digestion.

In general, specific costs depend on the order of magnitude; they decrease with increasing plant capacity (economy of scale). As a rule of thumb, the following populations should be related to the respective plants:

- Sanitary landfill > 300,000 to 500,000 inhabitants
- Simple composting plant > 20,000 to 100,000 inhabitants
- Advanced composting or digestion plant > 100,000 inhabitants
- Waste-to-energy plant > 1,000,000 inhabitants

Explanation of dynamic prime costs

Dynamic prime costs are the discrete total annual costs (capital costs, operating costs, additional costs, replacement investments, etc.) accumulated over the calculated lifetime of the investment, discounted to year 1 of the investment, divided by the cumulated annual discounted total quantity of waste being treated over this period. The dynamic prime costs correspond to the theoretical gate fee which an operator needs to charge to cover the total emerging costs including interest for treatment/disposal of the waste in the plant in order to balance surpluses and shortfalls over the total operating period.

9 "Results"

The results from the data entered and from the calculations as explained above are shown on different worksheets in the SWM-GHG Calculator:

Results for one scenario:
- "Results SQ": results of GHG emission balance for the Status Quo
- "Results Sc1": results of GHG emission balance for Scenario 1
- "Results Sc2": results of GHG emission balance for Scenario 2
- "Results Sc3": results of GHG emission balance for Scenario 3

“Results all”: GHG emission balance scenario comparison – waste quantities, GHG emissions.

“Results costs all”: Scenario comparison – annual costs and specific GHG mitigation costs.

9.1 Results for each scenario

First of all, all results referring to one scenario are shown on a separate worksheet. The worksheet is structured as follows:

- Waste treated in t/yr
- Results for GHG emissions recycling and disposal in t CO_2-eq/yr
- Results for absolute costs for the calculated scenario
- Results for specific costs per t CO_2-eq for the calculated scenario

Waste treated in tonnes per year are shown in a table, a bar chart and as a mass balance diagram.

Results for GHG emissions recycling and disposal are shown in a table and a bar chart (Figure 9-1). This figure shows the results for a theoretical Status Quo scenario as described in section 3. The bar chart shows the results separately for recycling and for disposal activities and also as the sum of both components ("Total MSW"). The first bar in the figure indicates the GHG emissions caused by recycling (Debits). The second bar represents the emission savings by recycling (Credits, negative values). The third bar shows the net effect, i.e. the difference between debits and credits (Net).

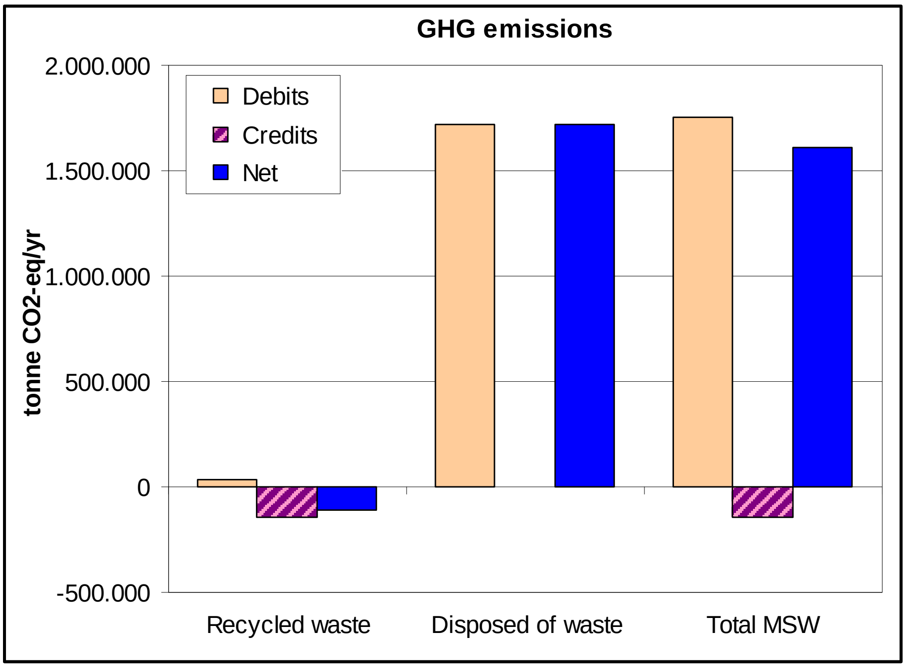


Figure 9-1 GHG emissions in a theoretical Status Quo scenario (see section 3)

Additionally, the results for GHG emissions are shown in more detail both for recycling (Figure 9-2) and for disposal (Figure 9-3).

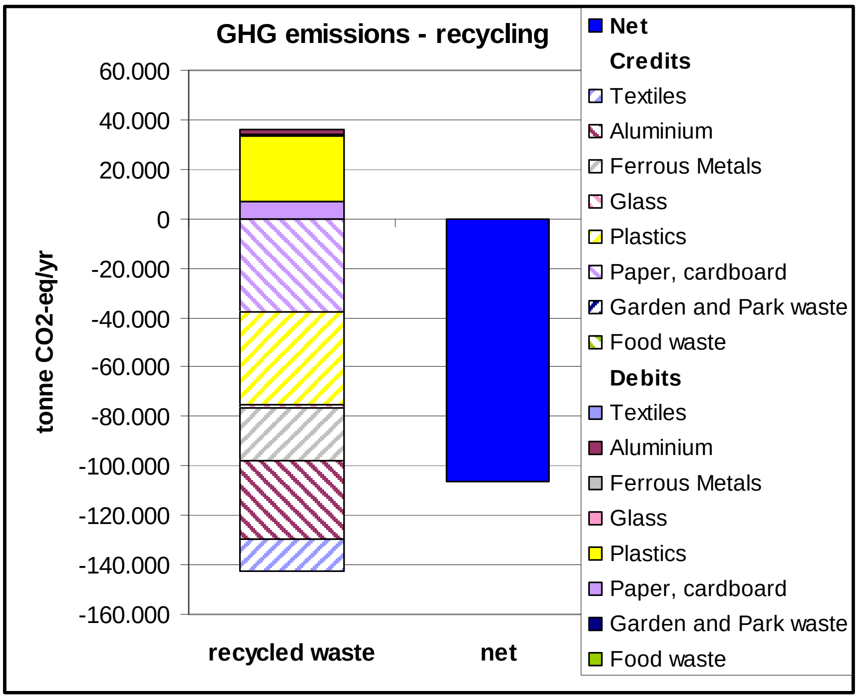


Figure 9-2 GHG emissions by waste fraction - recycling

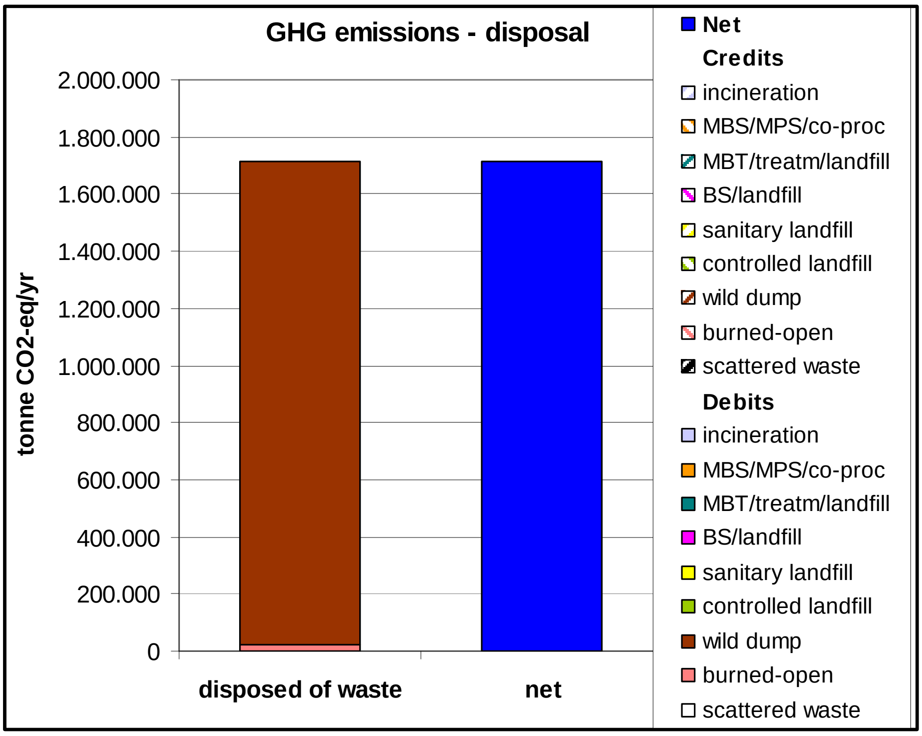


Figure 9-3 GHG emissions by treatment option - disposal

In the recycling figure (Figure 9-2) the bars with "Debits" and "Credits" are itemised into results for each recycled waste fraction. Thus the positive values in the first bar ("recycled waste") show the debits (GHG emissions from recycling of plastics and paper, the contribution of the other fractions is too small to be visible) and the negative values in the first bar show the credits (with the highest contribution made by plastics and paper, followed by aluminium recycling, ferrous metals and textiles). The second bar ("net") again represents the net result, the difference between positive (debits) and negative (credits) values, and is identical to the net result for "recycled waste" in Figure 9-1.

In the disposal figure (Figure 9-3) the bars with "Debits" and "Credits" are itemised into results for each type of treatment. Similar to the example for a Status Quo scenario MSW is scattered, open-burned is 10% and disposed of to wild dumps is 90%. Only these treatment options contribute to the result causing positive values (debits) in the first bar ("disposed of waste"). No benefits are derived from these treatment options, therefore no credits or negative values are seen. The second bar ("net") again represents the net result, the difference between positive (debits) and negative (credits) values, and is identical to the net result for "disposed of waste" in Figure 9-1.

Results for absolute costs and specific costs per t CO_2-eq are shown in tables.

9.2 "Results all"

This worksheet shows the results for the waste mass flows and the GHG emissions for all calculated scenarios. The upper part shows a table and a bar chart comparing the waste quantities treated in each scenario. The results for the GHG emissions are also shown in a table below and additionally in two bar charts. The examples shown below correspond to the results for the scenarios as defined in section 3. The first diagram (Figure 9-4) compares the four scenarios and shows the results in the same manner as in Figure 9-1. The first bar (Debits) shows the total GHG emissions in the Status Quo scenario, the second bar the credits, and the third bar the net result.

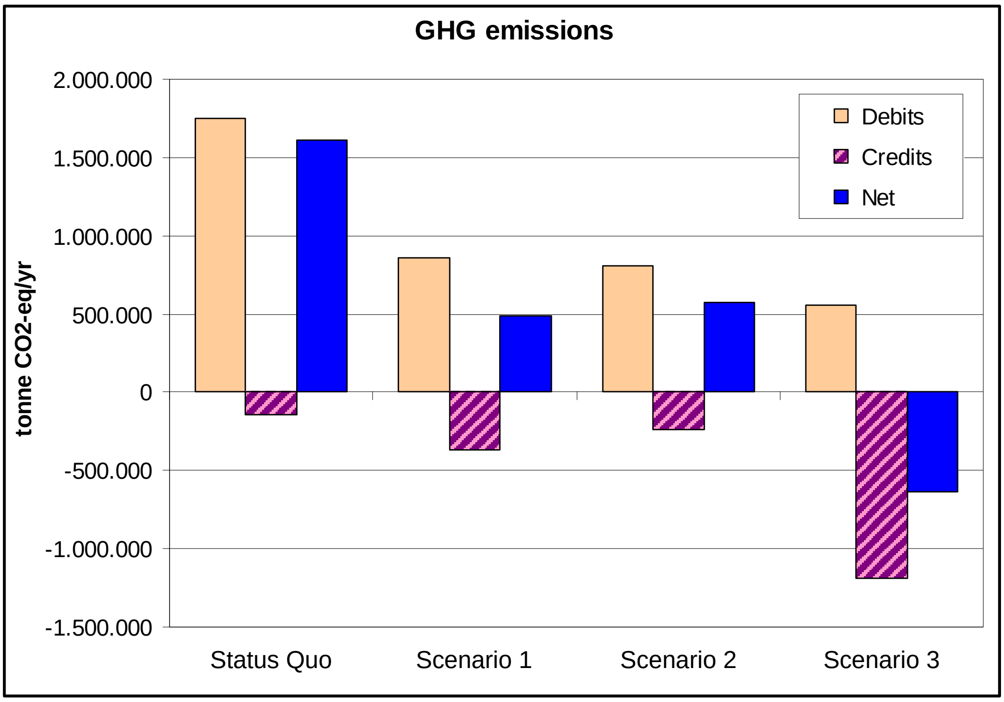


Figure 9-4 Overview of GHG emissions for all scenarios

Figure 9-5 also shows the results for the comparison of the four scenarios, but using a different structure and in more detail. The first section refers to the results for recycling. The first four bars show the debits from recycling in the four scenarios and the second four bars the credits from recycling in the four scenarios. The next section shows the same for disposed of waste. In the final section debits and credits and net results are shown for the total MSW treatment in each case for the four scenarios.

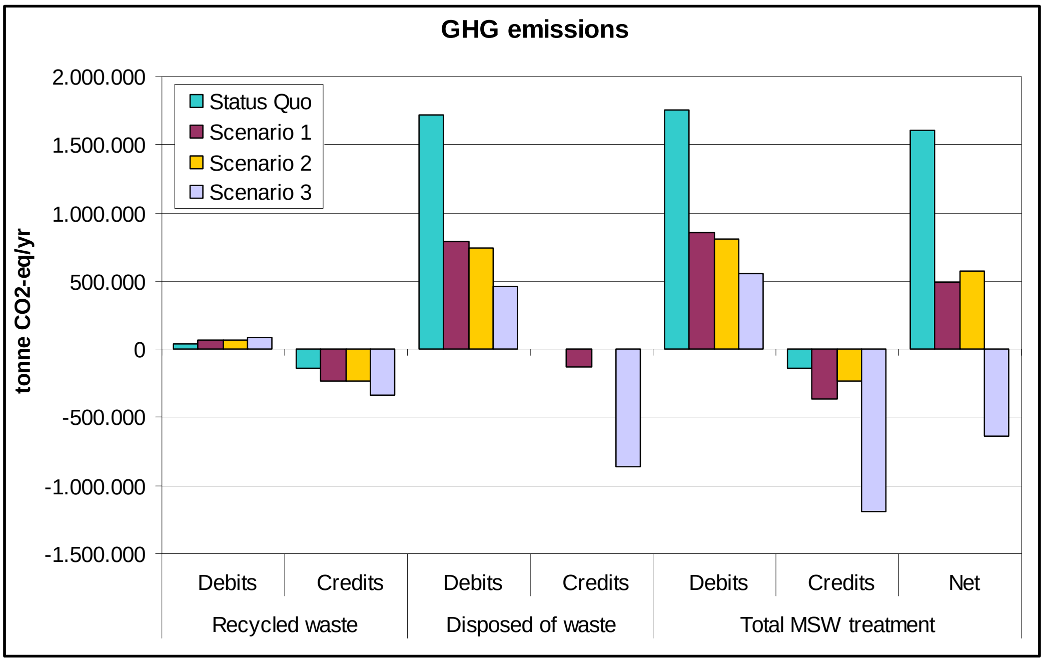


Figure 9-5 Overview of GHG emissions for all scenarios

9.3 "Results costs all"

This worksheet shows the results for the absolute costs for all calculated scenarios in one table. Additionally, the mitigation costs are shown in a separate table below. The mitigation costs are calculated as a comparison to the Status Quo scenario and per tonne of waste treated in each case. Depending on the results it may not be reasonable to indicate mitigation costs. For example, when a scenario causes more GHG emissions as the Status Quo scenario, no mitigation costs can be accounted as no GHG emissions are reduced. Nor can mitigation costs can be accounted if the total costs of a scenario that minimises GHG emissions are lower than the total costs in the Status Quo scenario. Although this case is not very likely or is more probably the effect of an incorrect entry, the resulting "costs" would not be mitigation costs but represent a profit.

10 "Calculation"

The final worksheet in the SWM-GHG Calculator contains all the calculations as described in the previous sections. In general, factors and linkages are used that should place users in a position to understand the calculations as well as possible. Additionally, further explanations are given in the Excel comments.

The following factors are given and calculations occur in the first sector of the worksheet:

- Emission factors of energy demand
- Carbon content of waste fractions
- Calorific value of waste fractions
- Total waste amounts, calorific value and carbon content
- Share of recycling, remaining residual waste; calorific value, carbon content
- Calculated composition of remaining residual waste
- Calculated carbon content, calorific value in residual waste

The emission factors are provided (recycling) or calculated (disposal) in the following sector:

- Emission factors for recycling
- Emission factors for residual waste treatment options

The following sector shows the results for the waste amount and GHG emissions (first for recycling and then below for treatment of the remaining residual waste) that are transferred to the result worksheets:

- Results of Global Warming Potential (GWP) recycling
- Results of GWP residual waste treatment

The final sector shows the results for the total costs that are transferred to the result worksheets:

- Results for total costs

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Abbreviations

BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung ("Federal Ministry for Economic Cooperation and Development")
BS	Biological stabilisation
C	Carbon
CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CHP	Combined heat and power unit
CO_2	Carbon dioxide
DOC	Degradable organic carbon
DIP	Deinking pulp
eq	Equivalents
ELCD	European LCA data platform
ERU	Emission Reduction Units
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
IMF	International Monetary Fund
ISWM	Integrated solid waste management
JI	Joint Implementation
kg	Kilogramme
LCA	Life cycle assessment
LIE	Low income economies
LWP	Light-weight packaging
MBS	Mechanical biological stabilisation
MBT	Mechanical biological treatment
MIE	Middle income economies
MPS	Mechanical physical stabilisation
MJ	Megajoule
MSW	Municipal solid waste
MSWI	Municipal solid waste incineration
PE	Polyethylene

PET	Polyethylene terephtalate
PO	Polyolefins
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
RDF	Refuse-derived fuel
t	Metric tonne
WtE	Waste to energy
UNFCCC	United Nations Framework Convention on Climate Change

Annex

Specific MSW generation and management data (IPCC 2006)

According to (IPCC 2006) municipal waste is generally defined as waste collected by municipalities or other local authorities. However, this definition varies by country. Typically, MSW includes household waste, garden (yard) and park waste, and commercial/institutional waste. The regional default composition data for MSW is given in Table 0-1.

Table 0-1 Specific MSW generation and management data (IPCC 2006)

TABLE 2A.1
MSW GENERATION AND MANAGEMENT DATA - BY COUNTRY AND REGIONAL AVERAGES

Region /Country	MSW [1, 2] Generation Rate IPCC -1996 values [4] (tonnes/cap/yr)	MSW [1, 2, 3] Generation Rate Year 2000 (tonnes/cap/yr)	Fraction of MSW disposed to SWDS IPCC-1996 values [4]	Fraction of MSW disposed to SWDS	Fraction of MSW incinerated	Fraction of MSW composted	Fraction of other MSW management, unspecified [5]	Source
Asia								
Eastern Asia	**0.41**	**0.37**	**0.38**	**0.55**	**0.26**	**0.01**	**0.18**	
China		0.27		0.97	0.02	0.01		1
Japan	0.41	0.47	0.38	0.25	0.72	0.02	0.01	2, 31
Rep. of Korea		0.38		0.42	0.04		0.54	3
Southern and Central Asia	**0.12**	**0.21**	**0.60**	**0.74**	-	**0.05**	**0.21**	
Bangladesh		0.18		0.95			0.05	4
India	0.12	0.17	0.60	0.70		0.20	0.10	4
Nepal		0.18		0.40			0.60	4
Sri Lanka		0.32		0.90			0.10	4
South-eastern Asia		**0.27**		**0.59**	**0.09**	**0.05**	**0.27**	
Indonesia		0.28		0.80	0.05	0.10	0.05	4
Lao PDR		0.25		0.40			0.60	4
Malaysia		0.30		0.70	0.05	0.10	0.15	4
Myanmar		0.16		0.60			0.40	4
Philippines		0.19		0.62		0.10	0.28	4, 5
Singapore		0.40		0.20	0.58		0.22	6
Thailand		0.40		0.80	0.05	0.10	0.05	4
Vietnam		0.20		0.60			0.40	4
Africa								
Africa [6]		**0.29**		**0.69**			**0.31**	
Egypt				0.70			0.30	4
Sudan		0.29		0.82			0.18	7
South Africa			1.00	0.90			0.10	4
Nigeria				0.40			0.60	4
Europe								
Eastern Europe		**0.38**		**0.9**	**0.04**	**0.01**	**0.02**	
Bulgaria		0.52		1.00	0.00	0.00	0.00	8
Croatia				1.00	0.00	0.00	0.00	8
Czech Republic		0.33		0.75	0.14	0.04	0.06	8
Estonia		0.44		0.98	0.00	0.00	0.02	8
Hungary		0.45		0.92	0.08	0.00	0.00	8
Latvia		0.27		0.92	0.04	0.02	0.02	8
Lithuania		0.31		1.00	0.00	0.00	0.00	8
Poland		0.32		0.98	0.00	0.02	0.00	8

Table 0-1 continued Specific MSW generation and management data (IPCC 2006)

TABLE 2A.1 (CONTINUED)
MSW GENERATION AND MANAGEMENT DATA - BY COUNTRY AND REGIONAL AVERAGES

Region /Country	MSW [1, 2] Generation Rate IPCC -1996 values [4] (tonnes/cap/yr)	MSW [1, 2, 3] Generation Rate Year 2000 (tonnes/cap/yr)	Fraction of MSW disposed to SWDS IPCC-1996 values [4]	Fraction of MSW disposed to SWDS	Fraction of MSW incinerated	Fraction of MSW composted	Fraction of other MSW management, unspecified [5]	Source
Romania		0.36		1.00	0.00	0.00	0.00	8
Russian Federation	0.32	0.34	0.94	0.71	0.19	0.00	0.10	9
Slovakia		0.32		1.00	0.00	0.00	0.00	8
Slovenia		0.51		0.90	0.00	0.08	0.02	8
Northern Europe		**0.64**		**0.47**	**0.24**	**0.08**	**0.20**	
Denmark	0.46	0.67	0.2	0.10	0.53	0.16	0.22	8
Finland	0.62	0.50	0.77	0.61	0.1	0.07	0.22	8
Iceland		1.00		0.86	0.06	0.01	0.06	8
Norway	0.51	0.62	0.75	0.55	0.15	0.09	0.22	8
Sweden	0.37	0.43	0.44	0.23	0.39	0.10	0.29	8
Southern Europe		**0.52**		**0.85**	**0.05**	**0.05**	**0.05**	
Cyprus		0.68		1.00	0.00	0.00	0.00	8
Greece	0.31	0.41	0.93	0.91	0.00	0.01	0.08	8
Italy	0.34	0.50	0.88	0.70	0.07	0.14	0.09	8
Malta		0.48		1.00	0.00	0.00	0.00	8
Portugal	0.33	0.47	0.86	0.69	0.19	0.05	0.07	8
Spain	0.36	0.60	0.85	0.68	0.07	0.16	0.09	8
Turkey		0.50		0.99	0.00	0.01	0.00	8
Western Europe	**0.45**	**0.56**	**0.57**	**0.47**	**0.22**	**0.15**	**0.15**	
Austria	0.34	0.58	0.4	0.30	0.10	0.37	0.23	8
Belgium	0.40	0.47	0.43	0.17	0.32	0.23	0.28	8
France	0.47	0.53	0.46	0.43	0.33	0.12	0.13	8
Germany	0.36	0.61	0.66	0.30	0.24	0.17	0.29	8
Ireland	0.31	0.60	1.0	0.89	0.00	0.01	0.11	8
Luxemburg	0.49	0.66	0.35	0.27	0.55	0.18	0.00	8
Netherlands	0.58	0.62	0.67	0.11	0.36	0.28	0.25	8
Switzerland	0.40	0.40	0.23	1.00	0.00	0.00	0.00	8
UK	0.69	0.57	0.90	0.82	0.07	0.03	0.08	8
Central, South America and Caribbean states								
Caribbean		**0.49**		**0.83**	**0.02**		**0.15**	
Bahamas		0.95		0.7			0.3	10
Cuba		0.21		0.90			0.1	11
Dominican Republic		0.25		0.90	0.06		0.04	12
St. Lucia		0.55		0.83			0.17	13
Central America		**0.21**		**0.50**			**0.50**	
Costa Rica		0.17						14, 15
Guatemala		0.22		0.40			0.60	16, 17, 18
Honduras		0.15		0.40			0.60	4
Nicaragua		0.28		0.70			0.30	4
South America								
South America		**0.26**		**0.54**	**0.01**	**0.003**	**0.46**	
Argentina		0.28		0.59			0.41	4
Bolivia		0.16		0.70			0.30	19

Table 0-1 continued Specific MSW generation and management data (IPCC 2006)

TABLE 2A.1 (CONTINUED)
MSW GENERATION AND MANAGEMENT DATA - BY COUNTRY AND REGIONAL AVERAGES

Region /Country	MSW [1, 2] Generation Rate IPCC -1996 values [4] (tonnes/cap/yr)	MSW [1, 2, 3] Generation Rate Year 2000 (tonnes/cap/yr)	Fraction of MSW disposed to SWDS IPCC-1996 values [4]	Fraction of MSW disposed to SWDS	Fraction of MSW incinerated	Fraction of MSW composted	Fraction of other MSW management, unspecified [5]	Source
Brazil		0.18		0.80	0.05	0.03	0.12	20, 21
Chile				0.40			0.60	4
Colombia		0.26		0.31			0.69	22
Ecuador		0.22		0.40			0.60	23
Paraguay (Asuncion)		0.44		0.40			0.60	24
Peru		0.20		0.53			0.47	4, 25
Uruguay		0.26		0.72			0.28	26, 27
Venezuela		0.33		0.50			0.50	28
North America								
North America	**0.70**	**0.65**	**0.69**	**0.58**	**0.06**	**0.06**	**0.29**	
Canada	0.66	0.49	0.75	0.71	0.04	0.19	0.06	29, 30, 31
Mexico		0.31		0.49			0.51	32, 33
USA	0.73	1.14	0.62	0.55	0.14		0.31	34
Oceania								
Oceania	**0.47**	**0.69**	**1.00**	**0.85**			**0.15**	
Australia	0.46	0.69	1.00	1.00				4, 31
New Zealand	0.49		1.00	0.70			0.30	4

[1] Data are based on weight of wet waste.
[2] To obtain the total waste generation in the country, the per-capita values should be multiplied with the population whose waste is collected. In many countries, especially developing countries, this encompasses only urban population.
[3] The data are default data for the year 2000, although for some countries the year for which the data are applicable was not given in the reference, or data for the year 2000 were not available. The year for which the data are collected is given below with source of the data, where available.
[4] Values shown in this column are the ones included in the *1996 IPCC Guidelines*.
[5] Other, unspecified, includes data on recycling for some countries.
[6] A regional average is given for the whole of Africa as data are not available for more detailed regions within Africa.

Source	Year	
1		Urban Construction Statistics Yearbook of China – Year 2000 (2001). Ministry of Chinese Construction. Chinese Construction Industry Publication Company.
2		OECD Environment Directorate, OECD Environmental Data 2002, Waste.
		Ministry of Environment, Japan (1992-2003): Waste of Japan, http://www.env.go.jp/recycle/waste/ippan.html.
3		1) '97 National Status of Solid Waste Generation and Treatment , the Ministry of Environment, Korea, 1998.
		2) '96 National Status of Solid Waste Generation and Treatment , the Ministry of Environment, Korea, 1997.
		3) Korea Environmental Yearbook, the Ministry of Environment, Korea, 1990.
4		Doorn and Barlaz, 1995, Estimate of global methane emissions from landfills and open dumps, EPA-600/R-95-019, Office of Research & Development, Washington DC, USA.
5		Shimura et al. (2001).
6	2001	National Environmental Agency, Singapore (www.nea.gov.sg.) and www.acrr.org/resourcecities/waste_resources/europe_waste.htm.
7		Ministry of Environment and Physical Development, Higher Council for Environment and Natural Resources, Sudan (2003), Sudan's First National Communications under the United Nations Framework Convention on Climate Change.
8	2000	Eurostat (2005). Waste Generated and Treated in Europe. Data 1995-2003. European Commission - Eurostat, Luxemburg. 131p.
9		Problems of waste management in Russia: Not-for-Profit Partnership "Waste Management – Strategic Ecological Initiative" http://www.sagepub.com/journalsProdEditBoards.nav?prodId=Journal201691.

Table 0-1 continued Specific MSW generation and management data (IPCC 2006)

TABLE 2A.1 (CONTINUED)
MSW GENERATION AND MANAGEMENT DATA- BY COUNTRY AND REGIONAL AVERAGES

Source	Year	
10		The Bahamas Environment, Science and Technology Commission (2001). Commonwealth of the Bahamas. First National Communication on Climate Change. Nassu, New Providence, April 2001, 121pp.
11	1990	OPS/OMS (1997). Análisis Sectorial de Residuos Sólidos en Cuba. Serie Análisis 1. Sectoriales No. 13, Organización Panamericana de la Salud, 206 pp., 2. López, C., et al. (2002). República de Cuba. Inventario Nacional de Emisiones y Absorciones de Gases de Invernadero (colectivo de autores). Reporte para el Año 1996/Actualización para los Años 1990 y 1994. CD-ROM Vol. 01. Instituto de Meteorología-AMA-CITMA. La Habana, 320 pp. ISBN: 959-02-0352-3.
12		Secretaría de Estado de Medio Ambiente y Recursos Naturales (2004). República Dominicana. Primera Comunicación Nacional a la Convención Marco de Naciones Unidas sobre Cambio Climático. UNEP/GEF, Santo Domingo, Marzo de 2004, 163 pp.
13	1990	Ministry of Planning, Development, Environment and Housing (2001). Saint Lucias's Initial National Communication on Climate Change, UNEP/GEF, 306 pp.
14		Lammers, P. E. M., J. F. Feenstra, A. A. Olstroom (1998). Country/Region-Specific Emission Factors in National Greenhouse Gas Inventories. UNEP/Institute for Environmental Studies Vrije Universiteit, 112 pp.
15		Ministerio de Recursos Naturales, Energía y Minas (1995). Inventario Nacional de Fuentes y Sumideros de Gases con Efecto Invernadero en Costa Rica. MRNEM, Instituto Meteorológico Nacional, San José, Septiembre 1995.
16		Ministerio de Ambiente y Recursos Naturales (2001). República de Guatemala. Primera Comunicación Nacional sobre Cambio Climático..
17		JICA (Agencia Japonesa de Cooperación Internacional) (1991). Estudio sobre el Manejo de los Desechos Sólidos en el Area Metropolitana de la Ciudad de Guatemala. Volumen 1.
18		Guatemala de la Asunción, diciembre 2001, 127 p.,OPS/OMS (1995). Análisis Sectorial de Residuos Sólidos en Guatemala, Diciembre 1995, 183 pp.
19	1990	Fondo Nacional de Desarrollo (FNDR). Cantidad de RSM dispuestos en RSA-años 1996 y 1997, La Paz, Bolivia., 2. Ministerio de Desarrollo Sostenible y Medio Ambiente/Secretaría Nacional de Recursos Naturales y Medio Ambiente (1997). Inventariación de Emisiones de Gases de Efecto Invernadero. Bolivia – 1990. MDSMA/SNRNMA/SMA/PNCC/U.S. CSP, La Paz, 1997.
20		Ministry of Science and Technology, Brazil (2002). First Brazilian Inventory of Anthropogenic Greenhouse Gas Emissions. Background Reports. Methane Emissions from Waste Treatment and Disposal. CETESB. 1990 and 1994, Brazília, DF, 85 pp.
21		CETESB (1992). Companhia de Tecnologia de Saneamiento Ambiental. Programa de gerenciamiento de residuos sólidos domiciliares e de services de saúde. PROLIXO, CETESB; Sao Paulo, 29 pp., IBGE: Instituto Brasileiro de Geografia e Estadistica. http://www.ibge.gov.br/home/estadistica/populacao/atlassaneamiento/pdf/mappag59.pdf in November 2004.
22	1990	Ministerio de Medio Ambiente/IDEAM (1999). República de Colombia. Inventario Nacional de Fuentes y Sumideros de Gases de Efecto Invernadero. 1990. Módulo Residuos, Santa Fe de Bogotá, DC, Marzo de 1999, 14 pp.
23		BID/OPS/OMS (1997). Diagnóstico de la Situación del Manejo de los Residuos Sólidos Municipales en América Latina y el Caribe., Doorn and Barlaz, 1995, Estimate of global methane emissions from landfills and open dumps, EPA-600/R-95-019, Office of Research & Development, Washington DC, USA.
24	1990	MAG/SSERNMA/DOA – PNUD/UNITAR (1999). Paraguay: Inventario Nacional de Gases de Efecto Invernadero por Fuentes y Sumideros. Año 1990. Proyecto PAR GLO/95/G31. Asunción, Noviembre 1999, 90 pp.
25	1990 1994 1998	Estudios CEPIS-OPS y/o Estudio Sectorial de Residuos Sólidos del Perú. Ditesa/OPS., Lammers, P. E. M., J. F. Feenstra, A. A. Olstroom (1998). Country/Region-Specific Emission Factors in National Greenhouse Gas Inventories. UNEP/Institute for Environmental Studies Vrije Universiteit, 112 pp.
26		Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente/Dirección Nacional de Medio Ambiente/Unidad de Cambio Climático (1998). Uruguay. Inventario Nacional de Emisiones Netas de Gases de Efecto Invernadero 1994/Estudio Comparativo de Emisiones Netas de Gases de Efecto Invernadero para 1990 y 1994. Montevideo, Noviembre de 1998, 363pp.
27		OPS/OMS (1996). Análisis Sectorial de Residuos Só,Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente/Dirección Nacional de Medio Ambiente/Unidad de Cambio Climático (2004). Uruguay. Segunda Comunicación a la CMNUCC. 330p. lidos en Uruguay. Plan Regional de Inversiones en Medio Ambiente y Salud, Marzo 1996.
28	2000	Ministerio del Ambiente y de los Recursos Naturales Renovables. Ministerio de Energía y Minas (1996). Venezuela. Inventario de Emisiones de Gases de Efecto Invernadero. Año 1990. GEF/UNEP/U.S CSP.
29	1992	Organization for Economic Cooperation and Development (OECD) http://www.oecd.org/dataoecd/11/15/24111692.PDF

Population and degree of urbanisation

Table 0-2 Population and degree of urbanisation in low, lower-middle and upper-middle income economies[1] (DSW 2007)[2]

Economy	*Code*	*Region*	**Population**	**Urbanisation**
Low income countries < 935 $			(DSW 2007)	%
Afghanistan	AFG	South Asia	31.900.000	20
Bangladesh	BGD	South Asia	149.000.000	23
Benin	BEN	Sub-Saharan Africa	9.000.000	39
Burkina Faso	BFA	Sub-Saharan Africa	14.800.000	16
Burundi	BDI	Sub-Saharan Africa	8500000	10
Cambodia	KHM	East Asia & Pacific	14.400.000	15
Central African Republic	CAF	Sub-Saharan Africa	4.300.000	38
Chad	TCD	Sub-Saharan Africa	10.800.000	21
Comoros	COM	Sub-Saharan Africa	*614.000*	-
Congo, Dem. Rep.	ZAR	Sub-Saharan Africa	3.800.000	60
Côte d'Ivoire	CIV	Sub-Saharan Africa	20.200.000	47
Eritrea	ERI	Sub-Saharan Africa	4.900.000	19
Ethiopia	ETH	Sub-Saharan Africa	77.100.000	16
Gambia, The	GMB	Sub-Saharan Africa	1.500.000	50
Ghana	GHA	Sub-Saharan Africa	23.000.000	44
Guinea	GIN	Sub-Saharan Africa	10.100.000	30
Guinea-Bissau	GNB	Sub-Saharan Africa	1.700.000	30
Haiti	HTI	Latin America & Caribbean	9.000.000	36
Kenya	KEN	Sub-Saharan Africa	36.900.000	19
Korea, Dem. Rep.	PRK	East Asia & Pacific	23.300.000	60
Kyrgyz Republic	KGZ	Europe & Central Asia	5.200.000	35
Lao PDR	LAO	East Asia & Pacific	5.900.000	21
Liberia	LBR	Sub-Saharan Africa	3.800.000	58
Madagascar	MDG	Sub-Saharan Africa	18.300.000	26
Malawi	MWI	Sub-Saharan Africa	13.100.000	17
Mali	MLI	Sub-Saharan Africa	12.300.000	31
Mauritania	MRT	Sub-Saharan Africa	3.100.000	40
Mozambique	MOZ	Sub-Saharan Africa	20.400.000	35
Myanmar	MMR	East Asia & Pacific	49.800.000	29
Nepal	NPL	South Asia	27.800.000	27
Niger	NER	Sub-Saharan Africa	14.200.000	17
Nigeria	NGA	Sub-Saharan Africa	144.400.000	44
Pakistan	PAK	South Asia	169.300.000	14
Papua New Guinea	PNG	East Asia & Pacific	6.300.000	13
Rwanda	RWA	Sub-Saharan Africa	9.300.000	17
São Tomé and Principe	STP	Sub-Saharan Africa	200.000	58
Senegal	SEN	Sub-Saharan Africa	12.400.000	41
Sierra Leone	SLE	Sub-Saharan Africa	5.300.000	36
Solomon Islands	SLB	East Asia & Pacific	500.000	17
Somalia	SOM	Sub-Saharan Africa	9.100.000	34
Tajikistan	TJK	Europe & Central Asia	7.100.000	26
Tanzania	TZA	Sub-Saharan Africa	38.700.000	23
Togo	TGO	Sub-Saharan Africa	6.600.000	40
Uganda	UGA	Sub-Saharan Africa	28.500.000	12
Uzbekistan	UZB	Europe & Central Asia	26.500.000	36
Vietnam	VNM	East Asia & Pacific	85.100.000	27
Yemen, Rep.	YEM	Middle East & North Africa	22.400.000	26
Zambia	ZMB	Sub-Saharan Africa	11.500.000	35
Zimbabwe	ZWE	Sub-Saharan Africa	13.300.000	36
Total			**1.225.214.000**	**27%**

[1] Classification of income groups according to the World Bank based on the 2007 gross national income (GNI) per capita. The groups are: low income: $935 or less; lower middle income: $936–3,705 and upper middle income: $3,706–11,455; high income: $11,456 or more

[2] The 2009 report can be found under http://www.dsw-online.de/pdf/dsw_datenreport_09.pdf

Table 0-2 continued Population and degree of urbanisation in low, lower middle and upper middle income economies (DSW 2007)

Economy	*Code*	*Region*	**Population**	**Urbanisation**
Lower middle income economies 936 - 3705 $ (World bank criteria)			(DSW 2007)	%
Albania	ALB	Europe & Central Asia	3.200.000	45
Algeria	DZA	Middle East & North Africa	34.100.000	58
Angola	AGO	Sub-Saharan Africa	16.300.000	40
Armenia	ARM	Europe & Central Asia	3.000.000	64
Azerbaijan	AZE	Europe & Central Asia	8.600.000	52
Bhutan	BTN	South Asia	900.000	31
Bolivia	BOL	Latin America & Caribbean	9.800.000	63
Bosnia and Herzegovina	BIH	Europe & Central Asia	3.800.000	46
Cameroon	CMR	Sub-Saharan Africa	18.100.000	53
Cape Verde	CPV	Sub-Saharan Africa	500.000	56
China	CHN	East Asia & Pacific	1.318.000.000	44
Colombia	COL	Latin America & Caribbean	46.200.000	72
Congo, Rep.	COG	Sub-Saharan Africa	3.800.000	60
Djibouti	DJI	Middle East & North Africa	800.000	82
Dominican Republic	DOM	Latin America & Caribbean	9.400.000	65
Ecuador	ECU	Latin America & Caribbean	13.500.000	62
Egypt, Arab Rep.	EGY	Middle East & North Africa	73.400.000	43
El Salvador	SLV	Latin America & Caribbean	6.900.000	59
Georgia	GEO	Europe & Central Asia	4.500.000	52
Guatemala	GTM	Latin America & Caribbean	13.400.000	47
Guyana	GUY	Latin America & Caribbean	800.000	28
Honduras	HND	Latin America & Caribbean	7.100.000	48
India	IND	South Asia	1.131.900.000	28
Indonesia	IDN	East Asia & Pacific	231.600.000	42
Iran, Islamic Rep.	IRN	Middle East & North Africa	71.200.000	67
Iraq	IRQ	Middle East & North Africa	29.000.000	67
Jordan	JOR	Middle East & North Africa	5.700.000	82
Kiribati	KIR	East Asia & Pacific	100.000	47
Lesotho	LSO	Sub-Saharan Africa	1.800.000	13
Macedonia, FYR	MKD	Europe & Central Asia	2.000.000	59
Maldives	MDV	South Asia	300.000	27
Marshall Islands	MHL	East Asia & Pacific	100.000	68
Micronesia, Fed. Sts.	FSM	East Asia & Pacific	100.000	22
Moldova	MDA	Europe & Central Asia	4.000.000	45
Mongolia	MNG	East Asia & Pacific	2.600.000	79
Morocco	MAR	Middle East & North Africa	31.700.000	55
Namibia	NAM	Sub-Saharan Africa	2.100.000	33
Nicaragua	NIC	Latin America & Caribbean	5.600.000	59
Paraguay	PRY	Latin America & Caribbean	6.100.000	57
Peru	PER	Latin America & Caribbean	27.900.000	73
Philippines	PHL	East Asia & Pacific	88.700.000	48
Samoa	WSM	East Asia & Pacific	200.000	22
Sri Lanka	LKA	South Asia	20.100.000	15
Sudan	SDN	Sub-Saharan Africa	38.600.000	41
Swaziland	SWZ	Sub-Saharan Africa	1.100.000	23
Syrian Arab Republic	SYR	Middle East & North Africa	19.900.000	50
Thailand	THA	East Asia & Pacific	65.700.000	33
Timor-Leste	TMP	East Asia & Pacific	1.000.000	22
Tonga	TON	East Asia & Pacific	100.000	24
Tunisia	TUN	Middle East & North Africa	10.200.000	65
Turkmenistan	TKM	Europe & Central Asia	5.400.000	47
Ukraine	UKR	Europe & Central Asia	46.500.000	68
Vanuatu	VUT	East Asia & Pacific	200.000	21
West Bank and Gaza	WBG	Middle East & North Africa	4.000.000	72
Total			**3.451.600.000**	**41%**

Table 0-2 continued Population and degree of urbanisation in low, lower middle and upper middle income economies (DSW 2007)

Economy	*Code*	*Region*	**Population**	**Urbanisation**
Upper middle income economies 3706 - 11455 $ (World bank criteria)			(DSW 2007)	%
American Samoa	ASM	East Asia & Pacific	200.000	22
Argentina	ARG	Latin America & Caribbean	39.400.000	89
Belarus	BLR	Europe & Central Asia	9.700.000	73
Belize	BLZ	Latin America & Caribbean	300.000	50
Botswana	BWA	Sub-Saharan Africa	1.800.000	54
Brazil	BRA	Latin America & Caribbean	189.300.000	81
Bulgaria	BGR	Europe & Central Asia	7.700.000	71
Chile	CHL	Latin America & Caribbean	16.600.000	88
Costa Rica	CRI	Latin America & Caribbean	4.500.000	59
Croatia	HRV	Europe & Central Asia	4.400.000	56
Cuba	CUB	Latin America & Caribbean	11.200.000	76
Dominica	DMA	Latin America & Caribbean	100.000	73
Fiji	FJI	East Asia & Pacific	900.000	51
Gabon	GAB	Sub-Saharan Africa	1.300.000	84
Grenada	GRD	Latin America & Caribbean	100.000	31
Jamaica	JAM	Latin America & Caribbean	2.700.000	49
Kazakhstan	KAZ	Europe & Central Asia	15.500.000	57
Latvia	LVA	Europe & Central Asia	2.300.000	68
Lebanon	LBN	Middle East & North Africa	3.900.000	87
Libya	LBY	Middle East & North Africa	6.200.000	85
Lithuania	LTU	Europe & Central Asia	3.400.000	67
Malaysia	MYS	East Asia & Pacific	27.200.000	62
Mauritius	MUS	Sub-Saharan Africa	1.300.000	42
Mayotte	MYT	Sub-Saharan Africa	200.000	28
Mexico	MEX	Latin America & Caribbean	106.500.000	75
Montenegro	MNE	Europe & Central Asia	600.000	64
Palau	PLW	East Asia & Pacific	20.000	77
Panama	PAN	Latin America & Caribbean	3.300.000	64
Poland	POL	Europe & Central Asia	38.100.000	62
Romania	ROM	Europe & Central Asia	21.600.000	55
Russian Federation	RUS	Europe & Central Asia	141.700.000	73
Serbia	SRB	Europe & Central Asia	9.500.000	52
Seychelles	SYC	Sub-Saharan Africa	100.000	53
South Africa	ZAF	Sub-Saharan Africa	47.900.000	53
St. Kitts and Nevis	KNA	Latin America & Caribbean	50.000	32
St. Lucia	LCA	Latin America & Caribbean	200.000	28
St. Vincent and the Grenadines	VCT	Latin America & Caribbean	100.000	45
Suriname	SUR	Latin America & Caribbean	500.000	74
Turkey	TUR	Europe & Central Asia	74.000.000	66
Uruguay	URY	Latin America & Caribbean	3.300.000	93
Venezuela, RB	VEN	Latin America & Caribbean	27.500.000	88
Total			**825.170.000**	**73%**

Table 0-3 Regional defaults for MSW composition data by percent (IPCC 2006)

TABLE 2.3
MSW COMPOSITION DATA BY PERCENT - REGIONAL DEFAULTS

Region	Food waste	Paper/cardboard	Wood	Textiles	Rubber/leather	Plastic	Metal	Glass	Other
Asia									
Eastern Asia	26.2	18.8	3.5	3.5	1.0	14.3	2.7	3.1	7.4
South-Central Asia	40.3	11.3	7.9	2.5	0.8	6.4	3.8	3.5	21.9
South-Eastern Asia	43.5	12.9	9.9	2.7	0.9	7.2	3.3	4.0	16.3
Western Asia & Middle East	41.1	18.0	9.8	2.9	0.6	6.3	1.3	2.2	5.4
Africa									
Eastern Africa	53.9	7.7	7.0	1.7	1.1	5.5	1.8	2.3	11.6
Middle Africa	43.4	16.8	6.5	2.5		4.5	3.5	2.0	1.5
Northern Africa	51.1	16.5	2	2.5		4.5	3.5	2	1.5
Southern Africa	23	25	15						
Western Africa	40.4	9.8	4.4	1.0		3.0	1.0		
Europe									
Eastern Europe	30.1	21.8	7.5	4.7	1.4	6.2	3.6	10.0	14.6
Northern Europe	23.8	30.6	10.0	2.0		13.0	7.0	8.0	
Southern Europe	36.9	17.0	10.6						
Western Europe	24.2	27.5	11.0						
Oceania									
Australia and New Zealand	36.0	30.0	24.0						
Rest of Oceania	67.5	6.0	2.5						
America									
North America	33.9	23.2	6.2	3.9	1.4	8.5	4.6	6.5	9.8
Central America	43.8	13.7	13.5	2.6	1.8	6.7	2.6	3.7	12.3
South America	44.9	17.1	4.7	2.6	0.7	10.8	2.9	3.3	13.0
Caribbean	46.9	17.0	2.4	5.1	1.9	9.9	5.0	5.7	3.5

Country-specific CO_2 emissions for electricity generation

Table 0-4 Direct CO_2 emissions of electricity production worldwide 2007

Country	g CO_2/kWh	Country	g CO_2/kWh
Afghanistan	215	Liberia	2,721
Albania	43	Libya	985
Algeria	1,238	Liechtenstein	46
Andorra	0	Lithuania	63
Angola	186	Luxembourg	774
Antarctica	0	Macedonia	932
Antigua & Barbuda	1,358	Madagascar	159
Argentina	441	Malawi	10
Armenia	97	Malaysia	799
Aruba	2,332	Maldives	1,768
Australia	1,051	Mali	432
Austria	236	Malta	1,295
Azerbaijan	528	Marshall Islands	579
Bahamas	1,221	Mauritania	1,046
Bahrain	509	Mauritius	1,129
Bangladesh	980	Mayotte	542
Barbados	2,019	Mexico	607
Belarus	733	Micronesia	445
Belgium	376	Moldova	166
Belize	423	Monaco	79
Benin	1,027	Mongolia	1,121
Bermuda	2,279	Montenegro	343
Bhutan	1	Morocco	995
Bolivia	323	Mozambique	1
Bosnia-Herzegovina	478	Myanmar	576
Botswana	2,414	Namibia	37
Brazil	51	Nauru	2,564
Brunei	1,053	Nepal	7
Bulgaria	456	Netherlands	714
Burkina Faso	903	Netherlands Antilles	616
Burundi	18	New Caledonia	1,636
Cambodia	642	New Zealand	233
Cameroon	56	Nicaragua	548
Canada	218	Niger	1,247
Cape Verde	1,478	Nigeria	358
Cayman Islands	928	North Korea	372
Central African Republic	118	Norway	1
Chad	2,012	Oman	850
Chile	466	Pakistan	418
China	1,009	Palau	600
Colombia	155	Palestine	347
Comoros	652	Panama	187
Congo	2	Papua New Guinea	588

Country	g CO_2/kWh	Country	g CO_2/kWh
Congo Republic	105	Paraguay	13
Costa Rica	7	Peru	174
Cote D'Ivoire	683	Philippines	557
Croatia	388	Poland	678
Cuba	1,298	Portugal	626
Cyprus	1,683	Qatar	848
Czech Republic	617	Romania	337
Denmark	382	Russia	606
Djibouti	1,779	Rwanda	0
Dominica	531	Samoa	446
Dominican Republic	758	Sao Tome & Principe	426
East Timor	664	Saudi Arabia	851
Ecuador	295	Senegal	1,310
Egypt	878	Serbia	751
El Salvador	244	Seychelles	768
Equatorial Guinea	613	Sierra Leone	1,759
Eritrea	500	Singapore	540
Estonia	569	Slovakia	362
Ethiopia	23	Slovenia	387
Faroe Islands	702	Solomon Islands	1,886
Fiji	105	Somalia	1,722
Finland	316	South Africa	819
France	74	South Korea	561
French Polynesia	1,143	Spain	566
Gabon	332	Sri Lanka	440
Gambia	2,688	St Kitts & Nevis	2,721
Georgia	76	St Lucia	2,721
Germany	517	St Vincent & Grenadines	821
Ghana	46	Sudan	562
Greece	1,020	Suriname	66
Grenada	2,700	Swaziland	23
Guatemala	434	Sweden	19
Guinea	385	Switzerland	5
Guinea-Bissau	2,208	Syria	964
Guyana	1,765	Taiwan (China)	601
Haiti	503	Tajikistan	14
Honduras	594	Tanzania	54
Hungary	443	Thailand	786
Iceland	1	Togo	200
India	886	Tonga	2,689
Indonesia	746	Trinidad & Tobago	1,468
Iran	791	Tunisia	1,201
Iraq	1,316	Turkey	746
Ireland	1,099	Turkmenistan	2,043
Isle Of Man	446	Tuvalu	717
Israel	1,073	Uganda	17
Italy	668	Ukraine	276
Jamaica	1,893	United Arab Emirates	502

Country	**g CO_2/kWh**	**Country**	**g CO_2/kWh**
Japan	356	United Kingdom	531
Jordan	1,631	United States	637
Kazakhstan	523	Uruguay	68
Kenya	118	Uzbekistan	717
Kiribati	2,620	Vanuatu	1,933
Kuwait	581	Venezuela	139
Kyrgyzstan	30	Vietnam	556
Laos	13	Yemen	2,573
Latvia	164	Zambia	4
Lebanon	782	Zimbabwe	441
Lesotho	2		

Source: EIA Energy information administration: official energy statistics from the U.S. government.
World total net electricity generation 2005 and CO_2 emissions from power plants worldwide using data from Carma (www.carma.org)

"Recycling" – description of treatment processes

GHG emissions for the recycled waste fractions are calculated based on the mass of waste recycled and a GHG emission factor. The GHG emission factors used are shown in Table 0-5. These GHG emission factors are derived from a European level study (Prognos/IFEU/INFU 2008). The corresponding treatment processes therefore refer to the European level. They are described below.

Table 0-5 GHG emission factors for recycling

kg CO_2-eq/t waste	Organic waste		Paper	Glass	Metals (steel)	Aluminium	Plastics	Textiles
	Digestion	Composting	Deinking	Melting				
Emissions	57	87	180	20	22	700	1,023	32
Avoided emissions	159	95	1,000	500	2,047	11,800	1,437	2,850
Net result	**-102**	**-8**	**-820**	**-480**	**-2,025**	**-11,100**	**-414**	**-2,818**

Source: (Prognos, IFEU, INFU 2008); metals (steel) estimation IFEU

Composting of organic waste

For the composting of organic waste a ratio of 50% open and 50% encapsulated composting plants is assumed. The average electricity demand of the latter is calculated as 30 kWh/t organic waste. Open composting is managed with diesel-engined machinery and the diesel demand was calculated as 1.5 l/t organic waste. The GHG emissions from composting are roughly one third CO_2 emissions from electricity and diesel demand, the remainder are methane and nitrous oxide (N_2O) emissions from the composting process and resulting from the agricultural use of compost.

Products were considered to be one third immature compost, which is used mainly in agricultural applications. For matured compost it was estimated that 20% are used in agriculture, about 40% for gardening purposes in professional and leisure applications or as a substrate. The rest becomes substrate material for recultivation purposes. The application pattern determines the substituted primary material. The agricultural application substitutes for mineral fertilizer, depending on the nutrient content in the compost. If the compost is used as a substrate or as humus supply then peat and/or bark humus is substituted for, depending on the content of organic matter in the compost. When compost is used for recultivation no primary material is substituted for, because usually only waste material is used for these purposes.

Digestion of organic waste

Instead of composting organic waste, the material can also be introduced into an anaerobic digestion facility. The outputs (products) of digestion are biogas (energy). It is assumed that the digestate is dewatered and a ratio of 50% direct application and 50% post-composting are assumed. The energy demand is covered by using the biogas produced. With a gas production rate of 100 m³ per tonne of organic waste and a methane content of 62%, the biogas can be used in a combined heat and power plant. Modern plants of this type have energy efficiency for electricity of 37.5% and heat of 43%. The electricity demand of the plant is then subtracted and the remaining electricity is supplied to the net. In the SWM-GHG Calculator only the net electricity produced is credited. Heat production is neglected because it is usually difficult to find an external customer. Main GHG emissions are methane emissions from the digestion process and nitrous oxide emissions from agricultural applications.

Application of the matured digestion compost is similar to application of matured compost from composting and the benefits were calculated in the same way. The electricity replaced is compared to electricity generation as indicated by the user (country-specific electricity mix).

Paper, cardboard

The GHG emission factor for paper and cardboard recycling includes sorting and production of deinking pulp (DIP). An overall sorting loss of 1% during the sorting process and 5.3% residues and sludge at the DIP were subtracted from existing plant data. These residues are incinerated in waste to energy (WtE) plants for municipal solid waste and co-incinerated at an industrial power plant.

The assumption for primary production was made to take the equivalent pulp production into consideration. It was assumed that the primary fibre consists of 50% thermo-mechanical pulp (e.g. for newspapers) of European production and 50% of Kraft pulp (sulphate pulp) of Nordic production. The benefits of energy generation from incineration of the residues are included.

Plastics

The GHG emission factor for plastics represents a mixture of 80% polyolefins (PO), 10% PET, 5% PS and 5% PVC, assumed as typical. In general, the GHG emission factor includes sorting and treating for secondary flakes.

<u>Polyolefins (PO)</u>
Polyolefins are a mixture of PE and PP. The electricity demand at the sorting and treatment plant was calculated from typical existing plants (IFEU/HTP 2001). About 20% sorting and treatment residues were assumed to go to MSWI plants with energy recovery. A mix consisting of 50% PP, 25% high density PE (HDPE) and 25% low density PE (LDPE) was assumed for the substituted primary production. Data from primary production were taken from Plastics Europe. Because secondary granulates have a lower performance than primary material, a functional equivalence was established using a substitution factor of 0.7. The benefits of energy generation from incineration of sorting and treatment residues are included.

<u>Polyethylene Terephthalate (PET)</u>
The electricity demand at the sorting and treatment plant was calculated using unpublished data provided to IFEU by existing plants. About 30% sorting residue was assumed as sorting and production losses, which go to MSWI plants with energy recovery. Data for the substituted primary PET production were taken from Plastics Europe. Because recycled PET is of high quality, a substitution factor of 1 was applied here. The benefits of energy generation from incineration of the residues are included.

Polystyrene (PS)
The electricity demand at the sorting and treatment plant was calculated using unpublished data provided to IFEU by existing plants. About 20% sorting residue was assumed as sorting and production losses, which go to MSWI plants with energy recovery. Data for the substituted primary PS production was taken from Plastics Europe. Because secondary PS is of high quality, a substitution factor of 0.9 was applied here. The benefits of energy generation from incineration of sorting and treatment residues are included.

Polyvinyl chloride (PVC)
The electricity demand at the sorting and treatment plant was estimated. About 20% sorting residue was assumed as sorting and production losses, which go to MSWI plant with energy recovery. Data for primary PVC production were taken from calculations by Plastics Europe. IFEU prepared a data update for the European Council of Vinyl Manufacturers and Plastics Europe, which is included. The primary production of suspension PVC was chosen as reference. A substitution factor of 0.9 was estimated and applied here. The benefits of energy generation from incineration of sorting and treatment residues are included.

Glass

The approach for glass and its system boundaries is different to other materials. This is due to the fact that glass factories normally operate with a mixture of primary material and glass from the waste stream. As data sets exist only for different shares of waste glass input, a specific model for glass production was developed. An additional sorting step to eliminate caps and labels is considered, the fate of the 3% sorting residues was ignored. The waste glass is then introduced into the smelting devices. The saved effort of using secondary glass was calculated from existing glass factory data. This is a non-linear relationship and is valid for a range between 50% and 90% of secondary glass (100% secondary glass input is technically not feasible). The GHG emission factor was calculated with a share of 75%.

Steel

It is difficult to distinguish between primary steel production and secondary steel production using the information published by the steel industry. The only available data (European LCA Data Platform, ELCD[1]) distinguishes between the two technologies, but it already includes credits for recycling. Unfortunately, no information is available from the steel industry to differentiate the figures. In (Prognos/IFEU/INFA 2008) the official global steel production figures from the ELCD web page ("steel rebar GLO") were used, including primary and secondary steel. However, this figure applies to both primary and secondary steel. A different approach was chosen for the SWM-GHG Calculator. It is assumed that steel production is the same regardless of whether pig iron or scrap is introduced into the furnace. Therefore, recycling ferrous metals substitutes for the production of pig iron, which is calculated based on data provided in Umberto[2].

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[1] http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm
[2] Umberto version 5.5 (life cycle assessment tool), main sources: Ecoinvent, Rentz et al.

Aluminium

Secondary aluminium is produced by separate smelting facilities. The data used is taken from European aluminium industry publications. Primary aluminium data from European industry are from 2002 and – in contrast to the steel industry – does not include any credits for recycling. A recycling rate of 88% is assumed in the data set of the European LCA Data Platform.

Textiles

Several obstacles render the generation of figures for material recycling or reuse of textiles difficult. No descriptions of production processes for secondary textiles or researchable details on which textiles are exported from the EU for reuse purposes are available. In addition, it is difficult to assess which primary material would have been substituted by such material recycling or reuse, because the type of textile fibre (cotton or synthetic) and its distribution is unknown. In (Prognos/IFEU/INFA 2008) it was assumed that textiles are exported to and reused in non-EU countries. Thus, the emissions from textile recycling roughly correspond to emissions for shipping. Additionally, it was assumed that reused textiles consist of one third cotton fibre and two thirds synthetic, polyester textile fibre. The lifetime of the reused textiles was assumed to be half of primary textiles, and a substitution factor of 0.5 was applied for the substitution of primary products.

"Disposal" – description of waste treatment and disposal processes

Unburned scattered waste

Scattered waste is waste randomly thrown into the landscape. It decomposes under aerobic conditions. In this way no methane emissions occur from waste degradation. Although this is favourable in terms of climate change, this practice should be avoided at all costs as it poses massive health hazards to the population and damages the environment.

Open burning of scattered waste

In some cases scattered waste is burned openly. This can also take place directly at households. The uncontrolled combustion of waste is extremely dangerous to health due to the emissions of toxic substances. These toxic substances have no influence on climate change. However, climate change is affected by open burning because fossil carbon in the waste is oxidised to CO_2. In the SWM-GHG Calculator open burning is calculated as complete oxidation of the fossil carbon contained in the waste. Considering the uncertainty of the quantities burned in the open and because the incompletely burned remains will decompose over time this is an insignificant simplification

Wild dumps/unmanaged disposal site

Wild dumps are uncontrolled and/or unmanaged landfill. In contrast to scattering, the waste is not disposed of over a wide area but at one location with deep disposal at a depth of roughly greater than five meters. Under these conditions the waste mainly decomposes anaerobically. The same applies to disposal sites where the waste is deposited in water such as a pond, river or wetland. Methane is generated under anaerobic conditions. The resulting methane emissions from wild dumps are calculated in the SWM-GHG Calculator as equal to methane emissions from "controlled dump/landfill without gas collection". This may overestimate methane emissions slightly; according to (IPCC 2006) unmanaged disposal sites produce less methane than managed anaerobic disposal sites because a larger fraction of waste decomposes aerobically in the upper layer in unmanaged disposal sites. In (IPCC 2006) this is taken into consideration by methane correction factors for unmanaged deep, unmanaged shallow and managed semi-aerobic disposal sites. The simplification in the SWM-GHG Calculator appears reasonable because generally no reliable data exist about the type of wild dump, let alone the total amount of waste being scattered or deep deposited.

Controlled dump/landfill without gas collection

According to (IPCC 2006) managed disposal sites must use controlled placement of waste. For example, waste should be directed to specific areas, a degree of control over scavenging and over fires should be exercised. Furthermore, managed disposal sites will include at least either cover material or mechanical compacting or levelling of the waste. Here, managed disposal sites without and with gas collection are differentiated, because this is a relevant factor for GHG emissions.

In general, waste disposal is calculated in the SWM-GHG Calculator following the IPCC Guidelines for National Greenhouse Gas Inventories (1996, 2006). The SWM-GHG Calculator uses the theoretical gas yield methodology to compare the different waste management options. This methodology is the simplest method for calculating methane emissions from waste disposal. It assumes that all potential methane is released from waste in the year that the waste is disposed of. Although, this is not what actually occurs, it is necessary for comparing different waste management options because only then are all future emissions for one tonne of waste taken into account for a correct comparison.

Sanitary landfill with gas collection

As discussed above, methane emissions from waste disposal are calculated consistently for all landfill types. In general, this accounts for the methane generation potential, if sanitary landfill gas is collected. These potential methane emissions are reduced as a function of gas collection efficiency and the type of gas treatment. Furthermore, sanitary landfills usually cover the final waste body with methane-oxidising material. This fact is considered in the SWM-GHG Calculator using the oxidation factor of 10% for managed, covered landfills according to (IPCC 2006) .

To define the efficiency of gas collection you are asked to enter a respective percentage in the SWM-GHG Calculator. Gas collection efficiency in this context means the share of all potentially generated methane from a given quantity of waste that can be captured, or in other words, the ratio of collected landfill gas relative to the total generated landfill gas from a given quantity of waste. The default values recommended in the SWM-GHG Calculator for this average net efficiency are 10% and 50%.

Measurements of efficiencies at gas recovery projects (IPCC 2006) have reported efficiencies between 9 and above 90 percent. These measurements reflect a momentary situation. Over the lifetime of a landfill it is assumed that only about 50% of all potentially methane generated can be captured even using technically advanced gas collection techniques. For example, in Germany, where the landfill ban for MSW came into effect in 2005, and where all landfills are sanitary and include a gas collection system, the gas efficiency rate was reported to be 60% in the 2007. This means that although no more MSW was disposed of in comparison to 2005 and all landfills are closed and covered, still only 60% of the methane generated was captured in the 2007 for technical reasons.

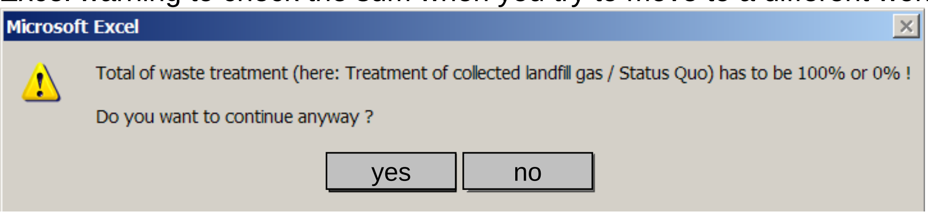
The average net efficiency of gas collection is time dependent. In the early stages of waste disposal to landfill, the waste is not generally covered. Only a small quantity of generated methane can therefore be captured in this phase. Later, when the waste body is covered, more of the methane generated can be captured although 100% is still not achieved due to technical limitations.

Example:

1 tonne of waste generates 200 m³ of landfill gas over a time period of 50 years. It is assumed that 60% of the landfill gas is generated during the first 10 years when the landfill is active and not covered. In this period it is assumed that 30% of the landfill gas generated can be captured. After 10 years the waste body is covered and more of the generated landfill gas can be captured in the remaining 40 years. Efficiency is estimated at 80%. The resulting average net efficiency then is: 200*(0.6*0.3 + 0.4*0.8)/200 = 0.5.

In addition to the efficiency of gas collection in the SWM-GHG Calculator you are also asked what happens to collected landfill gas. The gas may remain untreated but vented, e.g. with a simple chimney to prevent self incineration of the waste body. Methane emissions are not reduced in this model. Alternatively, the gas can be flared. In this model methane is oxidised to CO_2, which is climate-neutral because it comes from regenerative carbon. Finally, the collected gas can be used for electricity generation. In the SWM-GHG Calculator use in a combined heat and power plant is considered with a net electrical efficiency of 30%. The produced heat is not taken into account because it is generally difficult to find an external customer. The replaced electricity is credited with GHG emissions from electricity generation as indicated by the user (country-specific electricity mix).

The total of the percentages entered for the treatment of collected landfill gas must equal 100%. If you forget to fill in the respective green cells correctly you will be reminded by an Excel warning to check the sum when you try to move to a different worksheet.



BS + landfill

BS + landfill is defined as simple biological stabilisation (BS) of MSW and disposal of the residue with lower methane emissions than without stabilisation. The biological stabilisation takes place by building up the MSW in compost heaps which are aerated according to the chimney principle. No, or only simple, mechanical pre-treatment (e.g. homogenisation, shredding, modulation of water content) takes place. Biological treatment occurs over a period of at least 8 weeks. The output produced is less biologically active and is disposed of with lower resulting methane emissions. The mechanical energy demand for biological treatment and for disposal of the output is estimated at approx. 9 kWh/t waste following the energy demand for simple composting. The electricity demand is estimated at 2 kWh/t waste and is the same as for sanitary landfill.

MBT + further treatment + landfill

MBT + further treatment + landfill is an advanced technology concept of MSW treatment. In a mechanical-biological treatment (MBT) plant MSW is initially mechanically treated to separate metals, impurities and a waste fraction with a high calorific value. The latter is used as refuse-derived fuel for co-incineration. The remaining residual waste consists to a high extent of organic waste. It is biologically stabilised through encapsulated composting. The exhaust air from composting is collected and treated via thermal oxidation. The concept is typical for Germany where both MBT and MSWI must comply with the same threshold values for total organic carbon, methane and nitrous oxide.

The output from biological stabilisation is disposed of to MBT landfill. The material is much denser and has almost no remaining biological activity. Thus much less space is needed for disposal and methane emissions are minimised.

The aim of this treatment option is to separate recyclables from MSW and to produce a biologically inactive material that can be deposited with negligible negative impacts in terms of climate change. The electricity demand of the MBT plant is calculated at 38 kWh/t waste, the heat demand at 8 kWh/t and the natural gas demand for thermal oxidation of the exhaust air at 5 m^3/t MSW. The fractions separated by the MBT plant are shown in Figure 0-1. The values for energy demand and mass balance represent the average situation in Germany (Öko-Institut/IFEU 2009).

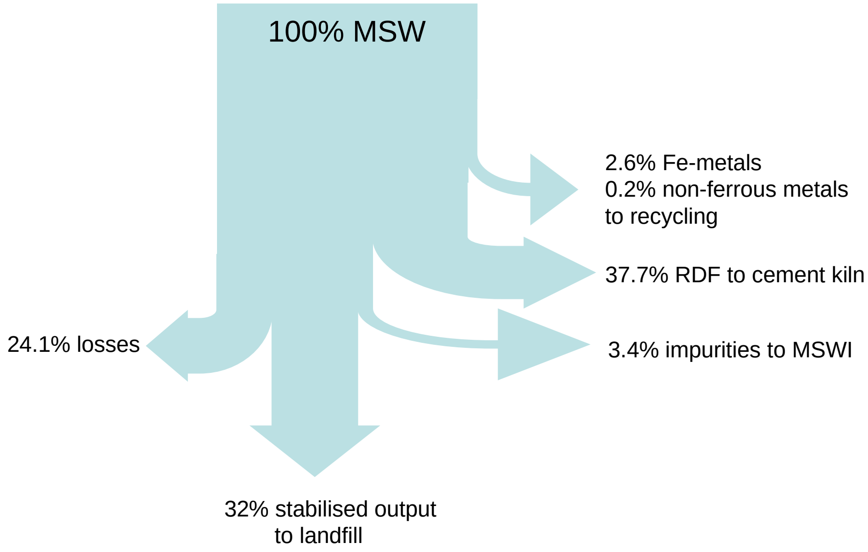


Figure 0-1 Mass flow diagram of an average MBT plant in Germany

The values for Germany have been chosen because currently this MSW treatment concept is almost only implemented in Germany. The mass balance therefore accounts only for the German situation. In other countries the composition of the remaining residual waste may differ and therefore the possible extraction rates for metals and RDF may also differ. A more precise approach would be to take into account the composition and recycling rates as defined in the SWM-GHG Calculator by the user. Additionally, recovery rates are needed from concrete treatment concepts (e.g. information from providers, stating that aggregates x% of the metal input and/or y% of the high calorific fraction in the residual waste can be separated using a specified mechanical treatment).

In the long-term it is assumed that the MBT concept may be also applied on a global scale. In this case the German values should be substituted by values that are valid on a more general basis. It is therefore planned to adjust the SWM-GHG Calculator in the future in such a way that the defined and calculated composition of the remaining residual waste is taken into account and specific provider's warranties are used to calculate the recovery rates.

In the SWM-GHG Calculator it is assumed that the separated RDF fraction is co-incinerated in a cement kiln. The RDF is specified with a calorific value of 13.3 MJ/kg waste and a fossil carbon content of approx. 19%. Thus the co-incineration causes fossil CO_2 emissions corresponding to the fossil carbon content with assumed complete incineration. The benefit of co-incineration is the substitution of fossil fuels with a typical input mix in Germany of 29.4% hard coal, 53.1% lignite, 11.8% coke, 4.4% heavy fuel oil, and 1.3% others (VDZ 2008).

It is assumed that the impurities are treated in a MSWI plant. They are defined as typical MSW in Germany with a calorific value of 9.2 MJ/kg and a fossil carbon content of approx. 9%. Thus the incineration causes fossil CO_2 emissions corresponding to the fossil carbon content with assumed complete incineration. In Germany most MSWI plants produce energy from waste incineration. On average, the net electrical efficiency is 10%, and the thermal efficiency 30%. The emissions from conventional electricity and heat production avoided are considered in the SWM-GHG Calculator. For electricity generation these are the CO_2 emissions as defined by the user (country-specific electricity mix), an average value was used for heat (50% oil, 50% natural gas).

MBS/MPS + co-processing cement kiln

Mechanical biological stabilisation (MBS) and/or mechanical physical stabilisation (MPS) + co-processing cement kiln is an advanced technology concept of MSW treatment similar to MBT. Also similar to MBT, MSW is initially mechanically treated to separate metals and impurities. But in contrast to MBT the complete remaining fraction is stabilised either biologically or physically to produce RDF. Thus no output to landfill is generated. However, the MBS/MPS plants also represent the German situation. Therefore, they also must comply with German threshold values, and exhaust air from stabilisation is collected and treated via thermal oxidation.

The aim of this treatment option is to produce RDF and to separate metals. The electricity demand of the MBS/MPS plant is calculated at 39 kWh/t waste, the heat demand at 6 kWh/t and the natural gas demand at 42 m³/t MSW. In this case natural gas is not only used for the thermal oxidation of the exhaust air but also to provide heat energy for the stabilisation process. The fractions separated by the MBS/MPS plant are shown in Figure 0-2. The values for energy demand and mass balance represent the average situation in Germany (Öko-Institut/IFEU 2009).

MBS and MPS are two different approaches to stabilising the otherwise biologically active remaining fraction after mechanical treatment. In both cases stabilisation is mainly achieved by drying the waste material to less than approx. 15% water content. With a water content as low as this the biological activity of the organic waste is brought to a halt. In case of biological stabilisation the biological fraction is introduced into a reactor where it starts to decompose and is systematically aerated. Physical stabilisation happens through drying of the biological fraction with heat.

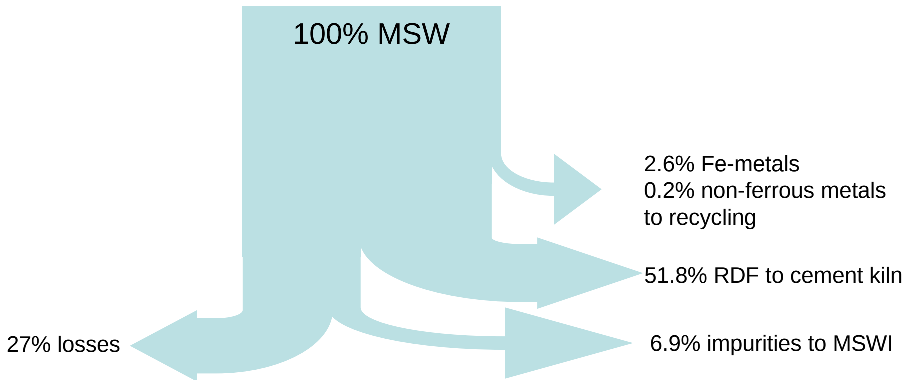


Figure 0-2 Mass flow diagram of an average MBS/MPS plant in Germany

Co-incineration of RDF in a cement kiln and incineration of impurities in a MSWI plant are calculated in the same way as for MBT (see above), because this corresponds to the average situation in Germany. The benefits from co-incineration of RDF and incineration of impurities are also calculated as described for MBT.

Incineration

Different MSWI plant technologies exist. The most common models are grate firing and fluidised bed combustion, with the first dominating in Germany. In terms of environmental concerns the most important aspect of MSWI technologies is the type of flue gas treatment. In general, MSWI plants should be in compliance with German and/or EU 27 emission standards, for example. Emissions hazardous to health needn't therefore be feared.

Additionally, the waste should be thoroughly tested for its suitability for incineration. The most important aspects in terms of waste characteristics and quality are explained in Section 5.4. As a rough rule of thumb it can be assumed that self-sustaining incineration usually requires a minimum calorific value of about 6 MJ/kg waste. In addition to waste combustibility data, information on the level of heavy metals is also important, because this has considerable influence on flue gas cleaning requirements and incineration costs. Determination of these parameters requires in-depth surveys of the waste composition and physical and chemical analyses.

The main relevant emissions in terms of climate change are fossil CO_2 emissions resulting from incineration of fossil carbon contained in waste. As a conservative simplification in the SWM-GHG Calculator, complete combustion is assumed for technologically advanced MSWI plants. The fate of the ash and slag output products is not considered in the tool.

Modern MSWI plants usually produce energy. In a further step in the SWM-GHG Calculator you are asked to enter the net energy efficiency. If MSWI plants have a steam turbine then they produce electricity and in some cases heat. If only electricity is produced the maximum electrical efficiency is about 20% for thermodynamic reasons. If heat is also produced the electrical efficiency is lower. The degree of heat production depends on whether it is possible to sell the heat. On average MSWI plants in Germany have a net electrical efficiency of 10% and a thermal efficiency of 30% (Öko-Institut 2002). These values are also applicable on a European level (CEWEP 2006).

The default values given in the SWM-GHG Calculator for net electrical efficiency and thermal efficiency are 15% and 0% respectively. These values were chosen because it is assumed that it is barely possible to find a customer for heat in developing countries and that therefore only electricity is produced.

The emissions avoided by the substitution of electricity and heat production are considered in the SWM-GHG Calculator. For electricity generation these are the CO_2 emissions as defined by the user (country-specific electricity mix); an average value was used for heat (50% oil, 50% natural gas).