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MBT's Contribution to Climate Protection and Resource Conservation

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Abstract

Mechanical-biological waste treatment involves the production and separation of waste streams that are subsequently routed to materials or energy recovery. The associated contribution to resource conservation and climate protection and the energy efficiency attained by MBT processes are presented by the example of real-life facilities and compared with the results of other disposal methods.

The result of the climate and energy balance strongly depends on the specific configuration and operating conditions of the facility. Despite major variations between the individual facilities, the study demonstrated clear advantages of the MBT facilities examined over alternative processes.

The results of the balances provide a basis for identifying potential for the optimization and further development of MBT from both environmental performance and economic aspects.

Keywords

Energy efficiency, net primary target energy, net primary efficiency, emission factor, MBT, MBS, MPS, AD, system boundaries, global warming potential GWP, anaerobic digestion

1 Introduction

While various publications are available on the climate balance of MBT processes, energy efficiency information on MBT facilities that covers all the building blocks of the process combination including MBT, materials / energy recovery and landfilling is so far not available in the literature.

The published CO_2 balances for MBT processes partly show great variability. In the same way, they frequently show major variations from the results presented in this paper. These variations can for the greater part be explained by the inventory analysis underlying the calculations and, in part, also by the approaches selected for the efficiency assessment.

The results presented in this paper are based on the actual operating data (material and energy balance) of mechanical-biological treatment facilities and the downstream plants utilizing the material streams generated by the MBT facilities examined.

The calculation model is based on the method presented in VDI Guideline 3460, Part 2, which has been expanded and/or matched to the requirements of a process combination. The model uses a closed and plausible energy and mass balance to calculate the net energy yield which, after deduction of the energy consumption of the treatment process, describes the energy benefit of the process.

The environmental lifecycle assessment of the waste treatment process is made by the example of the climate balance via the magnitude of climate-relevant CO_2 emission savings (expressed as CO_2 equivalents per unit volume of waste treated). The CO_2 equivalents are calculated with the aid of specific emission factors that describe the environmental impact in comparison with an equivalent system.

The system boundaries have been selected such that the computed performance indicators, i.e. energy efficiency and climate impact, allow both an assessment of the specific plant combination and a comparative assessment of alternative waste treatment processes.

In order to assess the magnitude of the values determined for the MBT processes, they are compared with literature data on identical processes and processes for the exclusive thermal treatment at municipal solid waste incinerators (MSWIs).

2 Background

Against the background of the current climate protection and resource conservation debate as well as soaring energy prices, the energy efficiency and climate impact of waste treatment is gaining growing importance. As a matter of fact, however, the waste management sector is already making a significant contribution to climate protection through its activities in the fields of materials and energy recovery and even more so by diverting untreated waste from landfills.

Nevertheless, the optimization of the treatment facilities, materials and energy recovery can open up significant untapped potential to boost energy efficiency and reduce climate-relevant greenhouse gases (see also [1]).

Waste stream-specific treatment in MBT, MBS and MPS facilities to produce refuse-derived fuels and biogas by anaerobic digestion is by its very concept already geared to the optimum use of the energy content of the treated residual waste. This holds true regardless of the fact that the energy content of the waste fractions subjected to aerobic treatment and subsequent landfilling is not recovered.

This has been confirmed by numerous comparative studies on residual waste treatment systems. On the other hand, some authors have repeatedly pointed out the inferior energy efficiency of MBT as against conventional waste incineration in their studies and publications, citing the unused energy potential of the landfilled fraction and the allegedly high energy consumption of MBT facilities.

These contradictory results are mainly due to differences in the assumptions and approaches underlying the studies.

Given the current debate over climate relevance and waste management, the differentiation between materials / energy recovery and final disposal processes and the growing importance of energy efficiency and climate relief effects, an up-to-date status assessment based on the actual operating results of MBT facilities and the recycling / WTE plants and landfills served by them is needed.

Based on a generally recognized methodology, a model was developed to determine the energy efficiency of process combinations using MBT and the resulting climate relief effect. Following the validation of the model against selected example facilities, status data are currently being established at several MBT facilities of different configuration and orientation.

The results so obtained can be used both to document the actual achievements and to identify further optimization potential. The prime objective of the modelling studies is to derive approaches to improving the energy and climate balance of mechanical-biological waste treatment rather than ranking the individual MBT facilities and their different process concepts with regard to their performance. Nonetheless, a comparison of the results with those of other facilities always allows conclusions to improvement potential for the further development of the own facility.

Against the background of the current discussion about the recyclables bin, the balancing model, which is actually limited to residual waste treatment, has been expanded to include the materials recovery aspect and the entirety of the waste and energy management measures at the location of the MBT facility and in the entire catchment area (extended system boundaries: central waste disposal facility or district). The model was developed by iba GmbH, Hannover on behalf of ASA with the expert support of Professor Beckmann (TU Dresden) and Professor Scholz (TU Clausthal).

3 Methodology

Waste treatment processes are increasingly assessed from resource conservation and climate protection aspects. Apart from direct savings in fossil energy sources, the reduction of climate-relevant greenhouse gas emissions is a prime factor considered in the assessment. Given the currently overriding climate protection debate, other environmental impact categories such as acidification, eutrophication, human toxicity effects, as analyzed by many LCA studies, play a secondary role.

For these reasons, the balancing model here presented is limited to the parameters energy efficiency and climate-relevant CO_2 emissions. All other impact categories are the subject of more comprehensive LCA studies.

The calculation model is based on the method presented in VDI 3460, Part 2 (Emission Control, Energy Conversion in Thermal Solid Waste Treatment) [2] which has been adapted to suit the requirements for a process combination involving the subsequent substance stream-specific treatment of the fractions generated in different treatment systems by an expansion of the system boundaries.

Using this method, the net benefit achieved through waste treatment after deduction of the energy demand of the treatment process is determined. Via substitution processes, the total energy demand (electricity, heat, gasoil, natural gas etc.) is set off against the benefit gained through the substitution of primary energy.

Within the defined system boundaries, the total energy demand of all waste treatment processes is set off against the target energy generated using energy type-dependent substitution processes (electricity, gasoil, gas). The remaining net target energy yield is related to the energy content of the waste volume treated in the MBT facility.

The climate relevance of waste treatment is modelled via specific CO_2 emission factors. Depending on the effect, the factors are considered as credit (e.g. for energy generated and materials recovery) or as debit (emissions, energy consumption). For materials recovery, e.g. metals recycling, the achieved CO_2 emission savings as against the production of primary raw materials are input to the model. Regarding emissions, only the greenhouse gas-relevant emissions such as methane, laughing gas and CO_2 originating from fossil carbon are modelled.

The method determines the following performance indicators which are used to document the benefit gained from waste treatment from lifecycle assessment aspects.

- ***Net primary target energy in MWh/a and kWh/Mg waste***
  as a measure for the net target energy yield from waste treatment after deduction of all additional energy inputs
- ***Net primary efficiency in %***
  as a measure for the relative net target energy produced from the energy content of the treated wastes. The net primary efficiency denotes the actual energy efficiency of the overall process.
- ***CO_2 credit expressed in kg CO_2 equivalents / Mg waste and Mg CO_2 eq./a***
  as a measure for the climate relief effect achieved by waste treatment through climate-relevant CO_2 emission reductions.

Regarding the methodology and terms, reference is made to VDI 3460/2.

The method uses the conventional lifecycle assessment (LCA) approaches and tools:

1. Definition of goals and system boundaries
2. Inventory analysis
3. Environmental impact assessment
4. Evaluation and assessment

The emissions generated by waste treatment and the downstream processes enter the balance as environmental burden. The relevant greenhouse gases identified by the inventory analysis are considered according to their global warming potential (GWP).

Table 1: Emission factors of greenhouse gas-relevant emissions in kg CO_2 eq. /kg

Greenhouse gas	Emission factor
Carbon dioxide CO_2, fossil	1
Methane CH_4, fossil	27.75
Methane CH_4, regenerative	25
Laughing gas N_2O	298

Source: IPCC 2007, quoted in [1]

The benefit gained from waste treatment in the form of secondary raw materials produced (for materials recovery) and energy generated (electricity, heat, steam) is valued via credits (= environmental relief).

The magnitude of the credit is determined by the savings in primary products and primary energy and/or savings in fossil energy sources in so-called equivalence processes (production process, power plant and the associated upstream process chains) realized through the manufacture of secondary products from secondary raw materials. The credits underlying the model are listed in Table 2.

Table 2: Emission factors credited for environmental benefits deriving from materials recovery from the separated fractions [1], [3], [4], [6]

Fraction	Credit in kg CO_2 eq./Mg
Ferrous metals	-1,927
Non-ferrous metals	-12,888
Plastics	-2,500
Paper, cardboard	-732
Wood	-942
Ammonium sulphate solution1) ASS	-5,660

1)credit related to the N content of the ASS

The energy produced in the combined process plants is used to cover the energy demand of all processes and systems within the system boundaries. The required additional energy in the form of electricity, heat and steam is directly set off against the target energy generated.

The additional energy input in the form of primary energy (natural gas, gasoil etc.) is considered via substitution processes which convert the target energy generated to energy-equivalent primary energy via arithmetic conversion processes. The conversion factors of the substitution processes have been selected such as to obtain a CO_2 burden corresponding in sum to the emission factors as per GEMIS [3] for natural gas and gasoil including the upstream process chain and use.

The net primary target energy remaining within the system boundaries after covering the own energy demand and substitution of the additional energy is valued with credits. For reasons of comparability, the factors derived in [1] including upstream process chains, other greenhouse gases and losses in the district heating network are used for attributing electricity and heat credits. The electricity credit is based on the assumption that the waste-derived electricity is used to substitute fossil energy sources (brown coal, hard coal, natural gas) while the substitution of household oil and gas heating systems is credited for the heat generated.

The credit for exported process steam is based on the value for heat generated by district heating plants.

Table 3: CO_2 credit for net primary target energy produced [1], [4]

Energy type	**g CO_2 eq./kWh**
Electricity	-887
District heat	-334
Steam	-303

Other studies use the national electricity mix, the electricity mix of the respective German Land, the regional utility or the credit for the actual fossil energy substituted in the individual case (e.g. brown coal-fired power plant) as a basis for the electricity credit (Table 4).

Table 4: Specific emission factors (EF) for electricity credits assigned for the substitution of different energy sources

	g CO_2 eq./kWh$_{el}$	**Source**
Mix of fossil energy sources	887	[1]
German electricity mix	598	[1]
Saxon electricity mix	915	[6]
Regional electricity mix	702/748/971	diverse
Brown coal substitution	1.071	[3, 6]
Austrian electricity mix	281	[5]

The significant variations between the emission factors are attributable to the different mixes of energy sources (coal, gas, nuclear power, regenerative energy) which not only differ from region to region (German Länder) but also from year to year.

With the range of emission factors presented, the result of the CO_2 balance is determined by the share of the fossil fraction in the selected or locally available electricity mix. For this reason, results from plant and system comparisons are not comparable beyond the territory boundaries of a grid operator.

However, as waste treatment, by its very concept, is aimed at producing energy from waste in order to substitute fossil energy sources rather than at crowding out regenerative energy sources, it makes sense to use the selected approach of a fossil energy source mix as a basis for the determination of achieved CO_2 emission reductions.

In the ASA balancing model, the selected specific emission or equivalence factors are therefore kept constant over a defined period of time so as to be able to assess and compare the facilities and their trends without superposition of the effect of different energy factors. In the individual case, an additional modelling run using the factors of the regional electricity mix can be conducted.

A point open to discussion is whether it would not make more sense or even be necessary to use the European electricity mix as a basis. Regardless of the selected approach, the downward trend of the emission factors resulting from continuous energy efficiency improvements in fossil-fired power plants must be taken into account as the long-term trend.

4 System boundaries

The system boundaries under review cover waste treatment at the MBT facility including transportation and transfer of the material streams generated to the users (Figure 1).

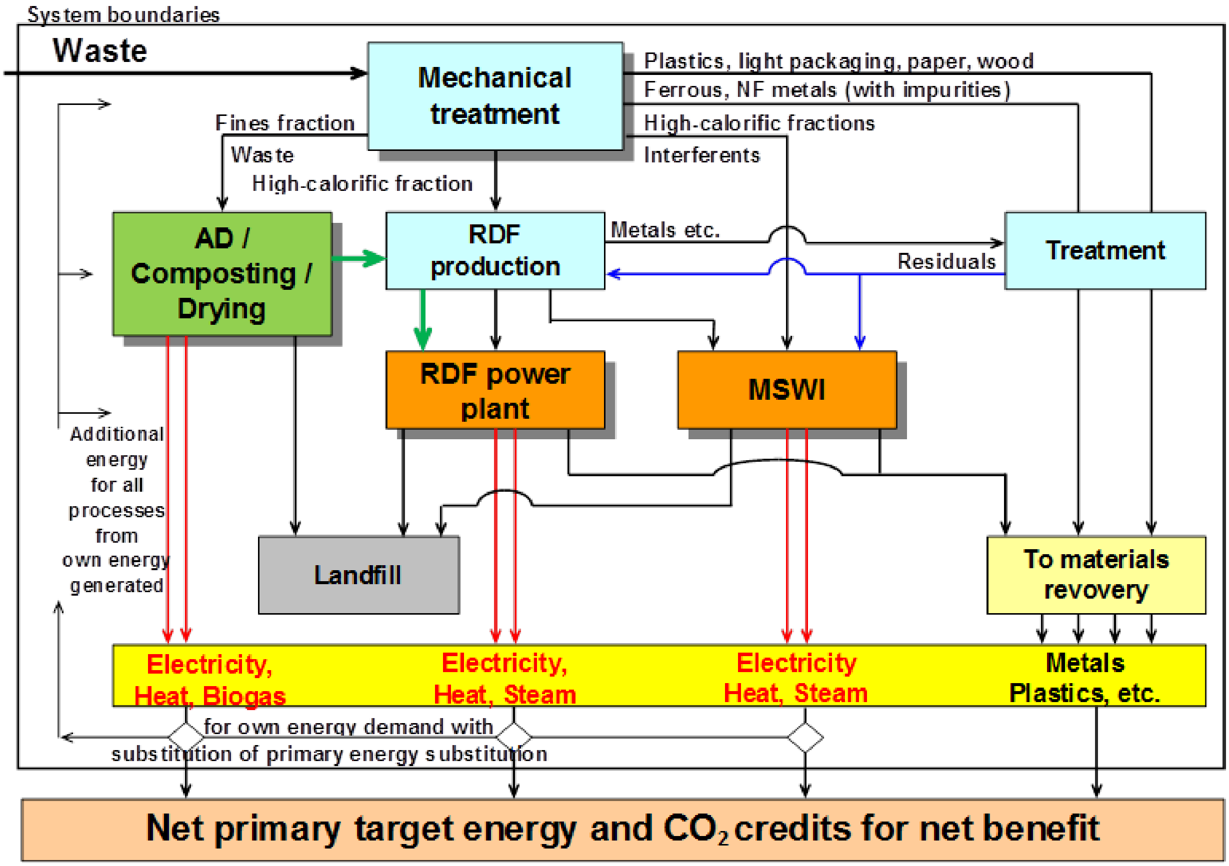

Figure 1: System boundaries for process combinations using MBT

In analogy with [1], accounting starts at the point where the waste occurs, in the present case, at the time at which the waste is delivered to the first waste treatment facility.

Following waste delivery, all energy inputs associated with waste treatment and materials/energy recovery including all energy inputs associated with transportation within the system boundaries are considered in balancing. The disposal of material streams comprises all downstream sorting, treatment, recycling / energy recovery and final disposal processes including the associated energy inputs.

This approach does not consider waste collection and transportation to the MBT facility because they are normally of minor relevance to the result and their impact is the same for all processes in a system comparison.

For a comparative assessment of residual waste treatment processes, the energy use for collection and transportation would only be of relevance if the energy consumption for transportation varied between the individual process alternatives.

5 System Boundaries according to VDI 3460/2

According to VDI 3460/2 [2], the system boundaries cover the balancing boundaries U including the computation of the net primary target energy as the indicator for the energy benefit associated with waste treatment (Figure 2).

Accordingly, the system boundaries for CO_2 balancing comprise the MBT facility plus all downstream processes and the associated environmental burdens through to the feed-in of the generated excess net target energy into the power grid and transfer of the separated resources for materials recovery.

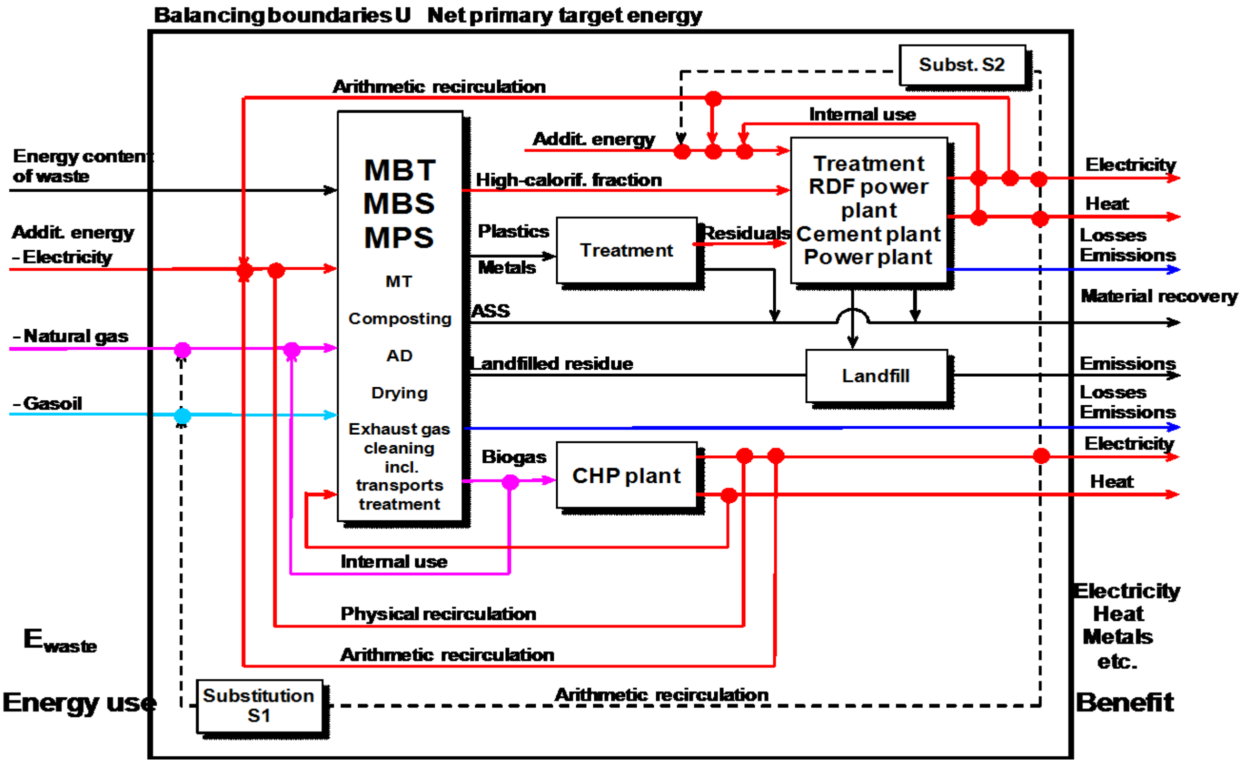

Figure 2 System boundaries as per VDI 3460/2 for process combinations [2]

The net primary efficiency η is determined by aggregating the electrical and thermal net primary target energy E_U generated and relating it to the energy content of the waste treated E_{waste}.

Energy efficiency as per VDI 3460 (2)

$$\eta_{gesamt} = \eta_{U,\,el} + \eta_{U,\,th} = \frac{E_{U,\,el} + E_{U,\,th}}{E_{Abfall}}$$

For energy recovery in MSWIs and power plants, separate system boundaries are created as part of a secondary modelling run. Here as well, only the plant-specific net primary efficiency is included in the system boundaries of the overall process. When the refuse-derived fuels are used as an energy source at a cement plant, the hard coal substituted by the refuse-derived fuels is transferred to a power plant via a coupling process. The average net efficiency of a German hard coal-fired power plant is used as a basis for the energy conversion (Figure 3).

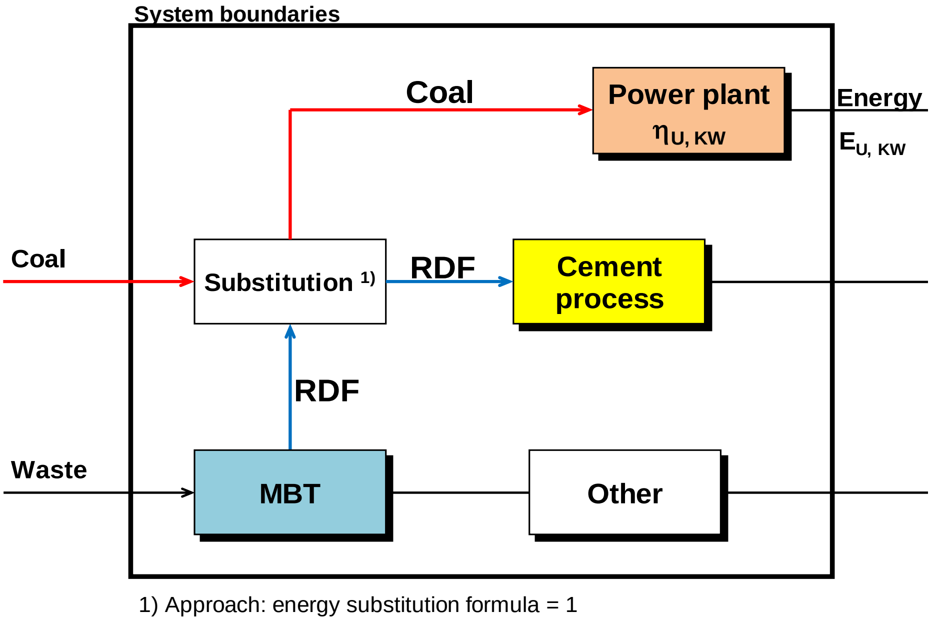

Figure 3: Simplified representation of the system boundaries for MBT with energy recovery from RDF at cement plants (as per [12])

Data basis / inventory analysis

The inventory analysis is based on the waste volumes and operating data indicated by the facility operators. These data were subjected to a plausibility check. Where necessary, missing data or implausible data were corrected such as to obtain a consistent material and energy balance.

6 Energy and Climate Balance of MSWI

ITAD collects mass throughput and energy data from operators of conventional municipal solid waste incinerators (MSWIs, WtEs) at yearly intervals [14].

According to this survey, the 70 German MSWIs burned a total waste volume of 19.07 million Mg in 2009. The mean calorific value stood at 10.09 GJ/Mg.

Table 5 Energy balance of MSWIs in 2009 (as per [14], complemented)

	million MWh	%
Energy content of waste	53.5	100
Imported energy (from external sources)	n. d. 1)	-
Heat generated	No data	-
Heat exported	6.75	12.6
Process steam exported	7.41	13.9
Electricity generated		14.3
Electricity (own demand)	1.95	3.6
Electricity exported	5.72	12.6
Energy exported	19.88	37.2
Net primary target energy 2)	-	36.4-36.8

1) Information on electricity imported and fossil energy sources indicated as resulting CO_2-burden only

2) Own calculation taking into account the imported additional energy (electricity, oil, gas)

The trend of the energy data for MSWIs is illustrated in Figure 4.

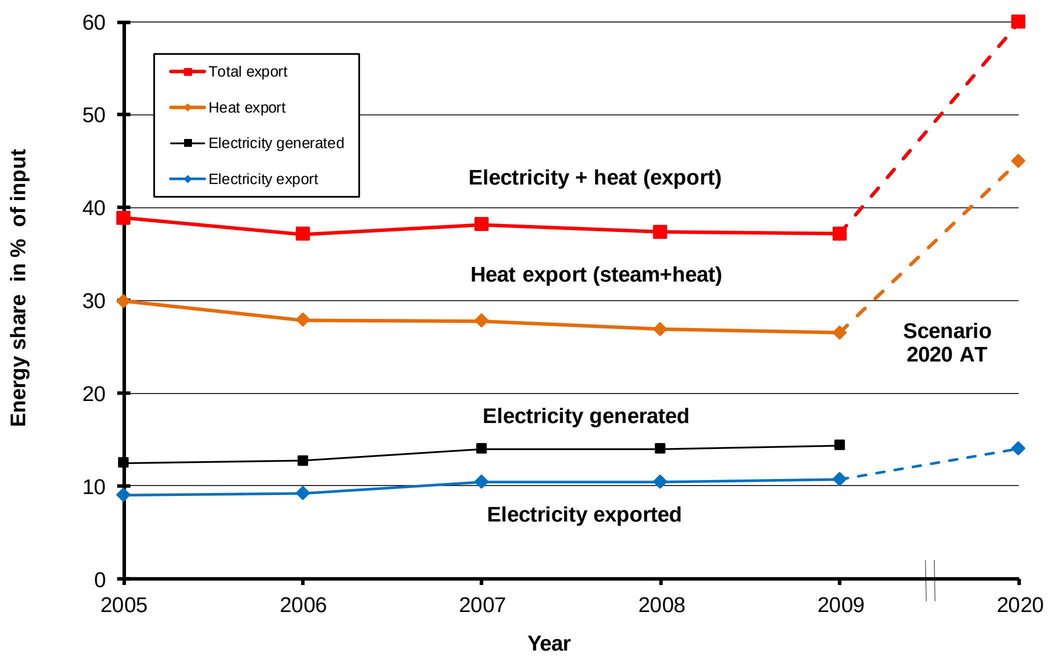

Figure 4: Trend of the MSWI energy balance (as per [14] and [1]) (without consideration of additional energy in the form of imported energy)

Despite rising absolute energy generation, the relative energy export shows a downward trend due to the (relative) decline in heat export.

For a comparison, the assumptions underlying the forecast variant 2020 AT for MSWIs (of [1]) are represented below. If the CO_2 emission savings determined by the above study are to be realized for MSWIs by 2020 heat utilization, in particular, would have to be increased by a factor of 2 compared to 2009. From climate protection aspects, this is both a desirable and challenging target.
According to [14], CO_2 emission savings associated with incineration [14] deliver a credit of -203 kg $CO_{2,e}$/Mg of waste treated. However, this value has been determined on the basis of the R1-formula approach and thus also includes a credit for the electricity use of the MSWI (Table 6). In terms of the climate balance, this own electricity demand is, however, no environmental benefit and can therefore not be posted as credit.

When considering the actually exported electricity only, the CO_2 emission reduction decreases to approx. -124 kg $CO_{2,e}$/Mg. Taking into account the imported energy (electricity, fuel oil, gas), a value of about -120 kg $CO_{2,e}$/Mg would be attained. If the factors (as per [1]) are entered into the balance as electricity and heat credits – which are also the factors used in the ASA model (Table 3) - the credit for MSWIs will increase to approx. -160 kg $CO_{2,e}$/Mg.

For a comparative assessment of MWSIs and MBT facilities, the following corrected values can therefore be used as a basis for MWSIs for the year 2009.

Net primary target energy MSWI: approx. 36.4-36.8 %
$CO_{2,e}$ savings MSWI : approx. 120-160 kg $CO_{2,e}$/Mg

These values do, however, not consider the different waste inputs of MSWIs (higher fraction of AS191210/12) and MBT facilities (predominantly AS200301).

The corrected values of the energy and CO_2 balances are in a range that compares well with the results for MSWIs obtained by other authors (e.g. [1], [13], [15], [16]).

Table 6 Climate balance for MSWIs 2009 (as per [14] complemented)

Burden			
	Mass	**$CO_{2\ eq.}$**	**Mass CO_2**
	Mg/a	Mg $CO_{2\ eq.}$/Mg	Mg $CO_{2\ eq.}$
Household waste AS 20 03 01	12,810,000	0.311	3,983,910
AS 19 12 10/12	3,270,000	0.465	1,520,550
Other wastes	2,990,000	0.443	1,324,570
Total /Average	**19,070,000**	**0.358**	**6,829,030**
Imported energy (estimate)	-	-	100,000
Relief / credits			
	Energy	**$CO_{2\ eq.}$**	**Mass CO_2**
	kWh/a	Mg $CO_{2\ eq}$/MWh	Mg $CO_{2\ eq.}$
Electricity (produced)	7,670,000	-0.786	-6,028,620
of which own demand	1,950,000	-0.786	-1,532,700
Steam to power generation (exp.)	5,100,000	-0.330	-1,683,000
Heat (exp.)	9,060,000	-0.278	-2,518,680
Total/average incl. own demand	**21,830,000**	**-0.469**	**-10,230,300**
Metal recovery from slag	(abt. 300,000)		-600,000
Balances			
Balance **incl.** own electricity demand		-0.205	-3,901,000
Balance **excl.** own electricity demand		-0.124	-2,369,000
Balance **incl.** imported energy		abt. -0.120	2,300,000
Balance w. energy type to Tab. 3		abt. -0.160	abt. 3,000,000

7 Data Basis for MBT

At the time of publication of this study, approximately one third of the MBT facilities operated in Germany had been examined.

Table 7: Participants in ASA's Energy Efficiency of MBT project (Status: 31/12/2011)

Process	MBT Compos-ting	MBA Anaerobic digestion	MBS	MPS	Total
Total facilities	18	12	13	3	46
Participants	7	6	2	1	15
Percentage participants	39 %	50 %	15 %	33 %	33 %
Percentage throughput capacity	38	59	20	28	36

For some of the facilities, balances over several years have meanwhile been prepared.

The waste input and the percentage distribution of the output streams produced at the MBT facility have a major influence on the balance sheet result.

At approximately 80 %, municipal solid waste was the predominant waste fraction processed the MBT facilities examined (Figure 5).

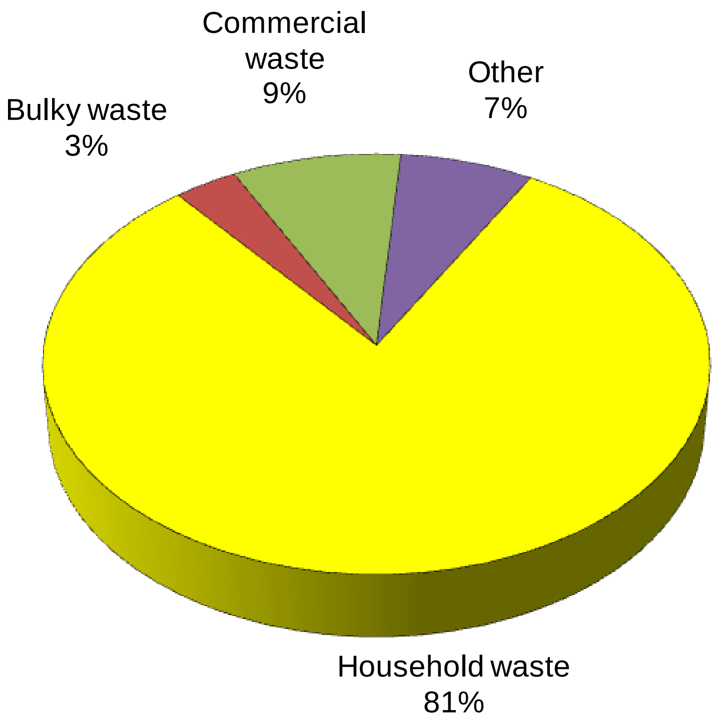

Figure 5: Waste input of the MBT facilities examined (weighted average from n = 15)

Moreover, the percentage distribution of the output streams at the MBT facilities depends on the process concept. A scale-up of the results from the 15 facilities examined is given in Figure 6. Here, mention should be made of the significant differences between the individual facilities and plant concepts.

The weighted average therefore represents only a snapshot based on the current operation of the facilities examined in the respective reference year 2009/2010.

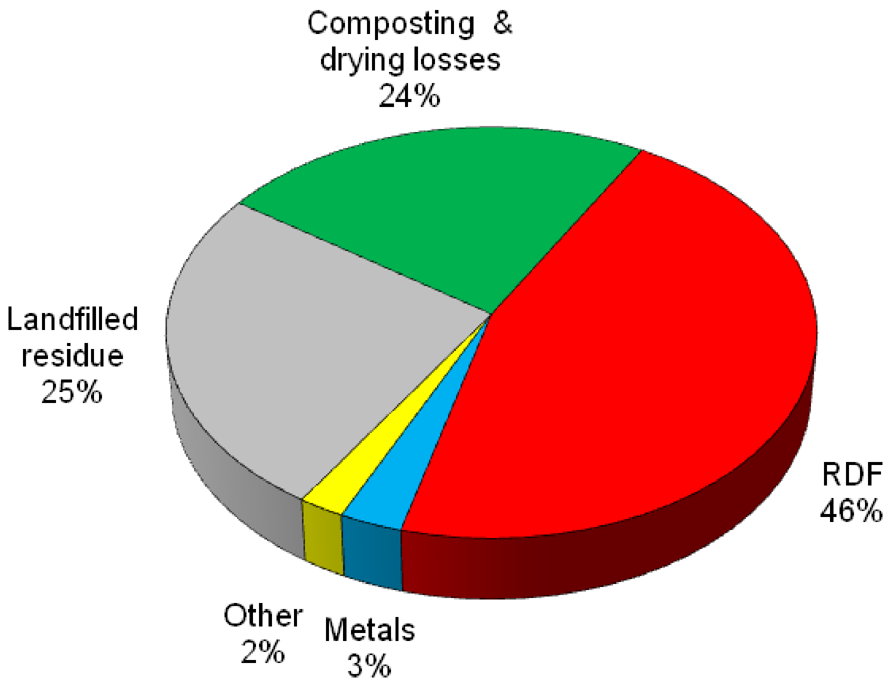

Figure 6: Material balance of the MBT facilities examined (weighted average of n = 15)

The energy consumption associated with the operation of the MBT facilities was compared with literature data (Table 8). The most relevant variations were observed for the MBT and MPS facilities. Some of the studies proceeded from a significantly higher electricity and gas consumption than actually encountered.

Table 8: Energy consumption of MBT

		MBA (C)	MBA (AD)	MBS	MPS
Literature data on the energy consumption of MBT facilities					
Electricity	kWh/Mg	37-52	45-48	63-129	32-170
Heat	kWh/Mg	0-8	0-17	0-8	0-8
Gas	kWh/Mg	20-56	45-52	31-212	324-541
Results from the energy efficiency project					
Electricity	kWh/Mg	45	65	100	85-100 C
Heat	kWh/Mg	0	included in gas	0	0
Gas	kWh/Mg	41	58	25	240-280
of which for RTO	kWh/Mg	39	45	25	17

C=composting, AD=anaerobic digestion

The higher electricity consumption of the MBS and MPS facilities is attributable to the higher energy requirement for the treatment of the “dried stabilate”.

The high gas consumption of the MPS facilities can be explained by the thermal drying step used in this treatment configuration. By contrast, the different values for composting-oriented MBTs versus AD-oriented MBTs can only partly be explained by differences between the composting and anaerobic digestion processes. Thus, the higher gas consumption for exhaust air treatment by the RTO process at AD-oriented facilities is not attributable to the anaerobic digestion process but to differences in the exhaust air concepts of the MBT facilities examined. While a higher specific exhaust air rate is routed to the RTO for cleanup at the AD-oriented MBT facilities, composting facilities send a higher exhaust air fraction to the biofilter.

The emissions of the MBT facilities are significantly below the emission limits. The facilities differ in the exhaust air routing concept (split-up of exhaust air over RTO and biofilter) and the operation of the acid gas scrubber and the maturation stage (laughing gas). The emission assessment is based on the conservative assumption that 80% of the clean gas TOC content is accounted for by CH_4-C.

Table 9: Emissions of the MBT facilities examined (n = 15)

Emissions			
	Unit	Average	Range
TOC	g/Mg_{MBT}	26	5-53
N_2O	g/Mg_{MBT}	19	1-50

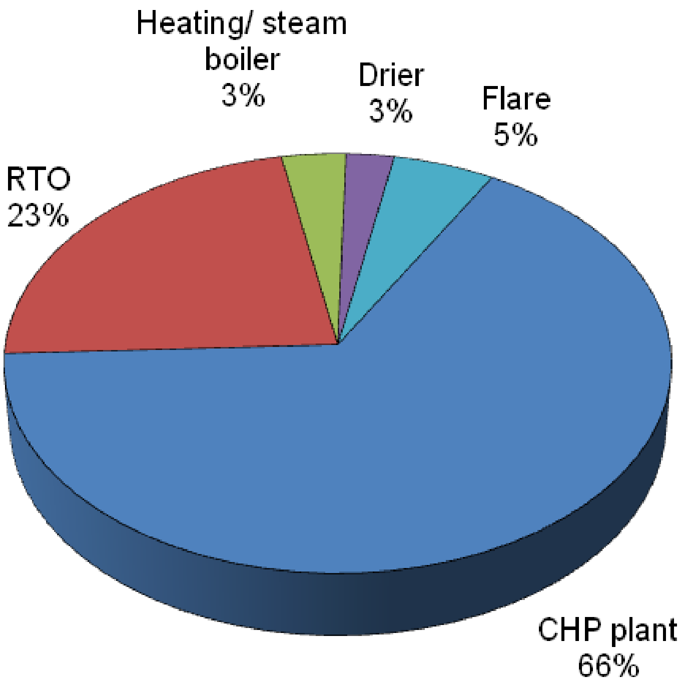

Figure 7: Use of biogas generated at AD-oriented MBT facilities (n = 6)

The average biogas yield from anaerobic digestion plants stands at 10 $m^3/Mg_{digested\ waste}$. Depending on the process and waste input, gas yields vary within a range of 70 to 170 m^3/Mg. On average, some 12 % (max. 18 %) of the MSW energy content were converted to biogas by anaerobic digestion.

Approx. 66 % of the biogas produced was used for electricity generation in CHP plants. On average, the 6 anaerobic digestion plants used 23 % of the biogas generated (instead of natural gas) for the operation of the RTO.

8 Results

The main factor determining the energy efficiency and hence, the climate balance of the combination processes is the efficiency of the WTE plants using the high-calorific waste fractions as fuel (RDF, stabilate, etc.). For anaerobic digestion plants, the utilization of the biogas translates into a relevant improvement of the result.

The highest net primary efficiencies were attained by plant concepts producing refuse-derived fuels for use in power plants or cement mills or high-efficiency RDF-fired power plants with high conversion efficiency for electricity and heat. Efficiencies attained by such plants were as high as 50 % (Figure 8).

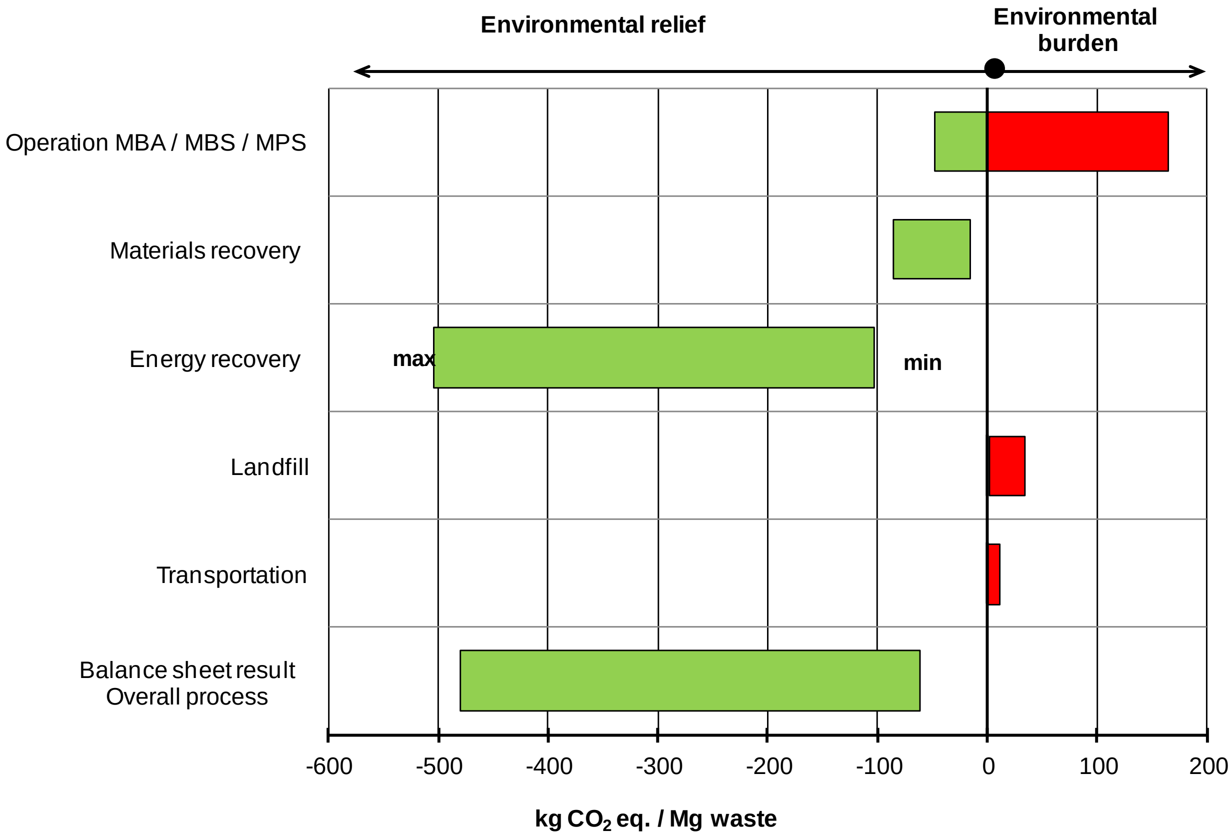

Figure 8: Energy efficiency of MBT facilities examined expressed as net primary efficiency

Table 10: Net primary efficiency and climate credit for MBT facilities examined compared with MSWIs 2009

		Average	Range	MWSI 2009[1)]
Calorific value, input	MJ/kg	8.2	6.9-9.8	10.1
Net primary efficiency				
Electrical	%	18	0-31	10
Thermal	%	14	0-40	27
Total	%	32	14-51	37
Climate credit (-)				
kg/CO_2 eq.Mg_{waste}		250 ± 30	60-480	120-160[2)]

[1)]as per [1], [2)]corrected values as per Table 6

On average, approx. 32 % of the energy content of the waste treated at the facilities examined was routed to external use.

Compared to MSWIs, electricity production was significantly higher for MBT. By contrast, the thermal efficiency is higher for MSWIs as the value also includes process steam converted to electric power in separate plants.

On average, the climate credit for MBT processes is significantly higher than for MSWIs Table 10), despite or actually, thanks to the lower calorific values of the wastes treated at MBT facilities (some 20 % lower than in MSWIs).

For process-specific reasons and due to the significant variations in the energy efficiency of the WTE plants using the RDF produced, the climate balance values of the examined MBT facilities vary over a broad range (Figure 10). However, a net climate benefit was demonstrated for all facilities investigated. A scale-up of the results from the examined facilities to all MBT facilities operated in Germany showed a mean value over all MBT facilities of approx. -250 kgCO_2 eq./Mg. Accordingly, this factor is significantly above the scale-up [1] for the year 2006. The partly significant variations from the literature data are due to different approaches underlying the inventory analysis and differences in the selection of the emission factors.

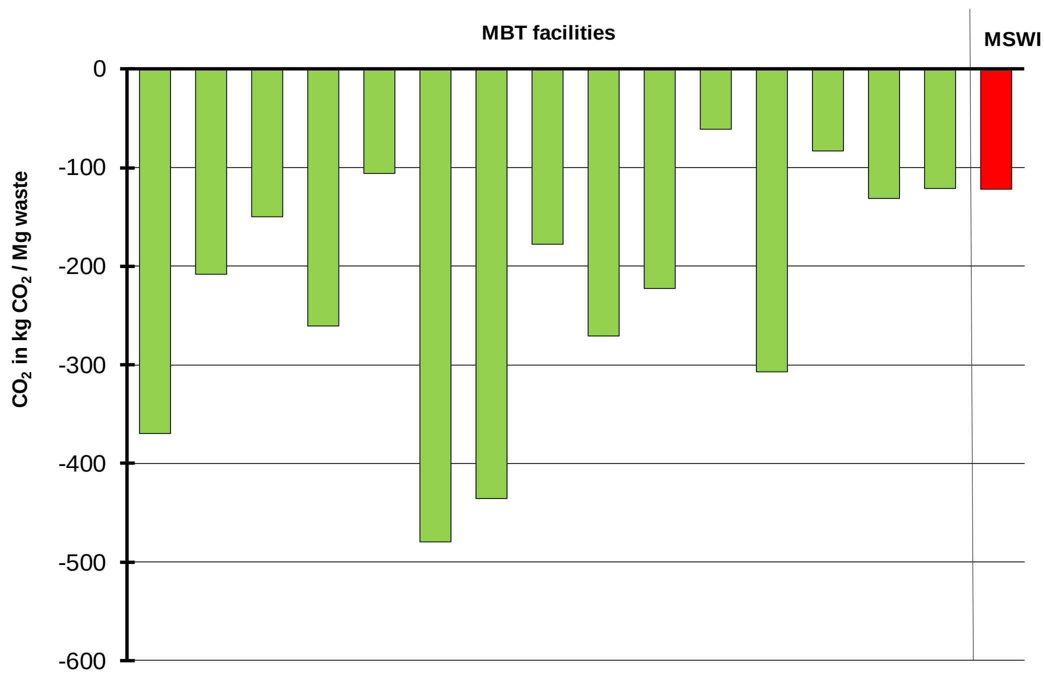

Figure 9: Climate credits of the MBT facilities examined versus MSWIs (corrected as per Table 6)

Table 11: CO_2 credits of MBT facilities examined versus literature data

	MBT (C)	MBA (AD)	MBS	MPS	Average
IFEU, [16] 1)	- (291-307)		- (690-721)	- (590-621)	-
BIWA ET AL. [6]	-17.4	No data	-53.2	+40.8	-
INTECUS [15] 2)	- (30-84)	- (15-148)	- (160-231)	- (457-470)	No data
IFEU, ÖKOINSTITUT [1] 3)	-	-	-	-	-138
ASA/IBA (n=15) 4)	**- (60-480)**				**-250 ±30**

1) Range attributable to differences in the RDF utilization in power plants and cement mills
2) Range due to variations in the substitution factors for electricity credits.
3) Mean value for MBA, MBS, MPS and MA in the reference year 2006
4) Scale-up from 15 facilities examined.
C=composting, AD=anaerobic digestion

Energy recovery from RDF in power plants and cement mills makes a major contribution to the balance sheet result of the overall process.

Segregation and recycling of the ferrous and, in particular, the non-ferrous metal fractions significantly improves the climate balance. Due to anaerobic digestion and utilization of the biogas generated, the operation of the MBT facility as such delivers a climate benefit.

The environmental burden associated with emissions from landfilling of the residues and transportation of the material streams from the MBT facility to the users can be considered to be of relative insignificance (Figure 10:, Table 12).

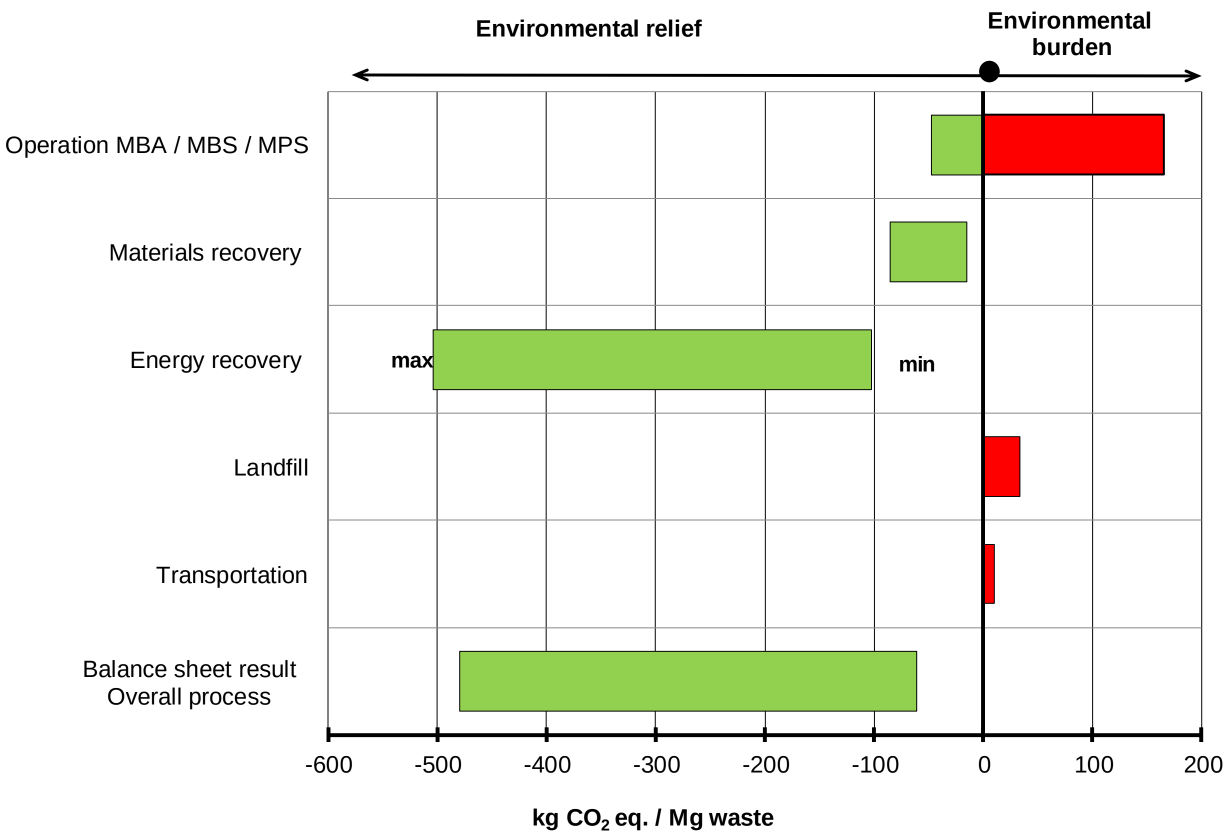

Figure 10: Net contribution of the individual processes to the CO_2-balance of the overall process (range over all facilities examined)

Table 12: Influence of MBT operation on the climate balance of the overall process

		Quantities		CO_2 credit	
		from	to	From	to
Credits MBA (-)				**-15**	**-196**
Ferrous metals	kg/Mg_{waste}	8	27.0	-15	-52
NF metals	kg/Mg_{Wwaste}	0	2.5	0	-32
Biogas/electricity	kWh/Mg_{waste}	0	126	0	-112
Debits MBA (+)				**25**	**130**
Electricity	kW/Mg_{waste}	25	100	22	88
Natural gas (RTO)	kW/Mg_{waste}	0	60	0	14
Gasoil	kW/Mg_{waste}	10	35	3	11
TOC emissions [1)]	$g\ C/Mg_{waste}$	5	55	0.1	1.5
N_2O emissions	kg/Mg_{waste}	1	50	0.3	15
Balance sheet result for overall process (comparison)				**-60**	**-480**

[1)] of which 80 % as CH_4-C (assumption)

Besides the selection of energy-efficient plants for energy recovery from the relevant output streams, the operation of the MBT facility as such may have an influence on the climate balance (Table 12). Main factors to be mentioned in this context are the increased utilization of the biogas generated and the effective segregation of metals to increase the credits on the one hand, and the reduction of the energy consumption to lower the debits on the other. Regarding the emissions, only the laughing gas emissions have an influence on the balance sheet result. These emissions can be minimized by optimizing the maturation stage and using acid scrubbers for exhaust gas cleanup.

9 Conclusion

Based on the 15 MBT facilities of different configuration and orientation so far examined, it was demonstrated that mechanical-biological waste treatment affords high energy efficiency and significant carbon emission savings at all facilities.

At an estimated throughput of 4.8 million Mg in 2009, the scale-up of the balance sheet results for the 15 facilities examined to the total of 46 MBT facilities shows a net production of

- **approx. 2.0 million MWh electricity**
- **approx. 15 million MWh heat and process steam**

from the wastes treated at the MBT/MBS/MPS facilities and transferred to third parties for energy recovery in 2009.

In addition,

- **approx. 110-140,000 Mg of metals**

plus further materials such as plastics, wood and ammonium sulphate solution were segregated from the residual waste and routed to materials recovery. In 2009, waste treatment at the MBT/MBS/MPS facilities resulted in a reduction of greenhouse gas emissions of between

- **1.1 and 1.4 million Mg CO_2 eq.**

Due to materials and energy recovery from waste, MBT/MBS/MPS facilities these days make a significant – frequently underestimated – contribution to climate protection and resource conservation.

By optimizing the processes and enhancing energy recovery from the so far unused energy content of the biologically treated fines fractions, the balance sheet result of the MBT/MBS/MPS facilities can be further improved in future.

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