Waste-to-energy Compared To Mechanical Biological Treatment (MBT) And Co-combustion Of Municipal Waste

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EXECUTIVE SUMMARY

In the current debate about the environmental impact of waste disposal techniques climate impact has highest priority. Thus, termination of deposit of untreated waste is by far the most important measure for reducing greenhouse emissions. This focuses attention on the still-emitting old landfills – is urgent need for action to reach the requirements of climate protection. The GHG emission savings achievable by the actually established treatment and recovery processes are also relevant for climate protection, but of secondary importance compared to the avoided emissions by ending deposit of untreated waste.

Comparison of different life cycle assessment studies show that under the aspect of climate impact there are only very small differences between mono- and co-incineration of solid recovered fuels (after mechanical-biological treatment). Here, energy efficiency of the thermal plants is the crucial point. Regarding the non-thermal plants, the energy demand and amount and quality of recyclable material output flows and even direct plant emissions are relevant for climate effects.

Consideration of other environmental impact categories in LCA studies identifies optimization potential, but does not lead to fundamentally different results. In sum, achievable environmental benefits are depending on the constellation of the case, e.g. on the energy efficiency of the plants or the total system, the credits for the chosen equivalence processes (e.g. non-ferrous metals) and – for the non-climate-related impact categories – the emission standards of the plants.

INTRODUCTION

In Germany, deposit had been the standard version of waste disposal in Germany since end of World War II. A few communities, however, tried alternative techniques. In the mid-1950s the first test and pilot facilities were built (Baden-Baden, Blaubeuren, Heidelberg I). Here garbage, sometimes mixed with sewage sludge, was rotted for generating compost useable for soil improvement. This so-called household waste composting ultimately failed because of the poor quality of the produced compost. As until end of the 1980s most of the MSWI plants showed high emissions of dioxins and other pollutants, engineers developed the so-called mechanical and biological treatment (MBT) as an alternative to MSWI. MBT was mainly located on landfills in operation. Here, the waste was mechanically crushed and homogenized, and then accumulated to heaps. The material was composted for months under additional feed of atmospheric oxygen until it reached a nearly stable status. Because of unsolved environmental problems (emissions, odor, fires), partly invasions of vermins in the neighborhood and finally tightened legal requirements (see below) these low-budget MBT-“plants” had to be closed. But there were also some approaches for the development of technically sophisticated M(B)T techniques. These were regarded as an alternative to the waste incineration technology which had poor acceptance by the public. One line of development, the so-called stabilization technique, aimed on biological drying of the organic fraction(s) with subsequent energy recovery and disposal only of separated inert material. The other line of development aimed on a technically controlled composting (digestion) of the organic fraction(s) with subsequent landfilling of the compost.

As the composting technique could not manage – within a reasonable amount of time and energy – to generate a landfill material keeping the limits for deposit material, the government changed the legal requirements of landfill material in 2001, so mechanically-biologically pretreated waste could be disposed of legally. However, the informations about the emission potential of MBT plants were striking, so the air- and water-based emissions of these facilities were limited by ordinance in parallel. At the same time, separation of calorific value carriers – these are plastics, wood, textiles, and more – was made mandatory.

In 2008, about 61 M(B)T plants were in operation. They follow different concepts like material flow separation, stabilization by drying and M(B)T for production of solid recovered fuels. These plants have at least one character in common: they all produce one or more output fraction(s) with increased calorific value (plastics etc.) for energy recovery. This material (solid recovered fuel, SRF) is transferred mainly to cement kilns. In 2008, 54 % of thermal energy input of cement kilns was based on secondary materials like used tyres, plastic wastes and other fractions from industrial and commercial wastes (in sum about 2.9 Mio. Mg/a). Minor parts went to co-incineration in eight power plants. Higher amounts entered mono-combustion in 21 SRF fired power plants, and a smaller part of SRF was treated in one of the 68 WtE-plants (MSWI) in operation (Thiel, 2008).

The following is a brief overview of important studies in recent years dealing with the environmental impact of waste-to-energy compared to mechanical-biological treatment (MBT) and co-combustion of municipal waste (fractions).

STUDIES COMPARING CLIMATE IMPACT

In Germany several studies comparing the climate impact of different waste management systems have been published. The results of five of them, published by well recommended institutes, will be reported below.

BIWA/BZL 2003 – Saxony

The study analyzed the status quo (2000) of waste management in the Free State of Saxony and created a forecast for the planned waste management solutions of the local government organisations until 2005 with regard to climate impact [BIWA/BZL 2003].

Regarding the treatment of residual waste, almost all modelled disposal options lead to a climate relief of usually 100 to 200 kg CO_2-eq/Mg. Only the option MBT (composting) + MSWI (only generation of electricity, no CHP) leads to a climate impact, see Figure 1. Background for this result are the energy demand of waste processing and the emissions from the disposal of the rotting fraction at the MBT plant. The climate impact of this demand cannot be overcompensated by the climate credits for the SRF-based energy recovery in a MSWI, which is only coupling out current.

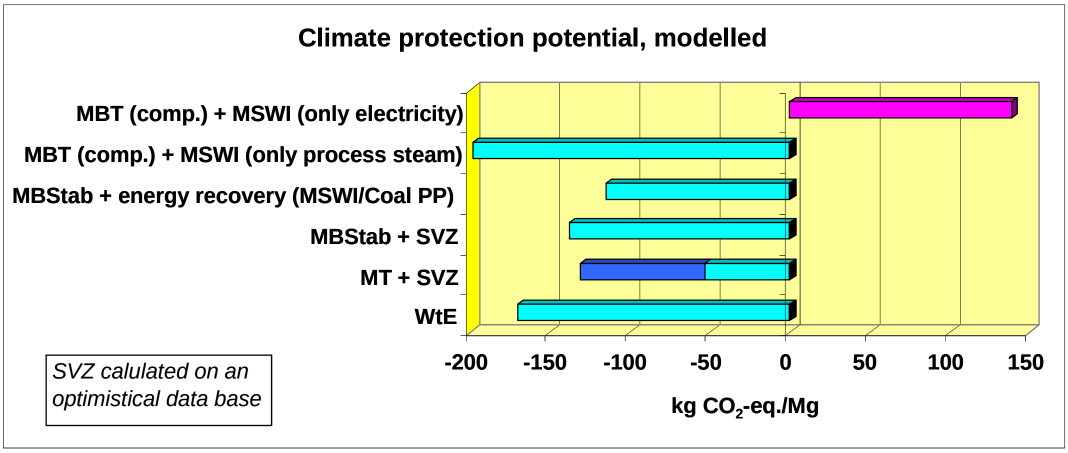

Figure 1: Climate effects of waste management in the Free State of Saxony – forecast 2005 (MT + SVZ: Range of results depending on assumptions) [Zeschmar-Lahl 2009]

More results and key messages from this study are (no highlighting in original text):
It turns out that the result is determined substantially by the emissions resulting from dumping of untreated residual waste, that hat been practiced for years and had been largely continued by mid-2005. *Measures for reducing emissions at landfills (use of landfill gas for energy generation, methane oxidation layer) lead to noticeable effects. The same applies to the waste management solutions already under construction or in the planning stage that largely dispense with landfill. Their climate-related effects consist almost entirely of credits for emission reductions compared to the equivalent processes. . . .* ***The biggest savings in climate-related emissions are achieved by avoiding methane emissions from deposition of untreated waste.*** *These savings lie one or more orders of magnitude above the savings that can be achieved by other means. Although only a rough assessment could be made – for example, the effect of a potential decline of waste amounts is not included – this statement retains its validity.*

Öko-Institut 2005 – Germany
In this study [Öko-Institut 2005] the authors regard the contribution of waste management to climate change goals set by Germany and Europe and discuss optimization potentials. The scenario of municipal waste in 2005 shows great advantages of thermal processes compared to MBT (Figure 2, left box). In contrast to other studies, only the charges from the treatment, but not the credits from the recovery of the separated fractions (energy and metal recovery) are attributed to MBT. The authors assume that 20 % of the MBT plants use anaerobic digestion as biological treatment step, and the recovered gas is used for electricity generation in a gas engine. 20 % of the MBT output are calculated to enter energy recovery. Referring to the **input of MBT**, the credits for energy recovery would result only in -206 kg CO_2-eq./Mg of residual waste (Figure 2, right box). In sum, the system MBT plus energy recovery would result in savings of 172 kg CO_2-eq./Mg residual waste (MBT input), which is below the savings of GHG emissions of direct incineration of this waste in an MSWI-plant (184 CO_2-eq./Mg).

However, here, in derogation to other studies, the separated metals (Fe and non-Fe) are balanced apart. Their inclusion will increase the credits for both scenarios. Metal removal is modelled with varying degrees: for MSWI, a separation of only 50% Fe and 10% non-Fe (aluminium) of the metal fraction of the plant input is calculated, while for MBT the spearation rates are set to 80% for Fe and to 30% for non-Fe (unfortunately the values are not listed separately). In sum, the variant MBT plus energy recovery + metal recovery will probably lead to higher credits than the variant MSWO + metal recovery.

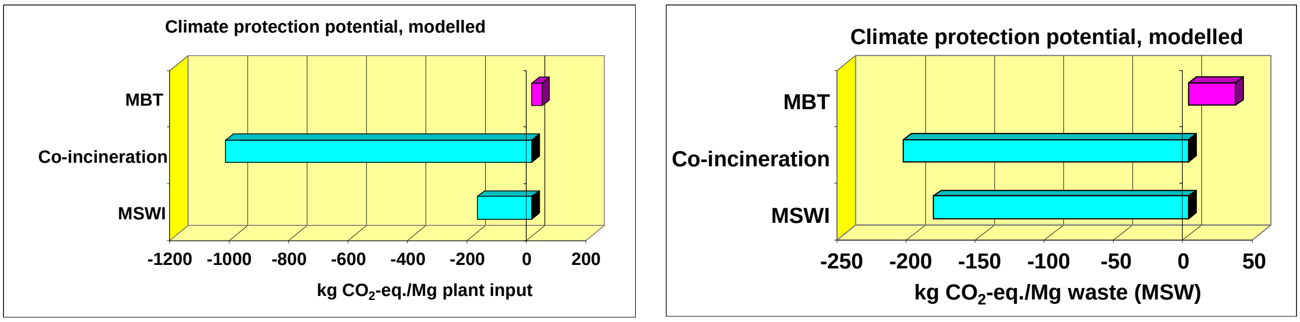

Figure 2: Results of the study by Öko-Institut (2005) based on 1 Mg plant input (left) and 1 Mg municipal waste (right) (without credits for separated metals) [Zeschmar-Lahl 2009]

"The balance for 1990 was dominated by methane emissions from landfill sites. Since the balance for 2005 is drawn up without landfill, emission reductions and balance sheet results between 2005 and 2020 are no longer possible on the scale seen between 1990 and 2005. But a potential of over 5 million t CO_2 equivalent remains as an important contribution to the German climate protection target. … On the whole, the disposal paths of waste incineration plants and co-incineration display the greatest potential for reducing emissions of greenhouse gases. Waste paper recycling is also of great importance, while all other paths make smaller contributions to climate protection, and even the expenditure involved in the collection of waste is relatively insignificant."

The authors see efficiency improvement potential in the following areas: 1. Intensification of combined heat and power generation in waste incineration plants and substitute-fuel special-purpose power plants. 2. Increased output and utilisation of process steam. 3. Input of quality-assured secondary fuels into co-incineration processes. 4. Intensification of efficient electricity generation in waste incineration plants, if possible in conjunction with combined heat and power generation.

IKr – Institut für Kreislaufwirtschaft 2006 – Bremen

The Institut für Kreislaufwirtschaft an der Hochschule Bremen has issued in 2006 on behalf of swb Erzeugung GmbH & Co. KG, Bremen an ecological and energy balance of the project MKK [IKr 2006]. The study has not been published in total, but its results were presented on a conference [Langer et al. 2007]. Some additional informations have been given by swb Erzeugung on request [Zeschmar-Lahl 2009]. At that time, swb Erzeugung planned to build a power plant in Bremen for an input of medium calorific value (11.8 MJ/kg) (Mittelkalorikkraftwerk, MKK) for energy recovery of selected non-hazardous waste fractions. The MKK plant was designed to replace the production of electricity from coal in Bremen. The plant is in operation since 2009.

Referring to the treatment of residual waste it is shown, that the existing waste fed heating plant even after optimization will not lead to savings of GHG emissions. Only energy material flow separation and using the fraction with increased calorific value for energy recovery in the MKK plant results in sum in GHG savings, see Figure 3.

The key messages of the IKr study are as follows (no emphasis in original*): „The use of waste and treated waste fractions in particular in energy-optimized systems contributes to the substitution of fossil fuels and significantly climate-related CO_2 emissions.* ***The high credits from the substitution of the current mix of Bremen, which are essentially based on the Mittelkalorikkraftwerk (MKK), makes it possible to achieve a positive climate balance in this disposal option.****"*

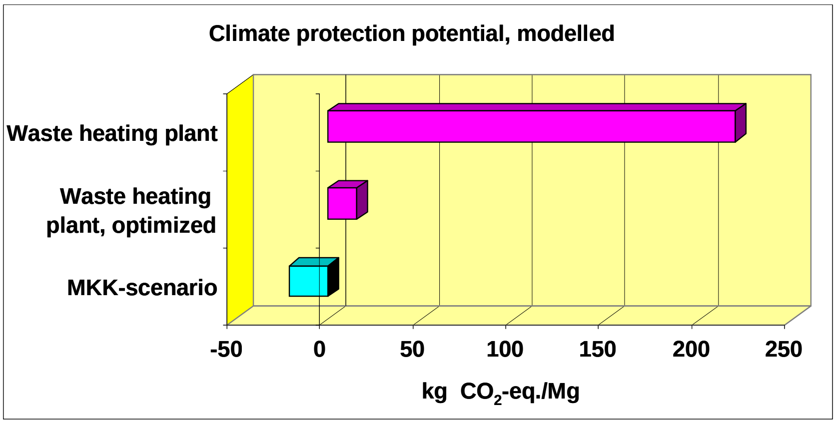

Figure 3: Ecological and energetic balancing of the MKK-project [IKr 2006] – results referring to 1 Mg municipal waste

The IKr study uses a methodical approach already applied in the cited study for Saxony [BIWA/BZL 2003]: Modeling of the electricity mix for the accounting area, here the electricity mix for the land of Bremen. This model has a significant impact on the outcome of the study: *„For interpretation of these results the high portion of the „Bremen electricity mix" generated by coal has again to be emphasized, whose substitution results in higher credits compared to the substitution of the german or the UCTPE electricity mix, resulting in an overall more positive balance. This statement applies to the Bremen site and cannot be generalized for the whole of Germany. At other sites, the respective electricity mix has to be considered, which possibly lead to relative, but to absolute CO_2 savings due to lower fossil energy components."*

Bifa 2007 – Bavaria

In recent years bifa Umweltinstitut has performed several times life cycle analyses of different waste management scenarios. In their study „Waste Management and Climate Change" [Peche et al. 2007], bifa's experts quantify the current contribution of the Bavarian waste management to reduction of greenhouse gas emissions. In addition they calculate the potentials for reducing GHG emissions for selected measures of waste reduction and recycling and estimate CO_2 abatement costs.

In Bavaria, a good 90 % of municipal solid wastes are treated in MSWI plants. Regarding the treatment options modeled, MSWI can save up to 400 kg CO_2-eq./Mg residual waste (Figure 4). MBT also causes here a positive effect. This is due to the subsequent recovery of the separated secondary materials, for example the credits for ferrous metals substituting crude steel. Unfortunately details of the modeling are not available.

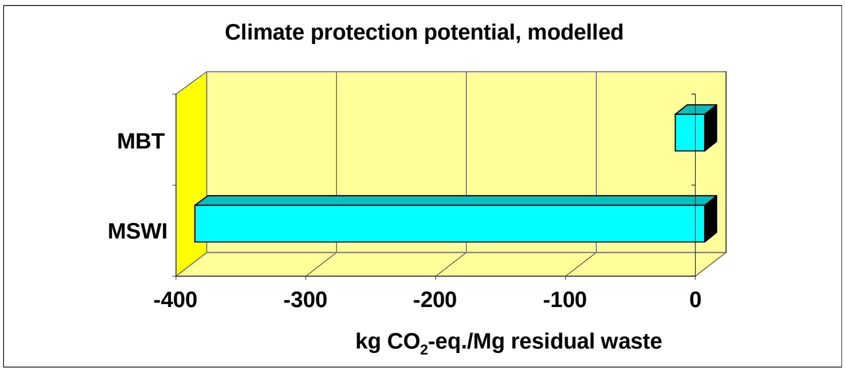

Figure 4: Climate effects of waste management in the Free State of Bavaria [Peche et al. 2007] – results referring to 1 Mg residual waste

MUNLV/IFEU 2007 – Northrhine-Westfalia
On behalf of the environmental ministry of Northrhine-Westfalia (MUNLV), IFEU has performed a life cycle analysis of thermal disposal systems for combustible wastes in this land [Fehrenbach et al. 2007]. The study includes the four MBT plants in operation, that produce solid recovered fuel from municipal waste fractions, sixteen MSWI plants, eleven coal-fired power plants and ten cement kilns. The results – see Figure 5 – in short are the following:
1. MBT with subsequent co-incineration of the SRF in cement kilns or power plants show on average a slightly better balance concerning GHG emissions and other energy-dominated categories than the disposal system of the mono-incineration in MSWI plants.
2. In case of optimal use of energy (complete steam recovery), mono-incineration systems can reach comparable results, or – depending on the individual case – be superior to co-incineration systems.
3. The climate-related results of co-incineration system are influenced mainly by three factors: a) the amount of SRF produced by waste treatment, b) the kind of the substituted regular fuel and c) the energy efficiency of the MSWI used for the disposal of the remaining fraction after mechanical-biological treatment.

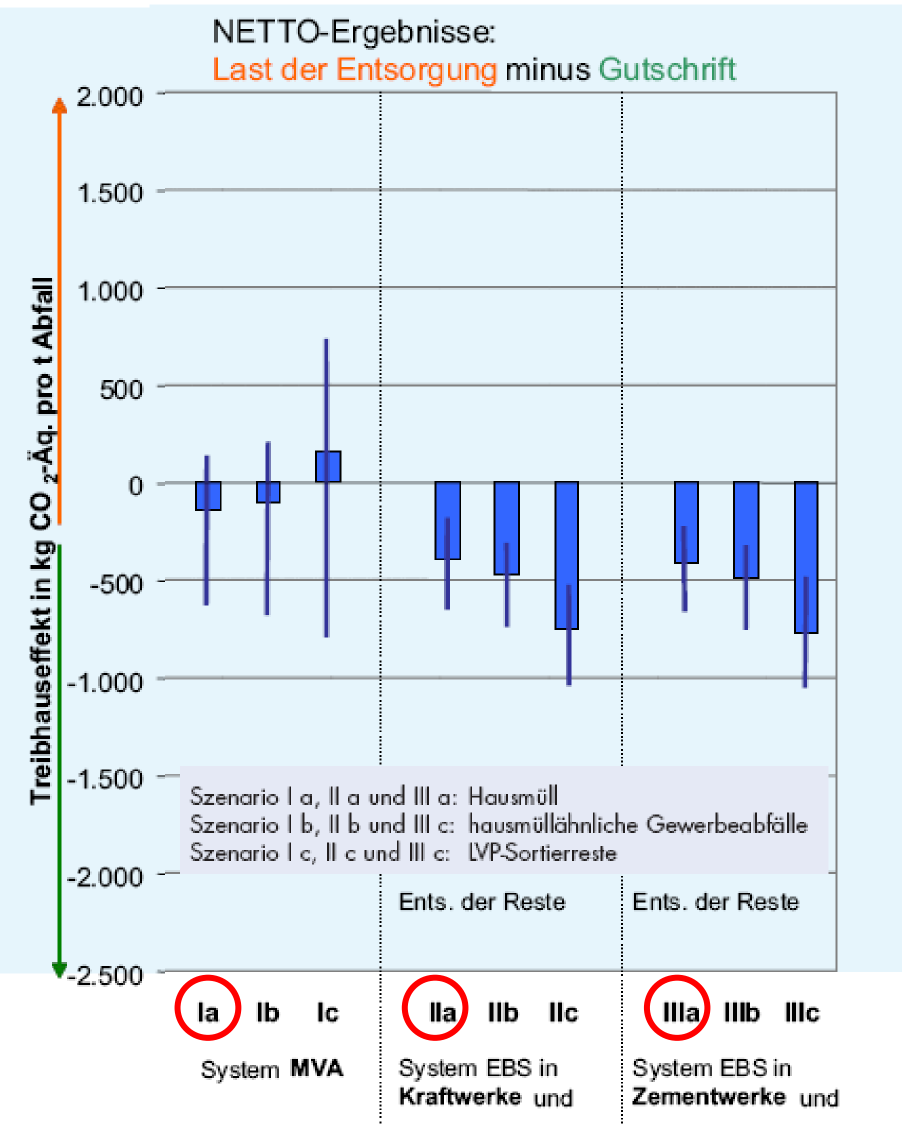

Figure 5: Climate effects of waste management in the North Rhine-Westfalia [Fehrenbach et al. 2007] – results referring to 1 Mg residual waste (I), commercial waste similar to household waste (II) and residues of sorting of lightweight packaging (III)

BIWA/BZL/Prof. Born 2009 – Saxony

In our *Study on the climate impact of waste management in the waste associations of the Free State of Saxony* [BIWA/BZL/Prof. Born 2009] we analyzed the climate impact of the waste management solutions realized by local government organisations (ÖRE/ZV) and compared them to estimations based on the planned solutions we had performed six years before [BIWA/BZL 2003].

Two local government organisations have realized solutions including an **MPS** plant – that is a mechanical treatment plant where the main fraction is dried physically (fired with natural gas). Energy recovery of its higher calorific fraction took place in different types of thermal plants like lignite fired power plant (LPP), SRF fired power plant (SRF-PP) or gasification/methanol production in the Sekundärrohstoffverwertungszentrum Schwarze Pumpe (SVZ). Figure 6 shows the climate effects of different moduls of this solution. In sum, this waste management solution does not lead to GHG emission savings. The main reason is the high energy demand of the MPS plant – especially the drying process with natural gas has strong impact on the result. Decoupling of energy and materials (methanol) does not give enough credits for compensation. The results will even deteriorate, if the power plants (SRF-PP1 and LPP1) do not have combined heat and power production, but supply only electricity, and if the energy demand of the SVZ process is higher than assumed.

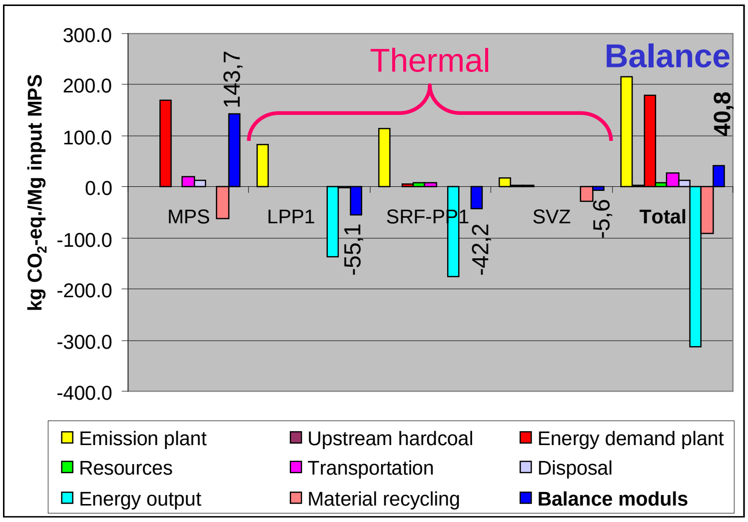

Figure 6: Climate effects of waste management in the Free State of Saxony 2006 – here: MPS + energy/material recovery [BIWA/BZL/Prof. Born 2009] – results referring to 1 Mg residual waste (input in MPS)

Three local government organisations have realized solutions including **MBS** plants – that is a mechanical treatment plant where the main fraction is dried (stabilized) biologically. Energy recovery of its higher calorific fraction took place in different types of thermal plants like lignite fired power plant (LPP), SRF fired power plant (SRF-PP) or gasification/methanol production in the Sekundärrohstoffverwertungszentrum Schwarze Pumpe (SVZ). Figure 7 shows the climate effects of different moduls of this solution. In sum, this waste management solution leads to GHG emission savings, as the coupling out of energy and material (methanol) saves more CO_2-eq. as is emitted by the energy and material demand of the system. This is mainly due to the high efficiency of the modeled CHP plants. The results will deteriorate, if the power plants (SRF-PP1 and LPP1) do not have combined heat and power production, but supply only electricity, and if the energy demand of the SVZ process is higher than assumed.

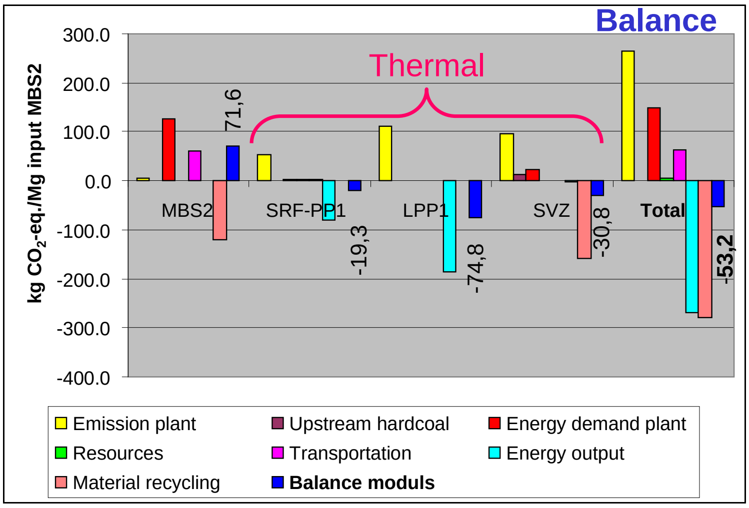

Figure 7: Climate effects of waste management in the Free State of Saxony 2006 – here: MBS + energy/material recovery [BIWA/BZL/Prof. Born 2009] – results referring to 1 Mg residual waste (input in MBS)

Three local government organisations have realized mono-incineration systems, including one MSWI plant inside and two plants outside Saxony. As a result (Figure 8), there is only a small credit for the MSWI plant inside Saxony and no credit for the plants outside. All incinerators only supply electricity, but no heat, and only one of them separates small amounts of iron scrap. The electrical efficiency for all plants is around 20%. For installations outside of Saxony, the credit for the products are not sufficient for compensating the debits from the direct emissions and other debit carriers. A major climate effect would result in the case of a combined heat and power, because then correspondingly higher credits would be granted.

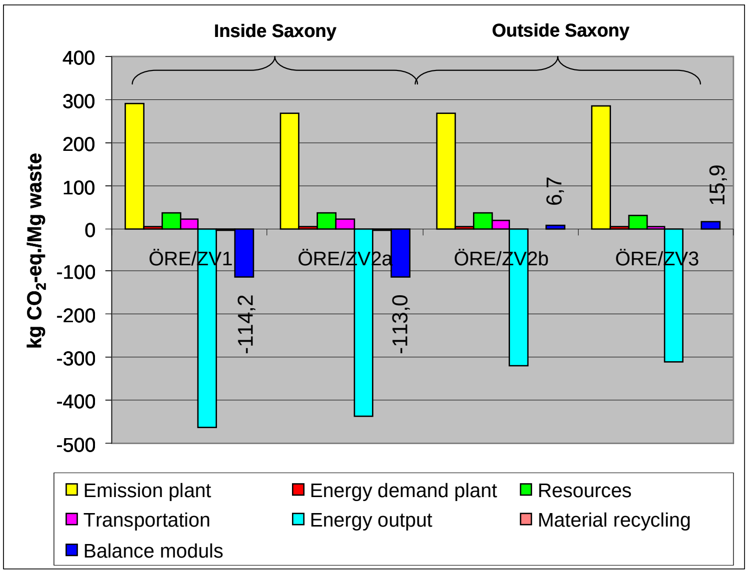

Figure 8: Climate effects of waste management in the Free State of Saxony 2006 – here: Incineration solutions realized in three waste management areas (ÖRE/ZV) [BIWA/BZL/ Prof. Born 2009] – results referring to 1 Mg residual waste

For the Saxonian MSWI plant the credit for the electricity generated was calculated with regard to the “Saxonian electricity mix” while the plants outside Saxonia were only given the credits for the “German electricity mix”. Compared to the “Saxonian electricity mix” the

“German electricity mix” is generated comparatively “clean” (higher amount of nuclear power and renewable energies): So the credit is 604 g CO_2-eq./kWh versus 915 g CO_2-eq./kWh. Hence the results obtained for power produced by plants outside Saxony (with Saxonian SRF) are about a third lower compared to the credits given inside Saxony. If for the Saxonian MSWI the “German electricity mix” would be used for granting credits, no saving of GHG emissions could be achieved.

CONCLUSION

The aggregation of the results of the studies discussed above (Table 1) shows: Under the aspect of climate impact there are only very small differences between mono- and co-incineration of solid recovered fuels (after mechanical-biological treatment). The crucial point is the energy efficiency of the thermal plants. Regarding the non-thermal plants, the energy demand and amount and quality of recyclable material output flows and even direct plant emissions are relevant for climate effects.

Table 1: Outcome of seven studies on climate impact of waste management systems

Study	Results / Climate effects
BIWA/BZL 2003	Almost all variants of waste treatment lead in sum to a reduction of GHG emissions, depending on the modeling of the case. Only the system MBT can lead to climate impact in case of poor energy recovery.
Öko-Institut 2005	Co-incineration solutions currently lead to a significantly higher to a reduction of GHG emissions than MSWI does. Optimization potentials are available. The system MBT leads to climate impact.
IKr 2006	Reduction of GHG emissions by MKK (power plant using SRF with a medium calorific value), if electricity based on charcoal is substituted.
Bifa 2007	Big climate relief potential for MSWI, and small (but existent) for MBT.
IFEU 2007	In general environmental relief, depending on the efficiency of thermal treatment plants; depending on energy efficiency, MSWI may be superior to co-incineration.
BIWA/BZL/ Prof. Born, 2009	Result (climate relief or impact) depending mainly o the energy efficiency of especially thermal plants and – in the special case of the Free State of Saxony – on the kind of energy substituted.
In general	The result is substantially provided by the energy efficiency of the recovering plant (MSWI, SRF fired plant). For MBT, the modeling of the case is mainly determining the result.

Consideration of other environmental impact categories in LCA studies [Fehrenbach et al. 2007] does not lead to fundamentally different results. In sum, achievable environmental benefits are depending on the constellation of the case, e.g. on the energy efficiency of the plants or the total system, the credits for the chosen equivalence processes (e.g. non-ferrous metals) and – for the non-climate-related impact categories – the emission standards of the plants.

The studies performed for Saxonia and Bremen show the great influence of the chosen equivalence process for electricity. “Greening” of electricity production in Europe will make such balances in the future more difficult – the higher the share of renewable energy sources in the selected electricity mix, the lower the credits for the substitution of this electricity. Some experts try to solve this problem by granting credits for the substitution of electricity produced by e.g. peak load power stations [BMU 2008]. With the increase of material recycling, this problem may also arise in the calculation of credits for output for material recycling. On the other hand, the scarcity of non-renewable resources will increase the importance of material recycling yet and thus quantify the actual credit level.

ACKNOWLEDGEMENTS

The investigation is part of a study commissioned by the Saxon State Office for Environment, Agriculture and Geology, Dresden.

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