Comparison of Methods for the Treatment of Mixed Municipal Waste from Households

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Vergleich von Verfahren zur Behandlung von gemischten Siedlungsabfällen aus Haushalten

Abstract

The “biological-thermal-way” for treatment of municipal solid waste (MSW) in the Styria region has been compared to the “thermal-only-way” by ecological and economical operating figures. The method of the study was to list data of 10 mechanical treatment plants (MTs), 6 biological treatment plants (BTs), 5 thermal treatment plants (TTs) and 4 landfills (LFs) in order to generate mass balances, energy balances, greenhouse gas emission balances as well as cost-balances. The study shows the commitment of the Styrian region to the principle in waste management “recycling before disposal“, mainly seen at the landfill volume demand which is considerably low (0.35-0.4 m³/t MSW). The greenhouse gas emission calculation includes the substitution of fossil energy sources according the applied method from the Intergovernmental Panel on Climate Change (IPCC). The study showed that the replacement of coal by natural gas can change considerably the greenhouse gas emission balance of the waste management in a region. The energy-balances, greenhouse-gas emission balances and cost balances of the mechanical-biological-thermal waste treatment concept and the single thermal waste treatment concept with heat recovery and electricity production showed similar results.

Inhaltsangabe

Der biologisch-thermische Weg der Behandlung von Restabfall in der Steiermark wurde mit dem rein-thermischen Weg an Hand ökologischer und ökonomischer Kennzahlen grundlegend verglichen. Für die vorliegende Studie wurden Daten von 10 mechanischen Abfallbehandlungsanlagen, 6 biologischen Abfallbehandlungsanlagen, 5 thermischen Abfallbehandlungsanlagen und 4 Deponien erhoben, um Massebilanzen, Energiebilanzen, CO_2-Bilanzen und Kostenbilanzen zu erstellen. Die Studie zeigt, dass sich die Steiermark zum abfallwirtschaftlichen Grundsatz „Verwerten vor Beseitigen“ bekennt, was insbesondere im relativ geringen Deponievolumenverbrauch von 0,35 bis 0,4 m³/t Restmüll zum Ausdruck kommt. Die CO2 Bilanz inkludiert die Substitution von fossilen Energieressourcen entsprechend den Vorgaben des Intergouvernemental Panel of Climate Change (IPCC). Die Studie zeigte , dass der Ersatz von Steinkohle durch Erdgas die CO2 Bilanz der Abfallwirtschaft einer Region signifikant verändern kann. Die Energie- CO2- und Kosten-Bilanzen des steirischen MBA-Konzepts bzw. des rein thermischen Abfallbehandlungskonzeptes mit Strom und Abwärmenutzung haben annähernd vergleichbare Ergebnisse geliefert.

Keywords

MBA, thermische Abfallbehandlung, Energiebilanz, CO2-Emissionen, Restmüll

MBT, thermal waste treatment, energy-balance, greenhouse gas emissions, MSW

1 Introduction

The aim of the present study was a reliable comparison of two main municipal solid waste (MSW) treatment methods, the biological-thermal way and the thermal-only way. The biological-thermal method includes mechanical pre-treatment to separate the MSW mainly in two fractions, one for composting (undersize fraction) and the other for incineration (oversize fraction), i.e. Solid Recovered Fuel. The subsequent biological and thermal treatments produce compost as a biologically stable product and incineration residues both for disposal in landfills.

In the Austrian province of Styria the biological-thermal treatment of MSW starts in the 1990s and was established for the whole region in 2004 to comply with the Austrian Landfill Ordinance. Because of continuous discussions between stakeholders of the two treatment ways reliable parameters would help to gain objective evidence of the pros and cons of the two methods for a whole region.

Three criteria should be evaluated by the present study:

1) economy (treatment costs without profits and losses),
2) global warming potential (greenhouse gas emissions, energy balance sheet) and
3) regional impact (jobs, surplus treatment capacities, number of treatment companies, waste fee for the average household).

In this paper MSW means residual waste from households. In the region of Styria besides the residual waste bin further separate collection from households exists for organic waste, for paper and cardboard waste, for plastic and metal packaging waste and for bulky waste. In 2007 there were produced 123 kg of residual waste per capita.

2 Method

Sources of the numerous data were the official data of the Styrian Government, Department 19D “Waste and Material Flow Management”, plant visits and answers of plant operators to a questionary. Furthermore numerous literature was consulted.

The actual MSW treatment situation of Styria is the biological-thermal way which is described for the year 2007. Two thermal-only treatment plants in neighbouring regions were chosen to describe alternative scenarios, called the “Thermal-only way 1” and the “Thermal-only way 2”. For these scenarios it was assumed to bring 100% MSW of Styria to these thermal treatment plants (TTs), as if there existed no biological-thermal treatment.

So three models were calculated:

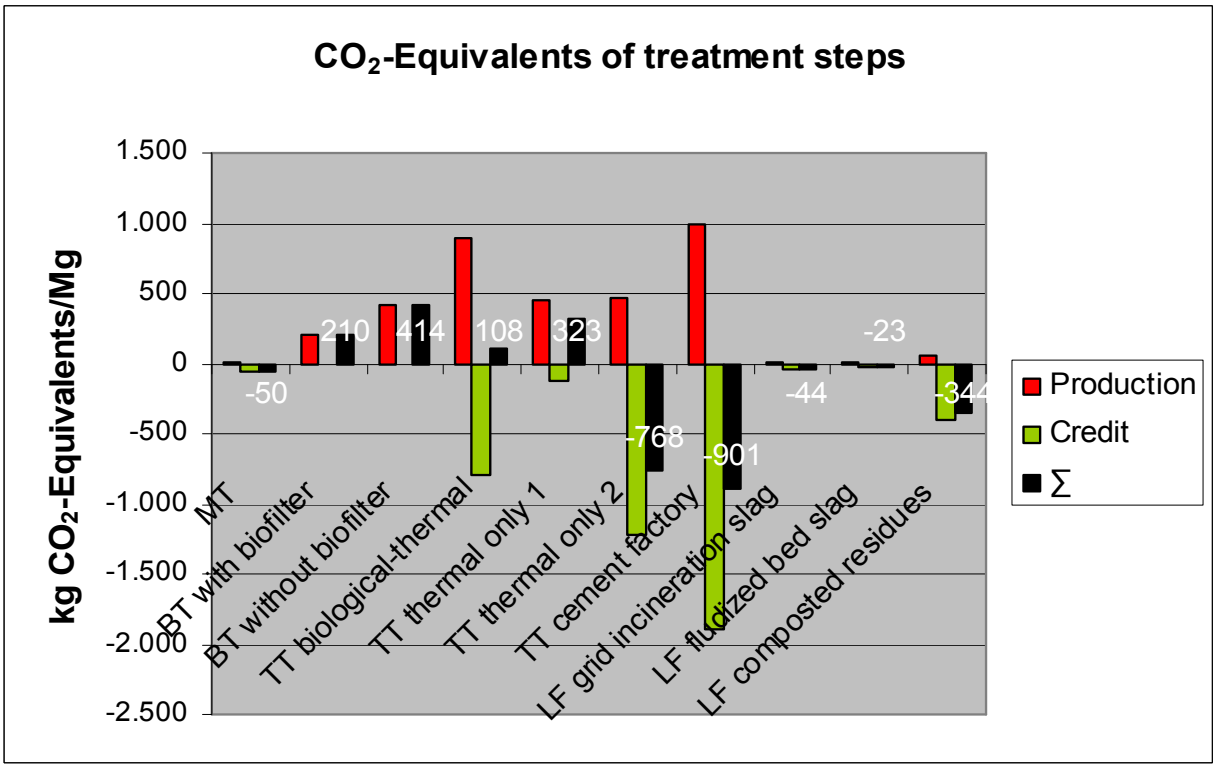
1. “Biological-thermal”, i.e. actual situation of Styria in 2007: The >80 mm oversize fraction (36% of MSW) is brought to two fluidized bed incineration TTs, both supplying electricity and steam to neighboring industry plants, a fibre factory and a paper factory. The energy efficiency factors of the TTs are 9.4 and 12.8% net electric efficiency (production minus consumption) and 57.2% and 63.5% net heat efficiency. Minor quantities of the oversize (6% of MSW) were brought to a cement factory. 55% of MSW were brought to biological treatment plants and 3% of MSW were metal fractions for recycling.

2. „Thermal-only 1“, i.e. complete thermal treatment in a grid incineration TT in Upper Austria, where electricity is produced for the grid. The net electric efficiency factor is 18.6% (Boehmer et al. 2007).

3. “Thermal-only 2”, i.e. complete thermal treatment in a grid incineration TT in Lower Austria, where electricity and steam are produced. The steam goes to a neighboring coal power plant. The energy efficiency factors are 12.8% net electric efficiency and 16.4% net heat efficiency (Anonymous 2007). The net heat efficiency includes the efficiency of the coal power plant of 42.6% (electricity only).

The method of the study was to list data for 10 mechanical treatment plants (MTs), 6 biological treatment plants (BTs), 5 thermal treatment plants (TTs) and 4 landfills (LFs) to generate a mass balance, an energy balance, a greenhouse gas emissions balance (Eggleston et al. 2006) as well as a calculation of the treatment costs. Waste collection was excluded from the study. Transport expenditures start at the MTs and end up at the LFs or at recycling plants (steel mill, aluminium mill, cement plant). This was done for each single plant and afterwards the overall sum was calculated to get the figure for the whole region. At the end a sensitivity analysis was made to identify crucial input parameters of the calculation.

In Figure 1 the greenhouse gas emissions balances of all observed treatment steps, separated in production, credits and summation are shown.



MT Mechanical treatment plant, BT Biological treatment plant, TT Thermal treatment plant, LF Landfill

Figure 1: Greenhouse gas emissions balances of all observed treatment steps, separated in production, credits and summation. Production (positive figures) includes fossil CO2-equivalents emissions by energy consumption and burning of fossil carbon waste composites (plastic). Credits (negative figures) include the replacement of fossil fuels by the production of heat, electricity and scrap and carbon storage via the compost disposal to the LFs

3 Results

In Styria in 2007 145.785 Mg of municipal solid waste were produced. The waste was delivered to 10 MTs for pre-treatment. There 79.573 Mg of undersize material (<80 mm) were separated and sent to 6 BTs for composting. 61.122 Mg of oversize material (>80 mm) from the MTs were sent to 2 TTs. Additionally 5.301 Mg of magnetic and non-magnetic metal scrap were separated in the MTs from the MSW. The quantity of the MSW input was reduced to 62.742 Mg (42%) due to the gaseous losses during composting and incineration. Finally 54.649 Mg (38%) were disposed to LFs. In Figure 2 the specific demand of landfill volume per Mg MSW is shown for the biological-thermal way and the two thermal-only scenarios.

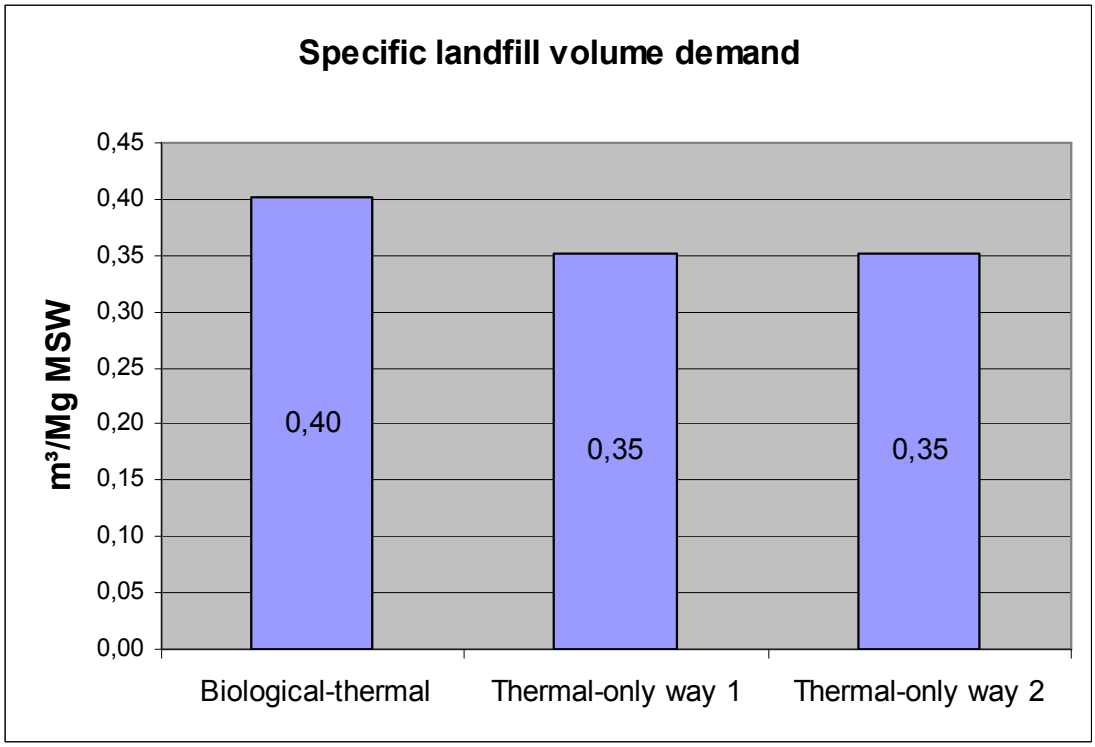


Figure 2: Specific demand of landfill volume after MSW treatment of the biological-thermal way (i.e. Styria in 2007) compared with the scenarios "Thermal-only way 1" and "Thermal-only way 2"

The energy balance of the MSW-treatment in Styria in 2007 showed up a total account of 116 GWh, which could be generated from the waste in the energy forms electricity and heat. The specific energy balance was -793 kWh/Mg MSW (the negative figure represents accounts), those of the thermal-only ways was -821 kWh/Mg and -308 kWh/Mg, see Figure 3.

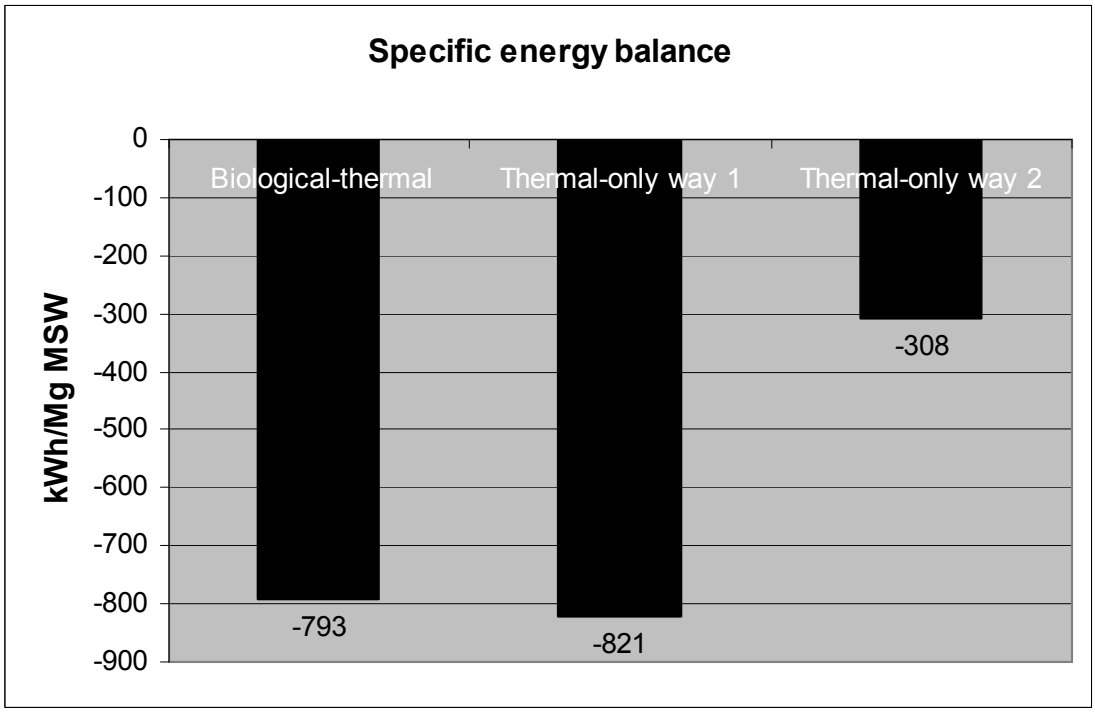


Figure 3: Specific energy balance of the biological-thermal way (i.e. Styria in 2007) compared with the scenarios "Thermal-only way 1" and Thermal-only way 2"

The costs of the MSW-treatment in Styria in 2007 run up to € 13 million for treatment without profits and losses. The specific costs of the MSW-treatment run up to 89 €/Mg, those of the thermal-only ways to 94 €/Mg (+ 6%) and 133 €/Mg (+ 49%), see Figure 4.

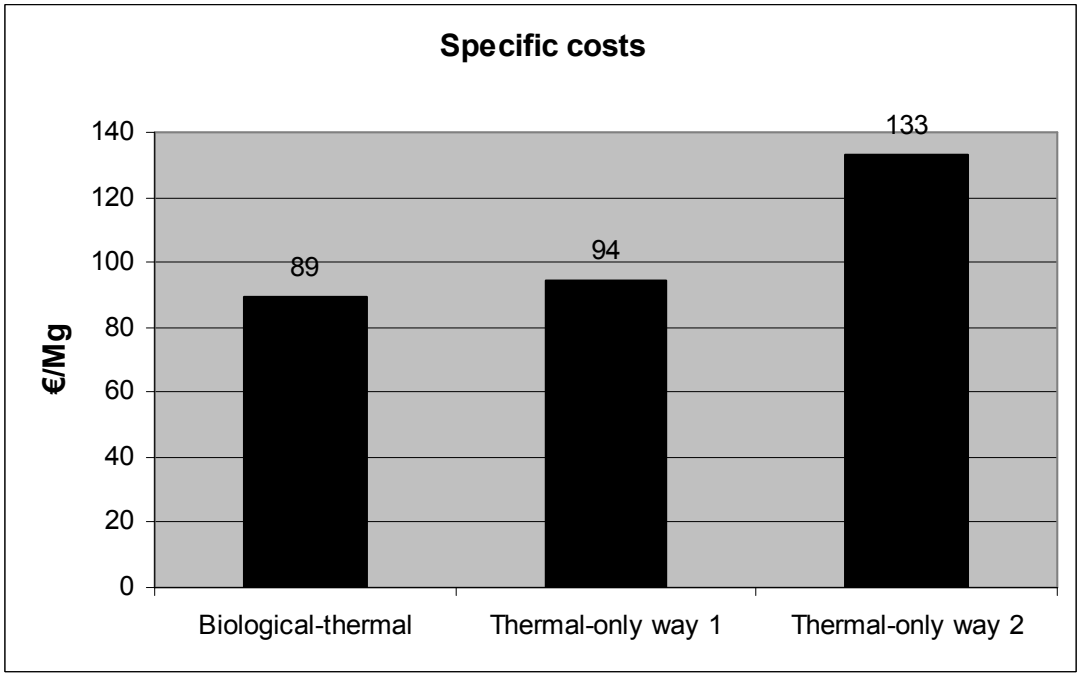


Figure 4: Specific costs of MSW treatment of the biological-thermal way (i.e. Styria in 2007) compared with the scenarios "Thermal-only way 1" and Thermal-only way 2" (without profits and losses)

Specific costs of MSW-treatment of Styrian plants are 14-40 €/Mg for MTs, 30-55 €/Mg for BTs, 34-122 €/Mg for TTs and 39-50 €/Mg for LFs.

The greenhouse gas emission balance results of MSW-treatment in Styria in 2007 show an overall credit of 7 Gg CO2-Equivalents, i.e. more CO2-Equivalents were avoided than produced. The specific CO2-Equivalents emissions run up to -48 kg/Mg MSW (credit) for the biological-thermal way, -771 kg/Mg MSW (credit) for the thermal-only way 1 and +327 kg/Mg MSW (emission) for the thermal-only way 2, see Figure 5.

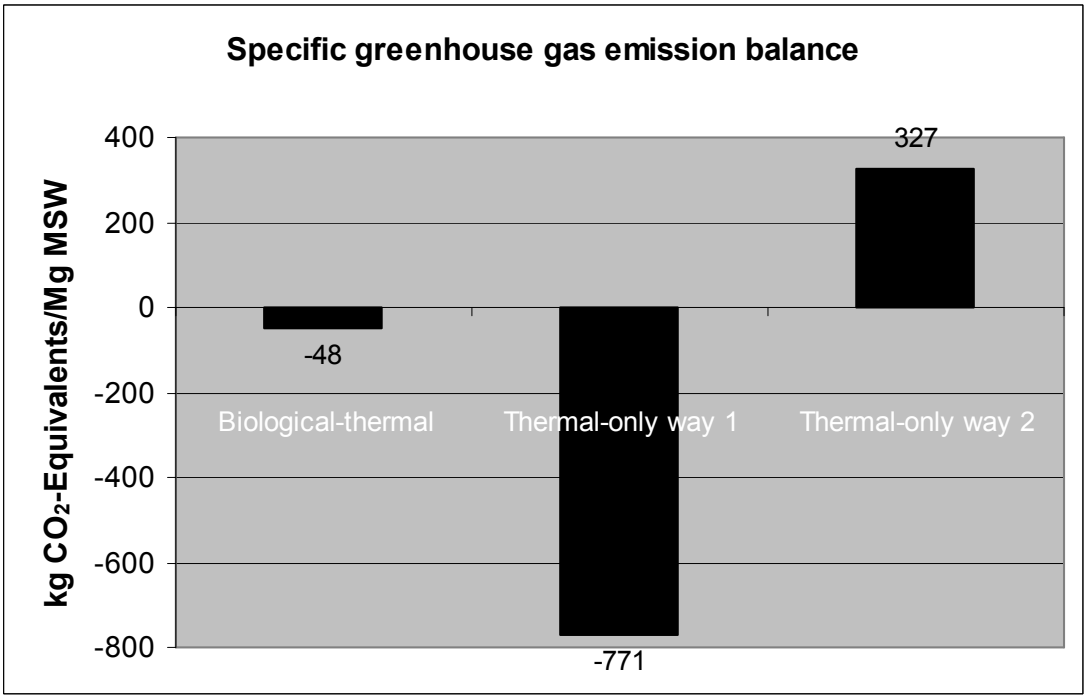


Figure 5: Specific greenhouse gas emission balance of the biological-thermal way (i.e. Styria in 2007) compared with the scenarios "Thermal-only way 1" and "Thermal-only way 2" (negative figures represent credits, positive figures represent emissions)

The sensitivity analysis for the scenario "Thermal-only way 1" shows a crucial influence of the replaced fossil energy source, e.g. if natural gas is replaced instead of coal by the steam production of the TT for the neighboring power plant, see Figure 6.

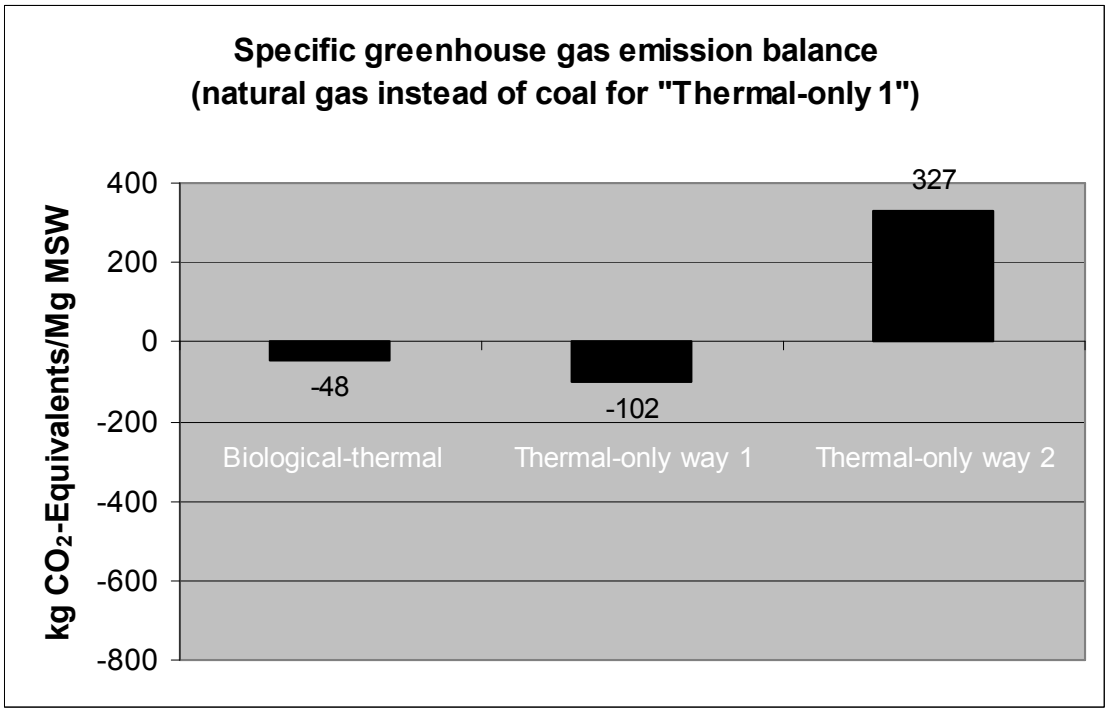


Figure 6: Sensitivity analysis for the scenario "Thermal-only way 1". Natural gas was replaced instead of coal by the steam production in the TT for the power plant. The biological-thermal way and the thermal-only way 2 were not changed.

Specific greenhouse gas emissions of MSW-treatment of Styrian plants are -7 to -84 kg CO2-Equivalents/Mg for MTs (credits for scrap recycling), 187 to 414 kg CO2-Equivalents/Mg for BTs (mainly by CH4-emissions), -901 to +169 kg CO2-Equivalents/Mg for TTs and 0 to 0,3 kg CO2-Equivalents/Mg for LFs.

Up to now no correlation between way of treatment and disposal fees for households was found (Anonymous 2005b). Available data vary notably and are difficult to compare because the costs are related to different household-units, e.g. per household or per bin in combination to the disposal interval. Furthermore the definition of the related unit sometimes is different, e.g. 3-person household or 4-person household. However a comparison was done and shows a cheap waste disposal fee in Styria compared to Vienna and the medium Austrian fee. Compared to Bavaria and Germany fees are similar, see Figure 7.

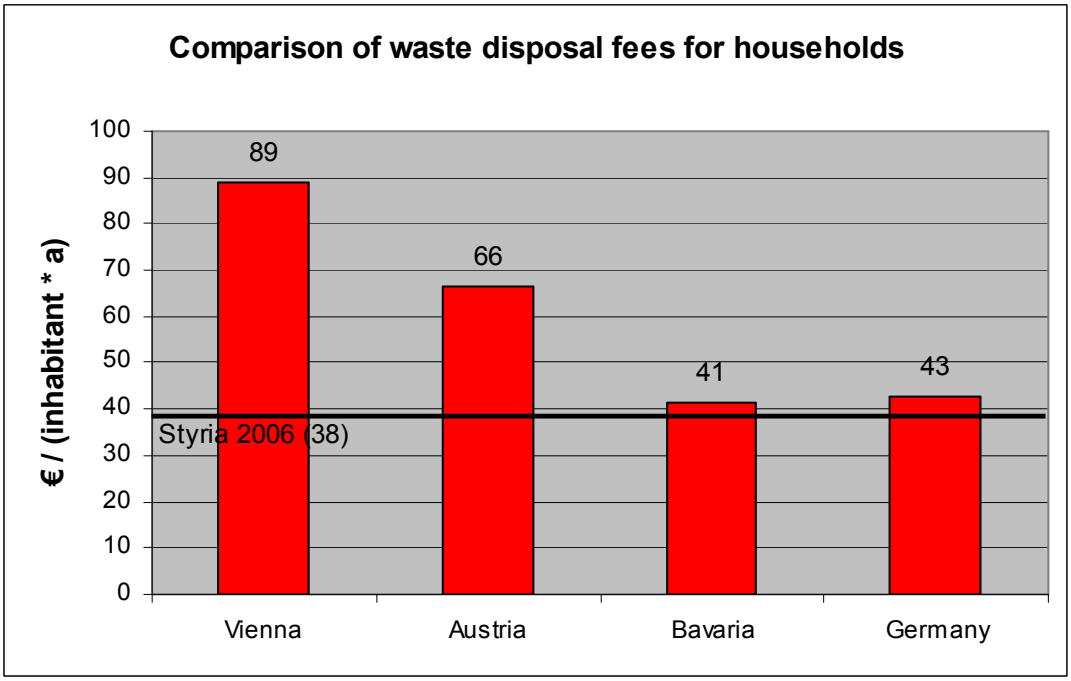


Figure 7: Comparison of waste disposal fees for households in different regions (Rogalsky 2008, Himmel 2008, Anonymous 2008)

The most important results are summarized in Table 1.

Table 1: Overview of the results of the biological-thermal way (i.e. Styria in 2007) compared with the scenarios "Thermal-only way 1" and Thermal-only way 2". Mg refers to Mg Input MSW. Negative figures represent credits.

	Biological-thermal	Thermal-only way 1	Thermal-only way 2
Energy balance	-793 kWh/Mg	-821 kWh/Mg	-308 kWh/Mg
Treatment costs	89 €/Mg	94 €/Mg	133 €/Mg
Greenhouse gas emission balance	-48 kg/Mg	-771 kg/Mg	327 kg/Mg
Landfill volume demand	0,4 m³/Mg	0,35 m³/Mg	0,35 m³/Mg
Jobs	50	39	48

4 Conclusions

The present study shows the commitment of the Styrian region to the principle in waste management "recycling before disposal" (Anonymous 2005a), mainly seen at the landfill volume demand which is considerably low (0,35-0,4 m³/Mg MSW). Above that the results give approaches to enhance this principle:

- There is still potential to reduce the organic content of residual waste. This fraction should be shifted to the organic household waste bin by the resident himself for subsequent recycling in the form of compost.

- 5 of 10 mechanical waste treatment plants of Styria do not apply eddy current separators to gain non-ferrous scraps and this valuable fraction is still disposed to landfills. There should be a legal obligation for the operators to recycle non-ferrous metals.

- The quality of ferrous and non-ferrous scraps is improvable. Now the scraps still contain considerably quantities of non-metal contaminants (up to 30%, mainly plastic and textiles). To enhance recycling of metals and improve the purity of the metal waste fraction the existing separate collection of metal packaging material should be enlarged for any kind of metals. Furthermore the use of combined screening and ballistic separation instead of usual screening and wind sifting would produce considerably better scrap purities.

The greenhouse gas emission calculation includes the substitution of fossil energy sources according the applied method from the Intergovernmental Panel on Climate Change (IPCC) (Eggleston et al. 2006). The study showed that the replacement of coal by natural gas can change considerably the greenhouse gas emission balance of the waste management of a region even though it does not have to do anything with the waste business. However the mixture of fossil energy source varies from region to region. So a comparison of the greenhouse gas emissions from waste management of two regions must consider this fact.

The disposal of waste residues to landfill rank among the duties of waste management. Applying the biological-thermal treatment of MSW the piling of carbon within the landfills reduces CO2-emissions. Even though they are non-fossil they help to reduce the release of CO2 to the atmosphere. The thermal-only way is not able to pile carbon in landfills.

The criteria for choosing one of the two investigated ways of treatment for a certain region are mainly the population density and the existence of relevant industry with capacities for waste incineration for heat and power generation. Positive criteria for the biological-thermal way are:

- Low population density (<200 inhabitants/km²)

- Easily accessible industrial waste incineration plants >40 MW input heat capacity

- Political commitment for a maximum recycling of wastes

- Existing mechanical and biological treatment plants, which show flexibility towards changes

Positive criteria for the thermal-only way are:

- High population density (>200 inhabitants/km²)
- Suitable sites for the operation of thermal-only incineration plants
- Reliability of waste management planning for about 20 years.

The present study for the Styria region with 1.2 million inhabitants and the surface area of 16,392 square kilometres shows that both ways do achieve similar energy balances, costs and greenhouse gas emission balances. However the results depend strongly on the regional characteristics.

The advantages of the biological-thermal way are:

- Flexibility towards changes in waste quantities and waste composition
- General recycling enhancement
- Strengthening of the region: economic diversity, more jobs in the region, the waste treatment know-how stays within the region, low waste fees for households
- Public acceptance of smaller treatment units
- Minimisation of transport expenditures
- Carbon storage within landfills

5 Literature

Anonymous 2005a Landes-Abfallwirtschaftsplan Steiermark 2005. Government of Styria, Department 19D „Waste and Material Flow Management“, Graz.

Anonymous 2005b *Einflussfaktoren auf die Höhe der Müllgebühren. Kammer für Arbeiter und Angestellte, Wien. www.arbeiterkammer.at/bilder/d49/InformationenUmweltpolitik164.pdf (Jan. 12, 2009)*

Anonymous 2007 *EVN Nachhaltigkeitsbericht 2006/07. Energie Versorgung Niederösterreich, Maria Enzersdorf.*

Anonymous 2008 *Abfallgebühren in Bayern liegen deutlich unter Bundesdurchschnitt. Euwid No. 25 on Jun. 17, 2008, pp. 25*

Böhmer, S., Kügler, I. Stiober, H. & Walter, B.	2007	*Abfallverbrennung in Österreich - Statusbericht 2006. UBA Report 0113. Umweltbundesamt GmbH Wien.*
Eggleston, S., Buendia, L., Miwa, K. Ngara, T. & Tanabe, K.	2006	*2006 IPCC Guidelines for National Greenhouse Gas Inventories. Published by the Institute for Global Environmental Strategies (IGES), Hayama, Japan;* www.ipcc-nggip.iges.or.jp/public/2006gl/index.html *(Jan. 12, 2009)*
Himmel, W.;	2008	*Die Zukunft der Müllgebühren bei steigenden Sekundärrohstoffpreisen. Presentation at the Entsorgungstag 2008 Vösendorf. Department 19D „Waste and Material Flow Management", Government of Styria.*
Rogalsky, W.;	2008	*Sammlung und Behandlung biogener Abfälle in Wien. Presentation at the ERFA Wels 2008. Department 48, Municipality of Vienna.*

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