Waste Management, Energy Use and Reduction of Greenhouse Gas Emissions

Bernt Johnke Umweltbundesamt Berlin and Martin Treder MVA Hamm

1. Introduction

Although the Kyoto Protocol has not yet been ratified internationally, climate protection – through future CO_2 emissions trading – has an ever larger role to play in economic decision-making, among the public and in political debates. The manufacture of products and trade in goods normally give rise to greenhouse gas (GHG) emissions and to residues that must be disposed of.

The residues generated[1] must be subjected to environmentally compatible treatment. The following contribution looks at waste management in the light of energy and climate-relevant aspects, starting out from the fact that harnessing the energy potential contained in waste is also becoming increasingly important in waste management, having regard to climate protection.

Waste management's relevance to climate aspects results not only from the emissions of methane (CH_4) from landfills or the emissions of carbon dioxide (CO_2) from municipal solid-waste (MSW) incineration plants. Waste management has various interfaces with other sectors which likewise affect, positively or negatively, climate-relevant processes.

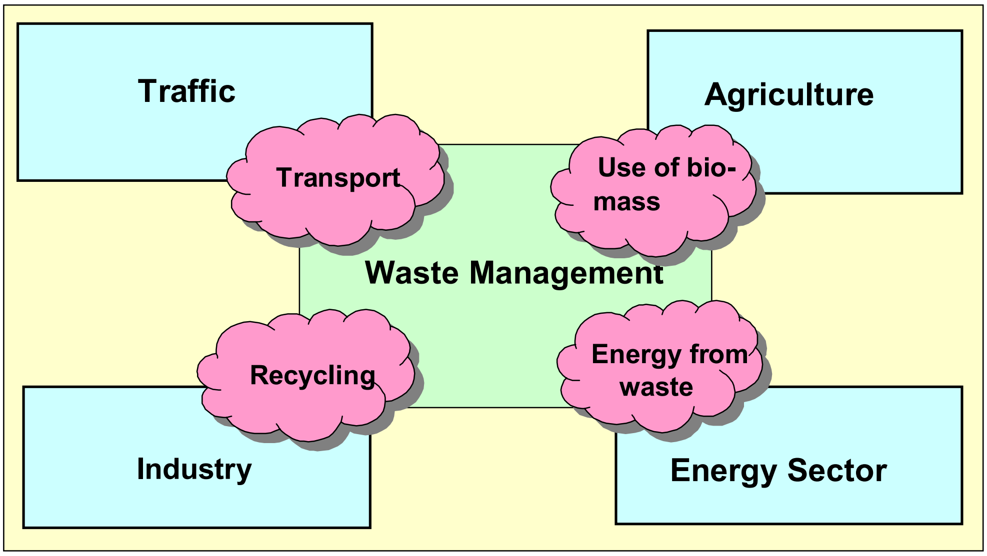

Figure 1: Interfaces between waste management and other sectors

[1] Waste prevention and reduction must be discussed elsewhere as this would go beyond the scope of this paper.

Recycling can reduce GHG emissions from goods manufacture in the various industrial sectors while the use of waste for energy recovery saves fossil fuels.

2. Climate-relevance of landfills and municipal waste incineration plants

The Kyoto Protocol distinguishes between six sectors that are regarded as particularly climate-relevant worldwide. It aims to reduce six gases in particular, whose global warming potentials (GWP) differ widely. To ensure comparability, their GWPs are normalised to CO_2. Methane, for example, is 21 times more harmful to the climate than CO_2. Biogenic CO_2 emissions are figured as zero.

The climate-relevant emissions of a country are determined according to the IPPC “Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories” [1 – IPPC, 2000]. This guidance document prescribes which GHG emissions from various sectors (see Table 1) need to be determined and how this has to be done.

The waste sector is subdivided into CH_4 emissions from solid waste disposal sites, CH_4 and N_2O emissions from wastewater handling, and emissions from waste incineration without energy recovery. In Germany, only methane emissions from landfills are reported separately in the Waste Sector, at present. The CO_{2eq} emissions of the 56 conventional MSW incineration plants in Germany are reported in the Energy Sector.

Table 1 below shows the development of GHG emissions [2 – EEA (2003)].

Table 1: **GHG emissions in Germany**

Sector	In million t CO_{2eq} 1990	1995	2001	Development 1990 – 2001 [%]
Energy processes	1,036.0	910.3	874.4	-15.6
Industrial processes	67.9	66.6	43.2	-36.4
Solvent and other product use	1.9	1.9	1.9	0.0
Agriculture	81.7	67.5	65.2	-20.2
Waste (landfills)	30.6	14.4	10.6	-65.4
Land-use change and forestry	-33.7	-33.4	-23.7	29.7
Total	**1,184.4**	**1,027.3**	**971.6**	**-18.0**

In percentage terms, the waste sector (landfills) has achieved the largest reductions compared to the other sectors. This trend will continue as a result of waste management measures, particularly implementation of the Landfill Ordinance.

It is known from climate-related calculations [3 – Johnke (1999)] that CO_2 is the greenhouse gas with the highest emissions in waste incineration, exceeding emissions of the other greenhouse gases (e.g. N_2O) by at least a factor of 100. In landfill, CH_4 is the primary GHG. A comparison of GHG emissions from waste incineration and from landfill is presented in Table 2. MSW incineration's share of total CO_2 emissions is well below 1%.

CH_4 emissions from the annual quantity of untreated biogenic mixed waste going to landfill account for about 18.4% of total CH_4 emissions and about 1.4% of total CO_2 emissions.

Table 2: GHG emissions from MSW incineration and landfill

Emission in 2002 [million t CO_{2eq}]	Total emissions	Landfill	MSW incineration
Carbon dioxide CO_2	863.5		6.45
Methane CH_4	74.5	13.7	
Nitrous oxide N_2O	49.5		0.03
HFCs	8.2		
PFCs	0.7		
SF_6	4.1		
Total	**1000.5**	**13.7**	**6.49**

Note: The figures on total emissions for 2002 come from an UBA survey as yet unpublished [4 – Umweltbundesamt (2003)] and are not temperature-corrected. Landfill emissions refer to waste quantities in 2000 and an activity over 20 years. Emissions from MSW incineration refer to waste quantities in 2001.

Energy generation contributes about 640 million t and the transport sector about 190 million t to total CO_2 emissions in Germany, of 863 million t (2002). CO_2 emissions from MSW incineration, at 6.45 million t, are about 1% of those from energy production.

3. Waste incineration's energy recovery and climate protection potential

The following deals with five subject areas, whose implementation could make a significant contribution to energy recovery and climate protection.

<u>Implementation of the Ordinance on the Landfill of Waste</u>

Waste management is among the most intensely regulated and monitored industrial sectors. It must be noted nonetheless that national waste statistics are neither up-to-date nor harmonised, reliable or sound. Even the waste category "waste from human settlements" shows enormous variations in reported quantities [5 – Treder (2003)].

According to the Federal Statistical Office, a total of some 49 million t of waste went to landfill in Germany in 2000, of which about 19.6 million t are classified as biological/organic mixed waste [6 – Johnke (2003)]. Multiplication of this quantity of waste by the relevant emission factor, which varies between 33 and 52 kg CH_4/t of waste/year according to the extent to which landfill gas is collected and the waste is pretreated, gives an annual methane load between 0.6 and 1.0 million t, equivalent to c. 13.7 to 21.4 million t of CO_{2eq} per year. In terms of specific emissions, this comes out to c. 0.7 – 1.0 t of CO_{2eq} per 1 tonne of untreated mixed organic waste landfilled.

Therefore, termination of the landfill of mixed biological/organic waste from 1 June 2005 as required by the Ordinance on the Landfill of Waste (Abfallablagerungsverordnung – AbfAblV) will make a contribution to climate protection.

The 19.6 million t of mixed biological/organic waste which at present still go to landfill without prior treatment, have an energy potential of nearly 44 TWh/year, or 156 million GJ/year (19.6 million t of waste x calorific value of 8 GJ/t waste).

If the 19.6 million t of waste currently landfilled without prior treatment were treated thermally in MSW incinerators, the resulting contribution to CO_2 (from the fossil waste fraction) would amount to c. 7.6 million t of CO_{2eq}. Energy recovery from this waste would result in a potential CO_2 reduction of c. 8.7 million t (based on a total energy-recovery efficiency of 20% electricity and 50% heat), as this energy would replace energy from fossil fuels.

Energy saving through recycling

Recycling is an essential element of waste management. By resulting in indirect energy savings, it normally contributes to an efficient use of primary energy and, therefore, to climate protection.

The following example illustrates waste recycling's current potential for indirect energy saving and contribution to CO_2 reduction in Germany.

The manufacture of products leading to 1 kg of waste requires on average 30 MJ of energy. The energy saving achieved when recyclable waste is recycled amounts to c. 12 MJ per kg of waste (including collection and transport), i.e. the manufacture of a new product from recyclable waste requires only 18 MJ instead of 30 MJ [7 – Johnke (1992)].

In Germany, the annual quantity of municipal waste for recovery is c. 21.5 million t (2000) [6 – Johnke (2003)]. Some 3 million t of waste destined for energy recovery has to be subtracted from this amount. Based on a specific energy saving of 12 MJ, recycling thus achieves a total indirect energy saving of 220 million GJ.

Assuming that the energy saved is exclusively electricity from lignite, with an emission factor of 100 t of CO_2/TJ, this comes out to a figure of 22 million t of CO_2. In other words, without recycling we could expect an additional CO_2 burden of up to 22 million t.

Energy recovery in thermal waste treatment

CO_2 emissions from MSW incineration plants (c. 13.34 million t of waste were incinerated in 2001) amount to c. 6.45 million t of CO_{2eq}. In specific terms, incineration generates c. 0.5 Mg of CO_{2eq} per 1 t of municipal waste [8 - Johnke (2003)].

When the energy from MSW incineration plants is utilised, in the form of electricity, steam and heat, thereby substituting fossil energy, these plants can be credited with a CO_2 reduction of 4 – 4.5 million t of CO_2/year. Electricity sales account for 1.04 million t and heat sales for 2.96 million t of CO_2/year of this amount.

The gross fuel potential of the municipal waste incinerated (lower calorific value = 2.826 MWh/t of waste, or 10.175 GJ/ t of waste) is 37.5 million MWh/year, or 37.5 TWh/year. Energy conversion in German MSW incineration plants (2001) takes place at boiler efficiencies (determined from annual steam production) between 75.2 – 84.2% (average: 81.2%). Due to site- and plant-specific circumstances, energy recovery in these plants is only c. 5.3 million $MWh_{absolute}$/year electricity and c. 13.6 million $MWh_{absolute}$/year heat, i.e. a total of c. 18.9 million $MWh_{absolute}$/year, with average overall recovery efficiencies of 46.8%. Best available energy generation techniques in German waste incineration plants achieve overall generation efficiencies of up to 22% (average 13%) absolute for electricity, up to 81% (average 34%) absolute for heat and up to 79% (average 50%) absolute for combined heat and power plants [9 - Johnke, Reimann, Treder (2003)].

The optimisation of energy recovery in existing plants could generate additional potential for CO_2 reduction. If framework conditions were established that lead to an increase in the overall recovery efficiency to a maximum of 60%, i.e. 18% electricity and 42% heat, or 60% heat only, some 1.5 million t of CO_{2eq} could be saved through substitution of fossil fuels. If overall recovery efficiencies were increased to a maximum of 70%, i.e. 20% electricity and 50% heat or 70% heat only, the saving would even be as high as 2.1 million t of CO_{2eq}.

Regarding the use of substitute fuels produced from commercial waste, it can be assumed that one tonne of such fuel replaces one and half tonnes of lignite and thus achieves a saving of almost 1 t of CO_2/t of substitute fuel.

Electricity from MSW incineration plants under the RES Act

Gross electricity generation in Germany in 2001 was about 570 TWh [10 – BMWi (2003)]. Electricity from renewable energy sources (not including waste) currently contributes 45.6 TWh (see Table 3), or 8%, to this gross electricity production
[11 BMU (2003)].

Table 3: Provision of electricity from renewable energy sources and installed capacity in 2002

	Electricity [GWh]	Installed electrical Capacity [MW_{el}]	Heat [GWh]
Hydropower	24,000	4,620	
Wind energy	17,200	12,001	
Biomass (electricity)	1,983		
Landfill and digester gas	2,200	900	
Photovoltaic systems	176	262	
Biomass (heat)			52,500
Solar heat systems			1,955
Geothermal energy (heat)			1,050
Total 2002	**45,559**	**17,783**	**55,505**

The Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG) is currently being amended, and it is likely that electricity from the biogenic fraction of the MSW burned in the incinerators will be recognised as “renewable electricity”, without however receiving any additional support (a support under this act is only possible if it is exclusive renewable fuel). This would, by definition, increase the share by 0.5%, to 8.5% (see Table 4).

If the additional energy potential of the existing incineration plants were utilised, this could increase the share of renewable energy sources in gross electricity production to c. 8.75% (biogenic waste fraction only). Energy recovery from those municipal wastes that at present are still sent to landfill could increase this share to c. 9.7% (biogenic waste fraction only).

Table 4: Provision of energy by waste incineration and additional energy potential

	Electricity [GWh]	Installed electrical capacity [MW_{el}]	Heat [GWh]
Current generation	5,257	1,154	13,609
of which, 60% biogenic	3,154		8,165
Additional energy potential in MSW incinerators	2,000	313	3,309
of which, 60% biogenic	1,200		1,985
Additional energy potential from waste currently landfilled	8,800	1,375	22,000
of which, 60% biogenic	5,280		13,200
Total (biogenic fraction)	**9,634**	**2,842**	**23,350**

Electricity generation in MSW incineration plants supports the formulated political goal of increasing the share of renewable energy sources to 12.5% by 2010.

Project-related climate protection measures in waste management

In addition to emission allowance trading, the Kyoto Protocol also provides for other flexible mechanisms, such as Joint Implementation (of projects, JI) and the Clean Development Mechanism (CDM). On 23 July 2003, the European Commission presented the so-called Link Directive (Proposal for a Directive of the European Parliament and of the Council amending the Directive establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms [12 – European Commission [2003)]. The central element of the Link Directive is the recognition of JI and CDM certificates for emission allowance trading, which is due to start on 1 January 2005 throughout Europe.

A number of issues, such as “double counting” and “national off-set projects” are still the subject of controversy.

For instance, the Commission sees double counting as presenting a risk both from the environmental and economic point of view. Double counting may happen if certificates earned via JI within the Community are generated in plants covered by the Emissions Trading (ET) Directive. Arguing that double counting should be forbidden following the principle that one tonne of emissions shall be accounted for only once and a reduction of it not be rewarded more than once, the Commission believes that an installation covered by the Community scheme cannot be, at the same time, eligible under JI. This would mean, however, that certain energy-efficiency projects would not be recognised. Below an example which assumes that, as currently under discussion within the Federal Environment Ministry, MSW incineration plants will be covered by the emission allowance regime.

> MSW incineration plants generate energy through thermal waste treatment. Many plants do not adequately utilise this energy because of economic conditions. In Germany, for example, there is still significant energy potential available that could be utilised for climate-neutral electricity production.
>
> If a **JI** project for additional production of electricity without additional use of primary energy is launched and the generated certificates help make the project economically viable, then this should certainly be welcomed from an economic and ecological perspective.
>
> However, since the additional electricity that would be fed to the grid would reduce electricity production in “another power plant” and a corresponding amount of emission allowances would be saved, this would be, in the opinion of the Commission, a case of double counting.
>
> Projects of this kind, therefore, could not be implemented.

Another key point of criticism is that so-called national offset projects are not covered by the Directive. This type of projects is comparable to JI projects, except for the following differences:

- It is not incorporated in the Kyoto Protocol
- It does not involve two country Parties, i.e. a German project developer can carry out his project in Germany.

In the explanatory memorandum of the first proposal for the Emissions Trading Directive of 2001, it is stated that national off-set projects may also be allowed provided that the project meets acceptable environmental, verification and certification standards. Since then, the Commission has gone back on this position.

Various parties, however, take a positive view of the inclusion of national off-set projects (cf. [13 - UAG IV (2003)]):

- If JI projects are allowed and national off-set projects are not, project developers could establish letter box companies in EU Member States and in this way meet the applicable formal criteria.
- Projects carried out abroad usually involve higher risks and are often tied to existing business relations. Therefore, domestic projects make it more possible even for smaller companies to profit from the flexible mechanisms.

It is to be hoped that the Commission will modify the Links Directive with a view to easing restrictions in order to provide project mechanisms with a good market opportunity. For there is a whole range of waste management measures that could be launched as climate-protection projects on a domestic level and have attractive potential to generate certificates:

- Increasing the energy efficiency of thermal waste treatment plants
- Collection and use of landfill gas
- Use of alternative fuels
- Composting
- Digestion (biogas) with energy recovery
- Recycling (indirect energy saving)

Given creation of the requisite political conditions, not only project-based climate protection measures via JI and CDM abroad, but also, in particular, national off-set projects carried out domestically would be steadily gaining in importance in waste management.

4. Waste management and the national climate protection programme

Germany's national climate protection programme of 2000 [14 - BMU (2000)], which is currently being revised, sets out measures and targets for CO_2 reduction by 2010. For GHG reduction, the Federal Government [cf. 14, 15 - BMU (2000), BMU (2002)] has set the following obligatory and voluntary targets:

1. In keeping with the EU burden-sharing arrangement, Germany has undertaken to reduce CO_{2eq} emissions by 21% by 2012 (this corresponds to 256 t CO_{eq} or 70% of the EU commitment) – the reduction commitment of the EU as a whole is 8%. According to the Coalition Agreement, the Federal Government will propose that the EU commit itself to reducing its GHG emissions by 30% by 2020; Germany will in that case aim to make a contribution of minus 40%.
2. Voluntary CO_2 reduction by 25% by 2005;
3. Voluntary CO_2 reduction by 40% 2020;
4. Voluntary CO_2 reduction by 80% by 2050;

The climate protection programme provides that should its implementation reveal that individual sectors are unable to meet their targets via certain measures, the initial priority should be to investigate other measures in that sectors. Any outstanding deficits must then be compensated via greater efforts in other sectors.

At present, an additional saving of c. 70 million t of CO_{2eq} must be made to fulfil the Kyoto commitment. More than 10 million t of CO_{2eq} could be saved by optimising energy recovery at existing MSW incineration plants and subjecting municipal waste that is currently still being landfilled to thermal treatment with energy recovery. In this way, waste management could, in addition to the reductions already achieved (see Table 1), contribute almost 15% to the saving yet to be made to achieve the reduction target.

5. Summary

Waste management is progressively becoming resource management, an element of sustainable development. The Closed Substance Cycle Waste Management and Waste Disposal Act of 1994 took sustainability objectives into account to some extent, thus enacting the resolutions adopted in 1992 at the World Summit in Rio de Janeiro.

With the termination of landfilling in 2005, an important step towards resource conservation will be made. Landfill makes materials unavailable for use as a resource, e.g. it withdraws high-calorific waste fractions from use as substitute for fossil fuels, and causes, at the same time, environmental impacts (leachate, landfill gas), particularly unavoidable methane emissions.

Public awareness of waste management's contribution to climate protection must grow. In addition to recycling where appropriate, energy recovery from waste must gain in importance. Optimised provision of energy by existing and new waste incineration plants requires additional financial incentives to ensure that the requisite investments can be made. In particular, efforts should be stepped up to develop new instruments and measures aimed at increasing use of heat.

It is certain, however, that waste management in Germany has already made a large contribution to the conservation of resources and to climate protection. The additional potential that exists must be further harnessed.

6. References

[1] IPCC (2000): Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories; IPCC/OECD/IEA Programme for National Greenhouse Gas Inventories, WMO Intergovernmental Panel on Climate Change UNEP; 2000; http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.html

[2] EEA (2003): Greenhouse gas emission projections for Europe; Technical report 77, 2003; www.eea.eu.int

[3] Johnke (1999): German Proposal for a Draft Meeting Report "Good Practice in Inventory Preparation for Emission from Waste Incineration", IPCC/OECD/IEA Programme for National Greenhouse Gas Inventories, WMO Intergovernmental Panel on Climate Change UNEP; Sao Paulo, Brazil, 27-29 July 1999

[4] Umweltbundesamt (2003): Unpublished data on total emissions in Germany, Berlin

[5] Treder (2003): Kapazitäten der deutschen MVA´s sowie Neuanlagenbedarf - Ist-Zustand/ genehmigte Kapazitäten /Stand 2005 sowie daraus resultierende Klimarelevanz; in: BAT-, energie-, preisorientierte Verfahrens-/ Dioxin-/Rauchgasreinigungstechniken 2003 für Verbrennungs- und Feuerungsanlagen; VDI-Wissensforum, Munich, 18. und 19.09.2003

[6] Johnke (2003): Unpublished survey carried out by UBA

[7] Johnke (1992): Unpublished survey carried out by UBA

[8] Johnke (2003): Emissionsberichterstattung/Inventarerstellung für das Jahr 2002; unpublished report of 10.11.2003

[9] Johnke, Reimann, Treder (2003): Unpublished internal survey by ITAD on energy generation by waste incineration plants in 2001

[10] BMWi (2003): Zahlen und Fakten - Energiedaten 2002; www.bmwi.de

[11] BMU (2003): Umweltpolitik – Erneuerbare Energien in Zahlen; Stand März 2003

[12] European Commission (2003): Proposal for a Directive of the European Parliament and of the Council amending the Directive establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms; Brussels, 23.07.2003

[13] UAG IV (2003): Unpublished report of Sub-Working Group IV (project mechanisms) of the Working Group on Emissions Trading of 17.12.2003; to be published shortly at www.bmu.de

[14] BMU (2000): Nationales Klimaschutzprogramm, Decision of the Federal Government of 18.10.2000; http://www.bmu.download/dateien

[15] BMU (2002): Nachhaltige Entwicklung in Deutschland; http://www.bmu.de/download/b_nachhaltigkeit_kurzfassung.php