



ROLE OF ENERGY PRODUCTION IN THE CONTROL OF GREENHOUSE GAS EMISSIONS FROM WASTE MANAGEMENT

R. PIPATTI and I. SAVOLAINEN

VTT Energy (Technical Research Centre of Finland)

P.O. Box 1606, FIN-02044 VTT (Espoo), Finland

Abstract - Greenhouse impacts of alternative municipal waste management chains are assessed. The considered alternative chains consisted of landfilling, landfill gas recovery and flaring or energy production, biological treatment and incineration of wastes. The most favourable options to limit the greenhouse impact due to waste management are those that minimize the methane emissions to the atmosphere and those that reduce the greenhouse impact even further by replacing fossil fuels in energy production.

1. INTRODUCTION

Waste treatment can cause emissions of all the important greenhouse gases: carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). Landfills and waste water and sludge treatment are the most important sources of the greenhouse gas emissions from waste management and cause about 20 % of the global anthropogenic methane emissions. In many industrialized countries the share of the methane emissions caused by the waste treatment is even larger, typically 30 - 40 % of the total national anthropogenic methane emissions (UN 1994, Pipatti et al. 1995).

Methane is a relatively reactive greenhouse gas with a lifetime in the atmosphere of about ten to fifteen years. Most of the other important greenhouse gases have considerably longer lifetimes. The warming impact of methane is tenfold compared with carbon dioxide: the GWP-factor (Global Warming Potential) for methane is 62 for 20 year, 24.5 for 100 year and 7.5 for 500 year time horizon (IPCC 1995). Due to methane's short lifetime, its concentrations are easier to control than the concentrations of the other greenhouse gases and it is possible to stabilize its concentrations to the current or an even lower level.

The organic matter in waste decomposes under anaerobic conditions in the landfills with time, and methane and carbon dioxide are emitted to the atmosphere. Alternative waste treatment methods like biological treatment (composting or anaerobic treatment) and incineration provide promising options to mitigate the greenhouse impact of waste treatment by reducing the methane emissions. Treatment methods that produce energy can further reduce the greenhouse impact by replacing fossil fuels in energy production. On the other hand, the landfills can act as a carbon sink of a relatively long duration.

In this paper the results of an ongoing study on the greenhouse impact of different waste treatment alternatives are presented. In the study the greenhouse gas emissions from municipal, industrial and

agricultural wastes as well as from waste water and sludge treatment have been estimated. This paper presents the results for municipal waste treatment. Only the direct greenhouse gas impact of the different treatment techniques has been assessed, not the impact of waste separation, recycling and transportation. Special emphasis is on the treatment techniques with energy production.

2. GREENHOUSE IMPACT OF WASTE TREATMENT ALTERNATIVES

2.1 Waste Treatment Techniques and Greenhouse Gas Emissions

One traditional way to handle municipal waste is landfilling. Methane is produced in landfills when organic matter decomposes under anaerobic conditions. Carbon dioxide is also produced but as it is released from renewable sources it is not considered in the emission estimate. Landfill gas recovery and combustion of the gas in a flare or for energy production provide means to mitigate the emissions.

The organic fraction of municipal waste can be composted or treated anaerobically in biogas utilities where methane is recovered and used for energy production. The greenhouse emissions from these treatment measures have been estimated to be negligible as the carbon dioxide emissions are not accounted for (organic waste is a biomass fuel) in the estimate and because methane and nitrous oxide emissions from the sources are minor. In the ongoing study the greenhouse gas emissions from different kinds of compostors will be measured. The preliminary results of the first measurements have confirmed the assumption that the greenhouse gas emissions from composting can be ignored.

Waste incineration produces emissions of carbon dioxide (fossil wastes: plastics), methane and nitrous oxide but compared with landfills the emissions are small. In the incineration mixed waste or only the combustible fraction of waste (paper, cardboard, wood and plastics, often called RDF = Refuse Derived Fuel) can be combusted. In the mass incineration the heat value per kilogram waste is low and emissions of HCl and heavy metals can cause problems. Burning only the combustible fraction allows higher burning temperatures to be used, the heat value is higher and the overall hazardous emissions lower than in mass incineration on average.

2.2 The Greenhouse Impact of Alternative Waste Treatment Chains

As the alternative waste treatment methods are not fully parallel (see Fig. 1) the greenhouse impact of alternative waste treatment chains was assessed. The comparison between the different chains was done by estimating the greenhouse impact of the treatment of 1 tonne (dry matter) of municipal waste. The composition of the waste was assumed to coincide with the average composition of municipal waste treated in Finland (table 1).

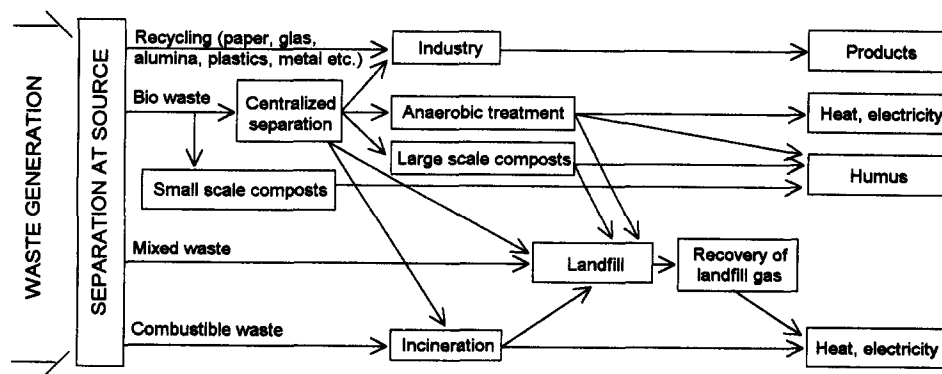


Fig. 1 Waste treatment options for different fractions of municipal waste.

Table 1. An estimate of the composition and carbon content of municipal solid waste (MSW) that is treated in Finland (Advisory Board for Waste Management 1992). The values are given for wet waste (corresponding values for dry matter are in parentheses).

Waste fraction	Treated waste m-%		Mean carbon content m-%		Carbon content of treated waste m-%	
Paper and cardboard	26	(37)	40		10,4	(14,7)
Textiles	1	(1)	40		0,4	(0,6)
Plastics	6	(9)	50 ^{*)}		3	(4,2)
Organic waste	46,5	(26)	16	(40)	7,4	(10,6)
Glass and metal	5,5	8)	-		-	-
Other waste	15	(19)	10 ^{*)}	(11)	1,5	(2,1)
Total					22,7	(32,2)

The total moisture content of MSW is assumed to be 30 %. Paper, cardboard, textiles, plastics, glass and metals are assumed to have 0 %, organic matter 60 % and other waste 10 % of water.

^{*)} Own estimate, other values for the mean carbon content have been given by Bingemer & Crutzen (1987).

The greenhouse gas emissions (CH_4 , N_2O and fossil CO_2) and energy production for the alternatives were estimated. The energy produced was assumed to replace energy produced by fossil fuels and so reduce emissions from fossil fuel combustion (emission savings). The emissions of combustion of fossil fuels were estimated as 77 g CO_2/MJ , 8 mg CH_4/MJ and 2 mg $\text{N}_2\text{O}/\text{MJ}$ which correspond to the emissions from oil combustion (Boström et al. 1992). As all landfilled organic matter will not decompose landfills will act also as carbon sinks. Landfilled carbon from renewable sources will therefore be partly removed from the carbon cycle and thus reduce the CO_2 concentration in the atmosphere. This was also considered in the assessment.

The greenhouse gas impact was estimated by calculating the CO_2 -equivalent for the emissions using GWP-values (GWP = Global Warming Potential). The savings in greenhouse gas emissions (expressed as CO_2 -equivalents, the time horizon of 100 years) achieved by energy production were subtracted from these figures, as were the CO_2 -equivalents for the carbon from renewable sources stored at landfills.

Altogether eight alternative waste treatment chains (combinations of landfilling, landfill gas recovery and energy use, biological treatment and incineration) were examined:

1. *All waste is landfilled.* The emission factor used in the calculations is 60 kg CH_4/t dry waste (42 kg CH_4/t wet waste or 214 kg CH_4/t degradable organic carbon in the waste).
2. *All waste is landfilled and the landfill gas is recovered and flared.* The recovery efficiency is assumed to be 40 % of all the methane produced in the landfill and the greenhouse gas emissions from the flare are estimated to be negligible.
3. *All waste is landfilled and the landfill gas is recovered and burned for energy production.* The recovery efficiency is assumed to be 40 % of all the methane produced in the landfill. Energy production is estimated using the heat value 50 MJ/kg CH_4 . The greenhouse gas emissions from combustion of the gas are estimated to be negligible.
4. *Organic waste is collected separately and composted. The rest of the waste is landfilled.* Greenhouse gas emissions from composting are estimated to be negligible.
5. *Organic waste is collected separately and treated in an anaerobic waste treatment facility. The rest of the waste is landfilled.* The methane produced in the anaerobic treatment is used for energy production. Part of the energy is used in the process and rest is sold to other consumers. Only the

part which is sold to the consumers is taken into account as energy produced in table 2. The energy balance for anaerobic treatment is estimated to be similar to that of the facility in Vaasa in Finland in 1990. Emissions from combustion of the gas are assumed to be negligible.

6. *Combustible waste (paper, cardboard and plastics) are collected separately and burned. Rest of the waste is landfilled.* Heat value used is 20 MJ/kg dry matter. Emissions from combustion are estimated as follows: 98 % of the carbon in plastics is oxidized forming CO₂, CH₄ emissions are 5 mg/MJ and N₂O emissions 85 g/t waste (dry matter).
7. *Organic and combustible wastes are collected separately. Organic waste is treated anaerobically and combustible waste burned.* Rest of the waste is landfilled. Emissions and energy production from anaerobic treatment are estimated as in option 5 and from combustion as in option 6.
8. *All waste is incinerated.* Heat value used is 16 MJ/kg dry matter and the greenhouse emissions from the combustion are estimated as in option 6.

The results are presented in Fig. 2 using two indexes: the greenhouse gas emissions and the net impact, both expressed in CO₂-equivalents. The net impact is defined as the greenhouse gas emissions subtracted with the emission savings which can be achieved by energy production (assumed decrease in the use of fossil fuels) and the amount of carbon that is stored in the landfills (carbon sink). In the calculation two values were used for the efficiency of the separation of organic waste and the combustible fraction: 100 % (maximal efficiency) and 50 % (a realistic efficiency).

3. RESULTS AND CONCLUSIONS

Landfilling has the largest greenhouse impact. By landfill gas recovery and combustion a significant reduction in the greenhouse emissions can be achieved. The net impact will be lowered even more, because the recovery does not influence the amount of carbon stored in the landfill. If the recovered gas is used for energy production then the net impact will be lowered further.

The alternatives including separating the biological fraction and treating it anaerobically or by composting and landfilling the rest of the waste produce greenhouse gas emissions which are comparable with landfilling combined with gas recovery. In the estimation of the net impact for biological treatment the humus is not expected to provide a carbon storage as the carbon in the humus is expected to participate in the carbon cycle. This assumption may be false and if 50 % of the carbon in the humus would be stored in the soil, the net impact of biological treatment would decrease with about 25 %.

Waste treatment alternatives which include incineration (either mass incineration or burning of the combustible fraction of municipal waste i.e. paper, cardboard, wood and plastics) are most favourable when considering the greenhouse gas emissions. The net greenhouse impact can be in fact negative for alternatives that include incineration and energy recovery.

The assessment includes uncertainty and the results can therefore be considered only as indicative at this stage of the study. The greenhouse gas emissions from waste transportation and mechanical treatment of waste at landfills or during composting have not yet been considered in the estimates. Other environmental impacts of the alternative waste treatment chains must also be considered before waste management strategies can be chosen. The volume of waste to be handled, separation efficiencies and the impact of the alternative waste treatment chains on transportation as well as on the management costs will be evaluated in the final comparison of the feasibility of the alternatives.

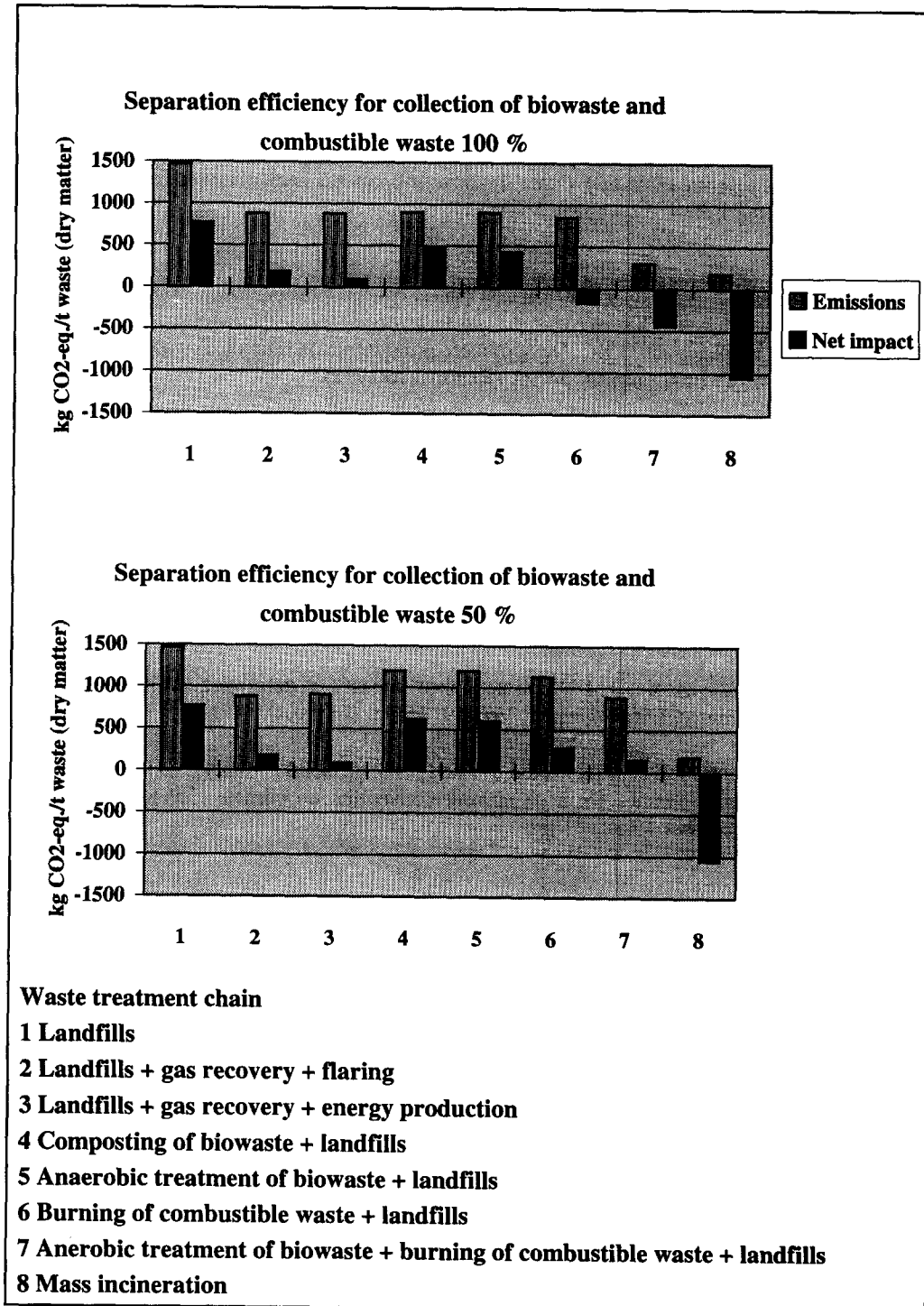


Figure 2. Greenhouse impact due to alternative municipal waste treatment chains per tonne dry matter of average municipal waste.

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