Survey of municipal solid waste combustion in Europe

Data for 17 European Countries

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Summary

Municipal Solid Waste (MSW) combustion has been discussed intensively over the last two decades. As a result of this over the last five years changes in regulations, equipment and techniques used have come very rapidly. In Europe different countries have adapted these changes in differing degrees and the overall situation is not clear. This prompted PWMI (European Centre for Plastics in the Environment) to compile a survey as they are investigating the influence of plastics on the combustion of MSW. The countries concerned in this survey are: Austria, Belgium, Switzerland, Germany, Denmark, Spain, France, Greece, Italy, Ireland, Luxembourg, Norway, The Netherlands, Portugal, Sweden, Finland and the United Kingdom.

In this report the results of such a survey are given. Besides MSW (amount and composition) and MSW combustors special attention was given to the plastic fraction in MSW. Regulations considering MSW combustion and plans or expectations for the future were also taken into consideration.

It was found that data on the amount and composition of MSW were very difficult to obtain. This was mainly due to differences in definitions (which were often not even mentioned) between the main sources. These problems were even greater for data on the plastics fraction because in many countries it has been a long time since the last analysis of the plastic fraction has been executed (sometimes 1984/85).

For combustors the data had to be compiled from many sources as none of the sources supplied the information needed for a total survey. For Italy only some of the combustion facilities which are in operation could be traced. In addition few data were found on steam parameters, amount of energy actually recovered and emission monitoring in combustion facilities.

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1 Introduction

In Europe Municipal Solid Waste (MSW) production is continuously growing. As industry produces more and people consume more, the amount of waste grows too.

In this growing amount of MSW plastic plays an important role. Although plastics only represent 7% (averaged) of the weight of the MSW, they make up around 25% of the volume of the MSW. Furthermore plastics are highly visible in piled waste and are usually not degradable in landfills. Because of this important role, PWMI (European Centre for Plastics in the Environment) is investigating all possible disposal routes for the plastics in MSW.

In the discussion on the disposal of the MSW first of all prevention of waste generation is promoted. As the effects of prevention will be limited (there will always be waste) other options need to be considered. In order of preference (generally accepted) these options are: material recycling, energy recycling (mainly combustion) and finally landfill in an environmentally safe way.

As combustion of MSW is one of the options, PWMI has set up a research programme to establish the impact of plastics in MSW on the combustion of MSW. The first phase of this research programme consists of a survey of:
- the amount and composition of the MSW in Europe (EC-member countries plus Austria, Switzerland, Norway, Sweden and Finland) with special attention on the plastic fraction;
- the number and characteristics of the combustion facilities in Europe which combust this MSW;
- the legislation in the different countries with respect to MSW combustion;
- plans and/or expectations for the future of the above-mentioned topics.

PWMI has requested TNO (The Netherlands Organization for Applied Scientific Research) to compile this survey.

This report covers the results of this survey and is in fact divided into two parts. The first part (chapters 1 to 3) covers remarks and facts which apply to all the countries considered in this study, such as the way the data were obtained, what definitions are used and so on. In the second part (chapter 4) the data are presented first of all for the whole of Europe as an overview or an average and secondly for each country separately.

2 Definitions

2.1 Waste and waste fractions

The definition of Municipal Solid Waste considerably differs between the countries concerned in this study. In general, MSW includes household waste and bulky waste as well as comparable wastes from small commercial or industrial enterprises (often called trade waste), and market and garden residuals, which are collected and treated by or for the municipalities. In this study separately collected fractions, mostly paper and glass, are also counted to the total amount of MSW. In chapter 4 for each country the used definition of MSW is given, if known.

The composition of the municipal solid waste is determined by sorting analyses. This is mainly done by sieving and picking by hand.
Among the different countries there are differences in the sorting fractions. In this study the following fractions are chosen:
- Putrescibles/Fines.
- Paper and Cardboard.
- Plastic.
- Glass.
- Metals.
- Textiles.
- Miscellaneous combustibles.
- Miscellaneous non-combustibles.

Most sorting analyses result in a fraction fines, but because of different sieve diameters these fractions are not comparable. A great part of the fines, however, consists of putrescibles (kitchen/yard waste, etc.), Therefore this part is counted to the putrescibles in this study.

The fraction 'miscellaneous combustibles' consists of wood, leather, rubber etc. 'Miscellaneous non-combustibles' stands for minerals, stones, bones, etc.

When a product consists of two or more fractions it is counted to the dominating fraction. This means that a waste item which is 70% textile and 30% plastics is considered to be 100% textile.

2.2 Waste treatment schemes

In this study the amount of waste produced is the amount after prevention but before recycling. Separately collected waste thus is included.

The residues from combustion and composting are left out of consideration in this study. For example: if a certain amount of residue from combustion is landfilled this amount is not included in the figure for landfill.

This is done for two reasons:

- First of all it is not known precisely how much residue is generated and what is done with the residues from combustion or composting: in theory composted MSW is used as fertilizer whereas in practice it is often landfilled.
- The second reason is that residues from these processes are often considered chemical or special waste and therefore have to be landfilled on special sites, separately from regular MSW.

3 General remarks validity and availability of data

3.1 Municipal Solid Waste composition

There are great differences in the total amount and composition of MSW between the different countries. To a certain extent these differences are caused by differences in definitions between the countries. There are differences in the waste streams that are included in the MSW, and differences in the definition of the waste streams. A consequence of this is that it is difficult to compare between the countries.

Apart from differences in the definitions used there is also great fluctuation in the composition of MSW due to differences in social conditions, living structure, geographical location and the season in which the waste is produced. This explains why even data of one country can show considerable differences in the amount and composition of the waste which is generated.

Compositions reported in literature often do not mention the definitions along with the data. This makes comparison very difficult. Especially if not all the data which are of interest to this survey are taken into consideration in a literature source. The gaps in the information then has to be filled in with data from other reports, with possible other definitions. Another problem with data from literature are the so-called primary and secondary sources. Primary sources actually analyse (fractions of) the waste whereas secondary sources copy the results of others. While copying definitions are lost or estimates are interpreted as truly measured. As primary sources are outnumbered by far by the secondary sources it requires an enormous effort to obtain good data. This effort has been made for this study.

This report, which in fact also will be a secondary source, relies as far as possible on primary sources. However, these primary sources sometimes are relatively old and possibly outdated. If this appears to be the case or if no primary reference is available, a considered estimate has been made and reported. In all cases the way the data are obtained is mentioned.

For all of the countries it was possible to obtain data on the total amount and the composition of MSW. Information on the composition of the plastic fraction was not found for Sweden, Finland, Greece and Portugal. For the other countries these data were found but often dated from 1984 or 1985. Information on MSW treatment schemes was not obtained for Greece and data on future trends and expectations were often very fragmented and not structured.

With the restrictions and difficulties in mind this report gives a good overview of the situation in Europe.

3.2 Municipal Solid Waste combustors

Definition problems like the ones encountered with the composition of MSW are not a real problem with information on combustors.
The only real confusion can occur if the total combustion capacity in a country is compared to the amount of MSW which is said to be combusted in that country. These data come from different sources and mismatches in the comparison can be caused by several factors:

- **definition**: the MSW which is combusted might not be the same as the MSW which is combusted; sometimes not only MSW is combusted but also industrial waste, sewage sludge, etc. A clear example of this confusion is Denmark. If the total combustion capacity in Denmark is related to the amount of MSW, the outcome is that around 70% of the Danish MSW is combusted. However, in the Danish combustors also industrial waste and some other kinds of waste are combusted, so that actually 'only' 48% of the Danish MSW is combusted.

- **Operating hours**: the design capacity in tonnes per hours is multiplied by an assumed number of hours in operation of 7000 per year. In The Netherlands, however, the average is much higher: 7500-8000 hours per year, whereas in other countries installations sometimes are not run 24 hours a day but only in daytime shifts. In Germany and Switzerland it is very common to build an extra unit to ensure waste disposal. This means that a plant with four units has a theoretically maximum availability of 75% (circa 6600 hours per year). Differences in operating hours are also caused by differences in maintenance practices: e.g. is the boiler cleaned once a year or once every two years?

- **Increasing heat of combustion**: the heating value of the MSW has increased considerably over the last two decades [2]. Because combustion facilities are limited in the amount of heat which can be generated per time period this means that at a certain point the increase of heat content per kg MSW had to be compensated by a decrease of MSW throughput. This caused these installations to combust less MSW then according to design specifications [2, 4].

The biggest difficulty in gathering the information on the combustors lies in the fact that information from one source never gave all the data on the combustors of interest to this study. This was solved by combining information from different sources, which sometimes is very well possible and other times requires a lot of effort.

Some of the parameters were very difficult to obtain, like the amount of energy which is actually recovered in a combustor or the emissions which are monitored (continuously or by sampling). Some information was confidential and could not be gathered. Special difficulties with the gathering of data were encountered in Italy, where a lot of combustors are temporarily out of order and the total situation is not clear at the moment. Also Belgium (especially Wallonia) required extra effort. For most of the countries some data are missing, but except for Italy these are not the most important data. In order to complete the information all the installations should be contacted separately, which would need too great an effort.

3.3 Information sources

In order to obtain information out of first hand a questionnaire with all kinds of questions on MSW (amount, composition, treatment), on combustion facilities and on future plans was send to all the environmental ministries of the involved countries. Most of them replied by filling in the form or by sending relevant reports, some forwarded the questions to experts, and some (A, B, GR, I, P) did not reply at all. Most of the answers concerned the combustion facilities.

Besides writing to the ministries also experts, if known, were contacted, per phone or per letter (fax). Also literature was searched for relevant information.

In the data per country the main information sources per country are mentioned by references. Besides these references used in the text the reference list at the end of the report also contains references which are not directly referred to but which have been used in this study for background or general information. Most difficult countries to obtain information (on the whole or on certain topics) from were: Italy, Portugal, Greece, Belgium, France and Ireland.

4 Emission guidelines in Europe

Almost each country in Europe (considered in this study) has its own legislation concerning emissions from MSW combustion. These regulations, however, differ a lot from country to country, not only in emission limits, but also in the number of pollutants for which there are limits. Some regulations only set limits to the emissions of dust, HCl, HF and CO, whereas others also imply SO_x, NO_x, total organic carbon (TOC), heavy metals, PCDD/F (polychlorinated dibenzo-para-dioxines and -furans) as well as certain performance demands, other than emissions (residence time, temperature, oxygen level).

Table 1 gives an overview of the emission limits which conform to the different regulations existing in Europe. The values in this table are related to an oxygen concentration in the flue gases of 11 vol% (dry, at standard temperature and pressure (stp): 273 K, 101.3 kPa) except for Norway (10 vol% O_2) and Sweden (10 vol% CO_2). An oxygen concentration of 11 vol% is assumed to correspond to a CO_2 concentration of 9 vol%.

Most of the regulations also require certain conditions to be met for the flue gases after the last (combustion) air injection. For example among other guidelines the German regulation requires that the flue gases, after the last injection of (combustion) air remain at a temperature of at least 850 °C and a concentration of 6 vol% O_2 (dry, at stp) for at least 2 seconds. This is meant as a sort of guarantee for destruction of combustible matter in the flue gases. The conditions required are also mentioned in table 1.

Besides the limit values it is very important over what period of time the measurements have to be averaged to meet the limit values. For example a limit value during half an hour is far more difficult to meet as the same value over a longer period of time (time to even out peaks). The remarks on the time basis for the limits are mentioned below per guideline.

Member countries of the European Committee have to comply with the EC-regulation as a minimum, but can have stricter limits (for dates, see later). This is the case for Germany and The Netherlands.

Spain, France, Greece, Portugal, Ireland and Luxembourg do not have regulations of their own and only have the EC-guideline to deal with. Belgium, Denmark, Italy and the United Kingdom have made small extensions to the EC-guideline.

From the non-member countries Austria and Switzerland have stricter guidelines than the EC proposes. Norway and Sweden have comparable guidelines whereas Finland does not have a guideline but follows the EC-guideline.

Some of the guidelines mentioned in table 1 have further regulations. These are mentioned briefly below.

Austria [33]
The Austrian guideline also requires a CO/CO_2-ratio of 0.002.

Table 1 Emission guidelines for Municipal Solid Waste combustion in Europe (see text for explanation)

Component		A 1989	B 1982	CH 1991	D 1990	DK 1991	I	N	NL 1989	S	UK 1992	EC 1989	Component
Dust	mg/Nm^3	15	100	10	10	30	30	10	5	20	30	30	Dust
HCl	mg/Nm^3	10	100	20	10	50	50	100	10	100	30	50	HCl
HF	mg/Nm^3	0.7	5	2	1	2	2	-	1	1	2	2	HF
SO_x (as SO_2)	mg/Nm^3	50	-	50	50	300	300	300	40	200	300	300	SO_x (as SO_2)
CO	mg/Nm^3	50	1000	50	50	100	100	100	50	100	100	100	CO
NO_x (as NO_2)	mg/Nm^3	100	-	80	200	-	-	-	70	400	350	-	NO_x (as NO_2)
TOC	mg/Nm^3	20	-	20	10	20	20	-	10	-	20	20	TOC
Heavy metals													Heavy metals
Hg	mg/Nm^3	0.05	-	0.1	0.05	-	-	0.1	0.05	0.03	0.1	0.2	Hg
Cd	mg/Nm^3	0.05	-	0.1	-	-	-	-	0.05	-	0.1	0.2	Cd
Hg+Cd	mg/Nm^3	-	-	0.1	-	0.2	-	-	-	-	-	-	Hg+Cd
Cd+Tl	mg/Nm^3	-	-	-	0.05	-	-	-	-	-	-	-	Cd+Tl
Pb	mg/Nm^3	-	-	1	-	1	-	-	-	-	-	-	Pb
Zn	mg/Nm^3	-	-	1	-	-	-	-	-	-	-	-	Zn
Pb+Zn+Cr	mg/Nm^3	2	-	-	-	-	-	-	-	-	-	-	Pb+Zn+Cr
Pb+Cr+Cu+Mn	mg/Nm^3	-	-	-	-	5	-	-	-	-	-	5	Pb+Cr+Cu+Mn
As+Ni	mg/Nm^3	-	-	-	-	1	-	-	-	-	-	1	As+Ni
As+Co+Ni	mg/Nm^3	0.5	-	-	-	-	-	-	-	-	-	-	As+Co+Ni
Tot.rest	mg/Nm^3	-	-	-	0.5	-	-	-	1	-	1	-	Tot.rest
PCDD/F	ng TEQ/Nm^3	0.1	-	-	0.1	-	4000[1)]	2	0.1	0.1	1	-	PCDD/F
Conditions		11% O_2	11% O_2	11% O_2	11% O_2	11% O_2	11% O_2	10% O_2	11% O_2	10% CO_2	11% O_2	11% O_2	Conditions
Temperature	°C		800		850	850	950	800	850		850	850	Temperature
Residence time	s		1		2	2	2	1.5	2		2	2	Residence time
Oxygen conc.	vol%		6		6	min. 6	6	-	6		6	6	Oxygen conc.

Sources:
Austria: Luftreinhalteverordnung (LRV 1989) [33]
Belgium: capacity > 0.75 t/h [21]
Switzerland: Luftreinhalteverordnung [29, 33]
Germany: 17BImSchG [51]
Denmark: Emission limits for Waste combustion. Stat. Order 4th Jan. 1991 [30]
Italy: [33]
Norway: [32]
Netherlands: Richtlijn Verbranden 1989 [52]
Sweden: Solid waste management in Sweden, August 1990 [23, 24]
UK: Environmental Protection Act, Process Guidance Note IPR 5/3 [65]
EC: European Directives [66]

[1)] ng/Nm^3, *not* expressed as TEQ

EXPLANATION (see also Appendix)

-	no limit value
(blank)	not known

ALL VALUES FOR DRY GASES AT 273 K AND 101.3 kPa

Belgium [21]
The present Belgian regulation also requires a greyness of the plume of less than 3 on Bacharach's scale and the following imission limits (half hour average):
- SO_2 0.1 mg/Nm³
- HCl 0.1 mg/Nm³
- HF 0.004 mg/Nm³
- dust (<10 μm) 0.1 mg/Nm³

This year the Belgian government will adopt the EC-regulations. An exception is proposed to be made for combustors with a capacity of more than 30 tonnes per hour. These will then have to comply with the German emission limits except for NO_x, which will have to be 100 instead of 200 mg/Nm³.

Germany [51]
- The emission of the remaining heavy metals which according to table 1 has to be less than 0.5 mg/Nm³ is supposed to be the total of the emissions of: As, Sb, Pb, Co, Cr, Cu, Mn, Ni, V and Sn.
- The emission values given in table 1 are daily averages. Besides this also half hour averaged limits are set:
  - dust 30 mg/Nm³
  - HCl 60 mg/Nm³
  - HF 4 mg/Nm³
  - SO_x 200 mg/Nm³
  - NO_x 400 mg/Nm³
  - TOC 20 mg/Nm³

  For CO a one hour average of 100 mg/Nm³ may not be exceeded. Also 90% of the CO-measurements in 24 hours have to be below 150 mg/Nm³.
  Finally the values for heavy metals and PCDD/F are averaged on the sampling time used.
- This 17.BImSchG is valid for new installations. For existing installations the emission limits will be valid starting 01-03-1994. Exceptions can be made until 01-12-1996.
- Starting up and closing down of the combustor has to be done with auxiliary burners (not burning waste). Waste is only allowed in the combustion chamber if the temperature in the chamber is above 850 °C.
- MSW combustors are obliged to recover energy. If more than 0.5 MW of energy is produced in excess of the internal need for energy electricity has to be generated.
- The following parameters have to be monitored continuously:
  - the emissions of CO, dust, HCl, HF (not if HCl-cleaning is applied), SO_x and NO_x;
  - the percentage O_2 in the flue gases;
  - the temperature of the flue gases in the required areas;
  - parameters needed for sensible operation (e.g. pressure, humidity and volume of the flue gases).
- If chemical waste is burned the required temperature is set at 1200 instead of 850 °C.
- If only liquid wastes are burned the O_2-concentration must be above 3 instead of 6 vol%.

Denmark [30]

- The values for dust and HCl are weekly averages. Besides that also daily averages are set: dust 40 mg/Nm^3 and HCl 65 mg/Nm^3. These values may be exceeded by up to 30%. For CO a one hour average of 100 mg/Nm^3 may not be exceeded. Also 90% of the CO-measurements (30 min. average) in 24 hours has to be below 150 mg/Nm^3. The other values are averaged on the sampling time used.
- CO, dust, HCl and the temperature have to be monitored on a continuous basis. The other components must be checked via sampling 6 times a year. If they comply with the limits each time this frequency drops to two times a year.

France

France has adopted the EC-guideline with one exception:

- Hg + Cd < 0.2 mg/Nm^3

Norway [32]

The existing regulations for small plants (capacity <2 tonnes per hour) only sets a limit to the dust emission: 100-250 mg/Nm^3 at 10 vol% O_2 (dry, stp) in the flue gases. These regulations will probably become more stringent in the near future:

- dust 30-100 mg/Nm^3
- HCl 100-200 mg/Nm^3
- Hg 0.1 mg/Nm^3
- CO 100 mg/Nm^3

The Netherlands [52]

- This guideline is valid for new installations, except for the limit for NO_x, which will become valid starting 01-01-1995. Existing installations will have to try to comply with this regulation by 31-12-1992, but must comply with it starting 30-11-1993, except for the limits for NO_x and PCDD/F. For these two the installations are obliged to make an effort to reach the limits.
- The emission of the remaining heavy metals which according to table 1 has to be less than 1 mg/Nm^3 is supposed to be the total of the emissions of: As, Sb, Pb, Co, Cr, Cu, Mn, Ni, V, Se, Te and Sn.
- The emission limits set in table 1 are hourly averages.
- For the emission limit for Hg an exception can be made if a removal efficiency of 90% (for Hg) can be demonstrated. For this reason the concentration of Hg in the raw (= uncleaned) flue gases has to be measured also.
- Starting up and closing down of the combustor has to be done with auxiliary burners (not burning waste). Waste is only allowed in the combustion chamber if the temperature in the chamber is above 850 °C.
- The following parameters have to be monitored continuously:
  - the emissions of CO, dust, HCl, TOC, SO_x and NO_x;
  - the percentage O_2 in the flue gases;
  - the temperature of the flue gases in the required areas.

  The emission of dust, heavy metals, HCl and HF have to be measured 4 times a year and of PCDD/F 2 times a year. For this each time three samples per chimney have to be taken.
- A combustion facility has to consist of two parallel units at least to guarantee the continuity of the operation.
- Big parts in the waste have to be diminished in size prior to combustion.

Sweden [23, 34]
- The limits for dust and HCl are monthly averages, whereas the CO-limit is hourly averaged.
- For existing plants the limit for Hg is 0.08 mg/Nm^3 and for PCDD/F 2 ng/Nm^3.

United Kingdom [65]
- This guideline will probably come into effect in August 1992. New plants and substantially changed plants will have to comply with these regulations directly. Existing plants have until 1 December 1996 to comply with the limits. Starting 1 August 1992 existing plants only have one emission limit to comply with: 100 mg/Nm^3 total particulate matter.
- The emission of the remaining heavy metals which according to table 1 has to be less than 1 mg/Nm^3 is supposed to be the total of the emissions of: As, Pb, Cr, Cu, Mn, Ni and Sn.
- For PCDD/F the emission limit is 1 ng TEQ/Nm^3; the operators, however, are urged to reduce this emission as far as possible with an aim of 0.1 ng TEQ/Nm^3.
- The process should not give rise to an offensive smell noticeable outside the premises where the process is carried on.
- During normal operation, including start-up (with 5 minutes delay) and shut-down emissions should be free from visible smoke.
- Starting up and closing down of the combustor has to be done with auxiliary burners (not burning waste). Waste is only allowed in the combustion chamber if the temperature in the chamber is above 850 °C.
- The limits set in table 1 are valid for non-continuous monitoring. If they are continuously monitored 95% of the hourly averages should not exceed the emission value in table 1. The peak hourly average should not exceed 1.5 times the emission value.
- For CO a one hour average of 100 mg/Nm^3 may not be exceeded. Also 95% of the CO-measurements (10 minutes averages) taken in 24 hours have to be below 150 mg/Nm^3.
- For existing installations with a capacity > 6 tonnes per hour the conditions (850 °C, 2 seconds, 6 Vol% O_2) will have to be implemented by 1 December 1996, or at the latest when the furnaces are replaced. The other installations (capacity <6 tonnes per hour) have until 1 December 1995 to comply with the following conditions: 850 °C and 6 Vol% O_2 for a sufficiently long time.

EC-guideline [66]
- The values in table 1 are directly valid for new installations with a capacity of more than 3 tonnes per hour. Installations with a capacity of more than 1 but less than 3 tonnes per hour have the following limits: dust 100 mg/Nm^3, HCl 100 mg/Nm^3, HF 4 mg/Nm^3, CO 100 mg/Nm^3 and TOC 20 mg/Nm^3. In addition the limits for heavy metals in table 1 apply. Installations smaller than 1 tonne per hour have the following limits: dust 200 mg/Nm^3, HCl 250 mg/Nm^3, CO 100 mg/Nm^3 and TOC 20 mg/Nm^3.
- Existing installations larger than 6 tonnes per hour have to comply with the values in table 1 starting 01-12-1996. Existing installations with a capacity of smaller than 6 tonnes per hour have to comply with the limits for new installations (see above) starting 01-12-2000. By 01-12-1995 the existing installations have to comply with the following limits:
  - capacity < 1 tonne/hour: CO 100 mg/Nm^3 and dust 500 mg/Nm^3;
  - capacity > 1 but < 6 tonnes/hour: CO 100 mg/Nm^3 and dust 100 mg/Nm^3.

- For existing installations the conditions 850 °C and 6 vol% O_2 for at least 2 seconds need only to be fulfilled from the moment the combustor is modernised.
- 90% of the CO-measurements in 24 hours have to be below 150 mg/Nm^3. For existing installations the CO-limit of 100 mg/Nm^3 is hourly averaged for installations larger than 1 tonne per hour and daily averaged for the smaller ones.
- New installations larger than 1 tonne per hour have to monitor the emissions of dust, CO and HCl and also the O_2-concentration and the temperature continuously. Heavy metals, HF, SO_x and TOC are to be measured by sampling. Small installations (< 1 tonne per hour) have to monitor the emissions of dust, HCl and CO and the O_2-concentration by sampling. The frequency of the sampling is to be determined by the permitting authorities.
- Existing installations have to monitor dust, CO and O_2-concentrations continuously (>1 tonne/hour) or by sampling (<1 tonne/hour) starting 01-12-1995, until the requirements for new installations have to be met (see above).

5 Data per country

In this chapter the data per country are presented. This is done with a similar structure for all the countries:
- amount and composition of Municipal Solid Waste;
- composition of the plastic fraction of MSW;
- treatment schemes of MSW;
- existing MSW combustors;
- future plans or expectations considering the MSW composition and treatment;
- future plans or expectations considering MSW combustion facilities.

For comparison the total overview over Europe is given in the same structure.

In the tables concerning the combustion facilities a lot of abbreviations and symbols are used. These are explained in the Appendix. In the Appendix also other abbreviations and a number of key words are explained.

The order of the countries is as follows:

5.0 Europe (the countries considered in this study)
5.1 Austria (A)
5.2 Belgium (B)
5.3 Switzerland (CH)
5.4 Germany (D) (former FRG)
5.5 Denmark (DK)
5.6 Spain (E)
5.7 France (F)
5.8 Greece (GR)
5.9 Italy (I)
5.10 Ireland (IRL)
5.11 Luxembourg (L)
5.12 Norway (N)
5.13 Netherlands (NL)
5.14 Portugal (P)
5.15 Sweden (S)
5.16 Finland (SF)
5.17 United Kingdom (UK)

5.0 Europe

In this study Europe stands for the countries considered in this study: the EC-member countries plus Austria, Switzerland, Norway, Sweden and Finland.
In this chapter the totals and averages of all these countries are presented and compared. This comparison, however, must be made very carefully due to the differences in definitions of (parts of) the Municipal Solid Waste in the different countries. Where this plays an important role, however, this will be commented upon shortly. Details (like the references) can be found in the following chapters treating the data per country.

5.0.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Europe per year, with elaboration of the plastic fraction

In this study Municipal Solid Waste is generally understood to be the total of:
- household waste;
- bulky waste;
- comparable wastes from small commercial or industrial enterprises;
- market and garden residuals;

as far as it is collected and treated by or for the municipalities. For some countries, however, the definition of MSW is slightly different. In the following chapters the definition, if known, is given per country.

In Europe a total population of 357 million people is living, producing a total of 140 880 ktonnes of Municipal Solid Waste per year. Per capita this is an amount of 395 kg per year. The total amount of MSW produced in each country is given in table 5.0.1 as well as the production per capita. Also the composition of the MSW per country is listed. A mean composition for the whole of Europe is given as a reference.

From table 5.0.1 it can be seen that the countries with relatively high standards of living also produce relatively more waste. An exception to this is found in Austria, Germany and Sweden where on a basis of economy a higher amount of waste would be expected. In Germany and Sweden prevention of waste is relatively well established, whereas the low amount in Austria might be due to a difference in definition.

There are large differences in the composition of the MSW between the different countries; e.g. between Germany and Austria and Switzerland, countries which are expected to have comparable standards of living. Nevertheless in Germany 44% of the waste is putrescibles/fines and 24% is paper, whereas for Austria and Switzerland these fractions are equally represented at 30% (table 5.0.1).
Ireland, Greece, Portugal and Spain are high in putrescibles/fines, but for Italy the putrescibles/fines content is on average (for Europe) whereas for France the lowest content is reported, together with Norway. However, this might be influenced by some differences in definitions: France and Norway have the lowest content of putrescibles but also the highest content of miscellaneous. This

suggests a difference in the definition of the fraction putrescibles/fines between the countries.

Table 5.0.1 *Composition of Municipal Solid Waste per country in Europe. All data consider total MSW per country (i.e. including separately collected waste, see chapter 2.2)*

Country	Amount of MSW		Putrescibles/ fines Wt%	Paper Wt%	Plastic Wt%	Glass Wt%	Metals Wt%	Miscell (textiles incl.) Wt%
	k tonnes /yr	kg/capita						
A	2800	370	30	30	9	10	4	17
B	3500	350	47	28	7	7	4	7
CH	3700	550	30	31	13	7	6	13
D	25000	410	44	24	7	9	6	10
DK	2600	510	40	35	5	4	5	11
E	13300	340	49	20	7	8	4	12
F	20000	360	25	30	6	12	5	22
GR	3150	310	53	18	7	3	4	15
I	17500	300	40	22	7	8	3	20
IRL	1100	310	55	20	10	3	3	9
L	180	480	47	28	7	7	4	7
N	2000	470	25	32	7	4	4	28
NL	7700	520	38	35	7	7	5	8
P	2650	260	60	22	4	3	4	7
S	3200	380	30	40	9	7	3	11
SF	2500	500	30	40	6	4	3	17
UK	30000	520	42	28	7	8	9	6
Europe	140880	395	40	27	7	8	6	13
min-max[1)]		260-550	25-60	18-40	4-13	3-12	3-9	6-28

1) Minimum and maximum encountered, not based on standard deviation

Looking at the percentage of plastic in MSW not very much difference is seen between the countries (table 5.0.1); most of the countries have a plastic content of around 7%. Only Switzerland (13%) and Austria, Ireland and Sweden (9-10%) have significantly more plastic in their waste, whereas Portugal (4%) and Denmark (5%) have relatively low levels of plastic waste. This evenness might be caused to some extent by the fact that a lot of the analyses are not from recent date, but from 1984/85. Also for 9 out of 17 countries no primary references (report on the actual analysis; secondary references use data from analyses executed in other reports, (see chapter 2)) were available, which means it often is not sure whether the data are actually measured or estimated.
However, if analyses are executed the plastic content of MSW appears to be very sensitive for the time and place of the analysis. An analysis of MSW in Lausanne (CH) resulted in a plastic content of 5%(!) whereas MSW combustion experts in Switzerland are convinced the plastic content of the feed of their MSW combustors is 13-14%. Reports of studies done by EMPA mention plastic

contents of 20% and more [6]. Based on the consumption the plastic content of MSW should be 7-9%, but these values disregard the appearance in MSW of plastics with relatively long lifetimes. Because this study is focused on MSW combustion the plastic content is assumed to be 13%.
However, in some countries (Belgium, Germany) very soon new analyses will be executed, so more recent data will be available soon.

Table 5.0.2 shows the composition of the plastic fraction in MSW, for so far known (no data available on the plastics composition for Greece, Ireland, Portugal, Sweden and Finland). The main part of the plastics is formed by polyethylene and polypropylene. The differences in composition between the countries are not very large.

Table 5.0.2 *Composition of the plastics fraction per country (except for Greece, Ireland, Portugal, Sweden and Finland: no data available)*
All values on total amount of plastic per country

Country	Amount of plastic ktonnes/yr	PE/PP Wt%	PVC Wt%	PS Wt%	Other (incl. PET) Wt%
A	250	65	9	20	6
B	260	66	10	16	8
CH	480	65	9	11	15
D	1750	65	10	15	10
DK	130	60	12	8	20
E	930	67	12	10	12
F	1200	54	21	13	12
I	1230	80	8	8	5
L	13	66	10	16	8
N	140	73	8	10	10
NL	540	70	7	14	10
UK	2100	56	10	11	23
Europe [1)]	9020	64	11	12	13

1) The amount of plastics in the waste for Greece, Ireland, Portugal, Sweden and Finland is not included in this total for Europe. If it were the total amount of plastics in the MSW would be 9870 ktonnes/year

5.0.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

All the MSW is disposed of in mainly 4 different ways: combustion, recycling, landfill and composting. The data in this study do not include the treatment of residues from composting or combustion. For example: if a certain amount of residue from combustion is landfilled this amount is not included in the figure for landfill. This is done for three reasons:

- First of all it is not known precisely how much residue is generated and what is done with the residues from combustion or composting: in theory composted MSW is used as fertilizer whereas in practice it is often landfilled.
- The second reason is that residues from these processes are often considered chemical or special waste and therefore have to be landfilled on special sites, separately from regular MSW.
- The third reason is to prevent confusion on the total amount of MSW. In order to have a good understanding of the combustion and composting capacity the total amount of the waste which is treated by these processes is mentioned. By adding the residues of these processes to the other (relevant) treatment methods the total of MSW treated by combustion, recycling, composting and landfill would become larger then the total of MSW produced (the residues are counted twice). To avoid this the treatment of the residues is not included in the data.

However, if the treatment of the residues was included the amount recycled would increase a little bit, whereas the amount landfilled would increase considerably. The amounts combusted and composted will stay the same. The amount of waste treated will become larger then the amount produced, because part of the MSW is treated twice (first combusted or composted then recycled or landfilled).
Table 5.0.3 gives an overview of how the waste is treated in Europe. The values for Europe serve as a reference and represent the average for the countries considered.

The (scarce) information available on Greece did not give any evidence on combustion, recycling or composting so it was assumed that all the MSW is landfilled.

From table 5.0.3 it is apparent that the Mediterranean countries (E, GR, I, P) have a relatively high level of landfill. The same goes for Ireland, the United Kingdom and Finland.

Furthermore the relatively low level of recycling in Belgium, Luxembourg, France and Austria are noticeable.

Table 5.0.3 Treatment of Municipal Solid Waste per country in Europe
All data (except amount) in Wt% of the total MSW per country

Country	Amount ktonnes/yr	Combustion	Landfill	Composting	Recycling
A	2800	11	65	18	6
B	3500	54	43	0	3
CH	3700	59	12	7	22
D	25000	36	46	2	16
DK	2600	48	29	4	19
E	13300	6	65	17	13
F	20000	42	45	10	3
GR	3150	0	100	0	0
I	17500	16	74	7	3
IRL	1100	0	97	0	3
L	180	75	22	1	2
N	2000	22	67	5	7
NL	7700	35	45	5	16
P	2650	0	85	15	0
S	3200	47	34	3	16
SF	2500	2	83	0	15
UK	30000	8	90	0	2
Europe	140880	24	63	6	8

5.0.3 Overview existing Municipal Solid Waste combustors in Europe

In Europe there are 358 MSW combustors with a nominal capacity of 3 tonnes per hour or more in operation at the time. All together these combustors have a capacity (based on 7000 hours of operation per year) of 40 050 ktonnes per year. If this is compared to the total amount of waste which is actually combusted in Europe (table 5.0.3: 140 880 ktonnes MSW, 24% combusted = 33 810 ktonnes combusted) there is a considerable difference (for explanation see chapter 3.2).

Table 5.0.4 shows in which country the combustors are located and how much of the total MSW they combuste.

First of all it should be mentioned that the information on the Italian combustors is not complete. The situation in Italy is very confusing and it is not clear which installations are in operation and which are not. For this overview 16 combustors are assumed to be in operation. These 16 have a capacity of 1480 ktonnes per year whereas the total amount of MSW combusted in Italy is 2800 ktonnes per year (table 5.0.3; see also chapter on Italy).

In table 5.0.4 it can be seen that France owns the most combustion facilities by far (137). However, these 137 combustors are relatively small as they represent 38% of the number of combustors in Europe but only combuste 26% of the total

European MSW. On the contrary the installations in Germany and The Netherlands are relatively large: 13% (Germany) and 3% (The Netherlands) of the combustors handle respectively 28% and 7% of the European MSW. The average for The Netherlands is, however, largely influenced by the presence of the worlds largest MSW combustor: AVR Rotterdam (see chapter on The Netherlands).

Greece, Ireland and Portugal do not have MSW combustors.

Table 5.0.4 MSW combustors in Europe

Country	Number of combustors per country	% of total number of combustors in Europe [%]	Combustion capacity per country [ktonnes/yr]	% of total combustion capacity in Europe [%]
A	2	0.6	336	0.8
B	25	7.0	2240	5.6
CH	30	8.4	2860	7.1
D	47	13.1	11230	28.0
DK	29	8.1	2060	5.1
E	7	2.0	680	1.7
F	137	38.3	10310	25.7
I[1)]	16	4.5	1480	3.7
L	1	0.3	168	0.4
N	5	1.4	410	1.0
NL	10	2.8	2800	7.0
S	17	4.7	1770	4.4
SF	1	0.3	70	0.2
UK	31	0.7	3640	9.1
Europe	358	100.0	40050	100.0

1) The information on Italian combustors is not complete

In Europe most of the combustors recover energy from the flue gases (67% by number representing 83% of the MSW combustion capacity). Also this is very different per country. Surprisingly low is the energy recovery level in the United Kingdom. From comparing the percentages based on number of installations and amount of MSW processed it can be concluded that always the combustors which do recover energy are larger (in average) than the ones which do not.
Table 5.0.5 gives an overview of the level of energy recovery per country. The purpose of the recovered energy is mentioned in detail (as far as known) in the following chapters per country. In general, however, the Scandinavian countries use a high percentage of the recovered energy to produce hot water for district heating whereas the other countries mainly produce steam for electricity generation, with or without usage of the remaining energy.

Of course Greece, Portugal and Ireland are excluded from these tables as they do not have any MSW combustion facilities.

Table 5.0.5 Level of energy recovery in the different countries in Europe

Country	Number of combustors per country	% of total number with energy recovery [%]	Combustion capacity per country [ktonnes/yr]	% of total capacity with energy recovery [%]
A	2	100	336	100
B	25	44	2240	62
CH	30	77	2860	90
D	47	100	11230	100
DK	29	100	2060	100
E	7	57	680	79
F	137	55	10310	75
I[1)]	16	63	1480	72
L	1	100	168	100
N	5	100	410	100
NL	10	90	2800	97
S	17	100	1770	100
SF	1	100	70	100
UK	31	19	3640	29
Europe	358	67	40050	83

1) The information on Italian combustors is not complete

Also the way the flue gases are cleaned differs a lot. In table 5.0.6 the flue gas cleaning used in Europe is showed. For this the installations which have scrubbers as well as dust removing equipment are only counted to the fraction with scrubbers. For a number of combustors in France the flue gas cleaning used is not known; they represent the fractions unknown in table 5.0.6. There are two combustors without flue gas cleaning: 1 in Spain and 1 in the United Kingdom.

Table 5.0.6 Extent of flue gas cleaning in MSW combustion facilities in Europe

Extent of flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Flue gas cleaning:[1)]				
- unknown	3270	8.2	76	21.2
- none	60	0.1	2	0.6
- cyclone	800	2.0	18	5.0
- esp	14590	36.4	121	33.8
- fabric filter	100	0.2	3	0.8
- dry scrubber	3220	8.0	35	9.8
- semi-dry scrubber	6380	15.9	31	8.7
- wet scrubber	11610	29.0	72	20.1
Total	40050	100.0	358	100.0
Extended flue gas cleaning:[1)]				
- DeNOx	2130	5.3	7	2.0
- active cokes	1400	3.5	7	2.0

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

From comparing the percentages based on number of installations and amount of MSW processed it can be concluded that on average the capacity of the combustors:

- with no flue gas cleaning is relatively small;
- of which the flue gas cleaning system used is unknown is relatively small;
- which use just a fabric filter or just cyclones is relatively small;
- which use wet or semi-dry scrubbers or just an electrostatic precipitator is relatively large (on average);
- which use dry scrubbers is relatively small.

In table 5.0.7 where the use of scrubbers (total of wet, dry or semi-dry) is given per country also on the whole the combustors which use scrubbers are relatively large (on average). An exception is formed by The Netherlands and Belgium. For The Netherlands this will change soon because scrubbers are planned for all the installations which do not already have one (see chapter on The Netherlands).

Table 5.0.7 Extent to which scrubbers are used in the flue gas cleaning of MSW combustors per country

Country	Number of combustors per country	% of total number with scrubbers [%]	Combustion capacity per country [ktonnes/yr]	% of total capacity with scrubbers [%]
A	2	100	336	100
B	25	28	2240	22
CH	30	47	2860	54
D	47	100	11230	100
DK	29	45	2060	58
E	7	0	680	0
F	137	17	10310	28
I[1)]	16	38	1480	39
L	1	100	168	100
N	5	100	410	100
NL	10	60	2800	25
S	17	82	1770	94
SF	1	0	70	0
UK	31	0	3640	0
Europe	358	39	40050	53

1) The information on Italian combustors is not complete

5.0.4 Emission guidelines

The emission guidelines are explained in chapter 4.

5.0.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

All of the information available (some information was available for each country except for Portugal) on future plans and expectations on MSW management contained the expression of preferences to prevention, material recycling, energy recycling and safe disposal in that order. All countries are trying to reduce the amount of landfill, by first of all increasing recycling and after that increasing combustion. As packaging waste represents a large fraction of the waste a lot of projects and regulations concern the increased recycling of packaging waste. In some countries (The Netherlands, Belgium) there are voluntary agreements between the government and the packaging industry to reduce the amount of packaging used and increase the recycling of packaging waste. In Germany this is not a voluntary agreement but it is regulated by law, and the same approach is considered in France. Also the European Community has set

up a number of targets for packaging waste, which is due to be adopted early 1993. The main points are as follows:

- 90 Wt% of the packaging waste shall be removed from the waste stream to be recovered and 60 Wt% of each material used shall be removed to be recycled (excluding energy recycling) within 10 years.
- As from 01-01-2000 any packaging which is not reusable nor recoverable will be banned.
- The quantity of packaging used must be minimized as well as the use of hazardous substances or heavy metals.

What the composition of the MSW will be in future is not known. The general expectations are that the heating value of MSW will increase in future, because of a decrease in the putrescibles content of MSW. More and more putrescibles are separately collected and composted. Besides that paper and plastics are expected to increase as a consequence of growing economical and technical level.

5.0.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

As to combustion facilities there is also a lot of uncertainty. Most countries have plans for extension of the combustion capacity but in a number of countries (among others Germany and The Netherlands) the opposition from the public and from environmental groups is getting so strong that plans are postponed or even cancelled. Even if there is in principle no opposition to new combustion plants there still are enormous difficulties in finding suitable locations ('NIMBY'= Not In My Back Yard).

However, the lack of other solutions (presently available) will make the construction of new MSW combustors inevitable. Especially because due to stricter regulations old combustors will be shut down. Others will be retrofitted with flue gas cleaning techniques or improved process control systems.

All countries (which have combustors) expect the combustion capacity to grow in the next two decades.

5.1 Austria

5.1.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Austria per year, with elaboration of the plastic fraction

Austria has a population of 7.6 million people which produce around 2800 ktonnes of Municipal Solid Waste per year, which is around 370 kg per capita per year. This MSW consists of household, bulky and trade waste. The composition of this MSW is given in table 5.1.1.

Data of MSW in Austria over the last years show an increase in total amount. This is not just an increase in waste produced because these data are influenced by a change in definition of MSW in Austria, which took place in 1985. Before that MSW was considered to be household waste alone. After 1985 also bulky and trade waste was included in the term MSW.
But the main reason is a more efficient collection of especially bulky and trade waste.

Table 5.1.1 Total amount and composition of Municipal Solid Wast generated in Austria per year (1990) [7, 9, 10, 12, 13, 14, 16]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	840	30
Paper & cardboard	840	30
Plastic	250	9
Glass	280	10
Metals	110	4
Textiles	80	3
Miscellaneous	390	14
Total	2800	100

In Austria 250 ktonnes/year plastics waste arise in household waste (including plastics arising in textiles, composite products and so on). Table 5.1.2 shows a distribution of this 250 ktonnes over the main plastics.

Table 5.1.2 Composition of the plastics fraction in the Municipal Solid Waste in Austria (1988) [18]

Component	Amount	
	ktonnes/yr	% of total plastics
PE/PP	175 - 195	63 - 71
PVC	19 - 33	7 - 12
PS	55 - 63	20 - 23
PET	0 - 14	0 - 5
Other	0 - 28	0 - 10
Total	250	100

5.1.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Table 5.1.3 shows how the MSW in Austria is managed.

Table 5.1.3 Municipal Solid Waste treatment per category in Austria (1990) [7, 12, 16]

Component	Municipal Solid Waste ktonnes/yr	Solid Waste %
Recycling	170	6
Composting	500	18
Landfill	1830	65
Combustion	300	11
Total	2800	100

In general, recycling of different materials is well established and enforced in Austria. Especially waste paper and waste glass are collected systematically around the whole country. Some other materials are collected locally, like scrap metal or plastic foils. But the collection level is rather low (table 5.1.3).

5.1.3 Overview existing Municipal Solid Waste combustors in Austria

At the moment there are 2 MSW operators working in Austria. They both are located in Wien. There used to be a third combustor in Wels but this is not in operation any more. A completely new combustor as part of a waste management system is being build at the same location in Wels. The technical data on these combustors are given in table 5.1.4.

Table 5.1.4 Municipal Solid Waste Combustors in Austria

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Incinerator type	Location	Start-up year	Manufacturer	Unit capacity	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Flue gas cleaning	Inhabitants connected (*1000)	Remark	Reference
1	Wels	1973	Keller-Peukert	2*3.4	2	50	6.8	Y	ep,w,nl,c	55	Closed at the moment, will be rebuilt 1994/5	16,17,38
1	Wien I (Flötzersteig)	1963	von Roll	3*6	3	84	18	el, dh	w, ep, nl	293	pilotplant fgc:c ; design cap: 180 kton/yr???	16,17,33,45
1	Wien II (Spittelau)	1971	Martin	2*15	2	210	30	el, dh	w, ep, nl	638	Design cap: 250 kton/yr; 230 MW	16,17,33

Explanation in appendix, page 5

The total combustion capacity of the two combustors currently in operation is 336 ktonnes per year(actually combusted amount: 300 ktonnes per year). Both combustors use an extended flue gas cleaning system, and recover energy for electricity production and district heating. In table 5.1.5 some relative data are extracted from table 5.1.4.

Table 5.1.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Austria

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery: – Yes – No	336	100	2	100
Total	336	100	2	100
Flue gas cleaning:[1)] – unknown – none – cyclone – esp – fabric filter – dry scrubber – semi-dry scrubber – wet scrubber	336	100	2	100
Total	336	100	2	100
Extended flue gas cleaning:[1)] – DeNOx – active cokes	336	100	2	100

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

The residues from these combustors are currently being landfilled. Several treatment processes for these residues are at the moment being investigated. First aim is to treat the residues in such a way that safe disposal in landfills can be guaranteed. Secondly among others at the university of Vienna processes are developed to reuse (fractions of) the residues (mainly in road construction) [19].

No information is available on the emission monitoring and the amount of energy which is actually recovered.

5.1.4 Emission guidelines

The Austrian emission guideline (Luftreinhalteverordnung; LRV 1989) is one of the strictest in Europe. In chapter 4 all the emission guidelines are compared.

5.1.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

In Austria the total amount of MSW is expected to grow according to the economical growth rate: 2% per year. The Austrian government have expressed the generally accepted intentions to promote prevention and increase recycling.

A similar development as in Germany is going on in Austria on the recycling of packagings. According to the German model of 'duales Entsorgungssystem' an association of bottlers has formed a company of its own, the ARGEV, with the goal to build up a collection system for waste packaging from their members [20].

A regulation has been sent out requiring the following recovery rates for glass and cans (refilling and recycling) [26]:

Beer	90% by 1992	90% by 1993
Carbonates	60% by 1992	80% by 1993
Juices	25% by 1992	40% by 1993

From April 1991 all one way glass, plastic and metal beverage packs (other than for milk and wine) are bearing a waste management contribution of ÖS 0.5 (up to 1 litre) or ÖS 1 (larger sizes). Refillable PET is subject to a mandatory deposit of ÖS 4. (1 ÖS is approx. 0.15 DM or 0.09 $)

In Austria 250 ktonnes/year plastics waste arise in household waste (including plastics arising in textiles, composite products and so on). Estimates are that at the maximum 160 ktonnes/year can be recycled. The plastic waste production, before recycling, is estimated to grow quicker than the total amount of MSW: 4% per year.

5.1.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

As already mentioned a new combustor will come into operation in 1994. The two combustors which are operating right now will remain open. The total capacity then will be 396 ktonnes/year. In the new combustor the energy is recovered for electricity production and district heating, the same as in the two existing installations. This new combustor (located in or near Wels) will have an extended flue gas cleaning system with a wet scrubber and a DeNOx-installation like the two existing combustors. In addition an active cokesfilter is used. One of the existing installations (Flötzersteig) is performing pilot scale tests with this technique. It is not known whether, after testing, the technique will be applied.

5.2 Belgium

5.2.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Belgium per year, with elaboration of the plastic fraction

There are 9.9 million Belgians living in Belgium, divided over three parts: Flanders, Wallonia and Brussels. They produce 3500 ktonnes MSW per year which consists of household and bulky waste. (The reference used does not give a clear definition of MSW). Per capita this means 352 kg MSW produced per year. The composition of this MSW is given in table 5.2.1.

Table 5.2.1 Total amount and composition of Municipal Solid Waste generated in Belgium per year (1990) [7, 9, 10, 16, 21, 28, 49]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	1650	30
Paper & cardboard	980	30
Plastic	260	9
Glass	245	10
Metals	140	4
Textiles	70	3
Miscellaneous	175	14
Total	3500	100

The last analysis of Municipal Solid Waste took place in 1985/1986. In late 1992 again an analysis will take place. The average percentage of plastic in MSW is 7% (weight). This amount is split up in table 5.2.2.

Table 5.2.2 Composition of the plastics fraction in the Municipal Solid Waste in Belgium (1984) [53]

Component	Amount	
	ktonnes/yr	% of total plastics
PE/PP	170	66
PVC	30	10
PS	40	16
PET	10	4
Other	10	4
Total	260	100

5.2.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Since 1981 there has been continued devolution of responsibility for environmental matters to the three regions, Flanders, Wallonia and Brussels. The regional governments control emissions to air and water, the treatment and disposal of waste, and (since 1988) the implementation of EC Directives [20].

Regionally, Flanders is generally seen to be more advanced than either Wallonia or Brussels. Flanders currently levies a tax on waste disposal, which is likely to encourage similar measures in Wallonia and Brussels.
This charge was instituted in 1987 and updated 1 January 1990. It is approximately 50% of disposal cost but depends on the type of waste. The funds generated go towards environmental purposes as OVAM (The Public Company of Wastes) and waste water treatment.

Table 5.2.3 Municipal Solid Waste treatment in Belgium (1990) [16, 21, 28]

Component	Municipal Solid Waste	
	ktonnes/yr	%
Recycling	100	3
Composting	0	0
Landfill	1500	43
Combustion	1900	54
Total	3500	100

Recycling is done in some projects on a stand-alone basis. There is no overall strategy and many of these projects are executed from private initiatives.

Solvay collects PVC bottles in 160 municipalities [54]. Volunteers collect the bottles. In 16 municipalities plastic bottles are collected in containers at several collection points throughout the city. The collected material is recycled. ECO recycling recycles 3 ktonnes of all kind of plastics per year to produce for instance garden fences and such. The production will be expanded to 5 ktonnes per year [55].

All municipal waste in Brussels is combusted.
In Wallonia the percentage landfill is higher and combustion is lower relative to Flanders.

5.2.3 Overview existing Municipal Solid Waste combustors in Belgium

In Belgium 25 MSW combustors with a capacity of 3 tonnes/hr or more are in operation at the moment: 20 in Flanders, 1 in Brussels and 4 in Wallonia (table 5.2.4) These combustors combusted 1900 ktonnes MSW in 1990, though their design capacity (capacity per hour * 7000 hours per year) is approximately 2240 ktonnes per year. In table 5.2.5 the percentage of the installations which use energy recovery or flue gas cleaning is calculated from the values in table 5.2.4. The same is done for the amount of waste processed in these combustors, based on the design capacity.

Table 5.2.4 Municipal Solid Waste Combustors in Belgium 1991

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Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Steam [bar]	['C]	Flue gas cleaning	Remark	Reference
1	Antwerpen (Merksem)	1978	Volund	2*3.5	2	24	7	N			d, ep		16,21,38,43,48
1	Brugge	1981	Martin	3*9	3	172	27	el,dh			ep,w		16,21,48
1 r	Brussels (B)	1985	Martin	3*23	3	450	69	st	39	400	ep	940 kton st/yr: 200 GWh	16,21,46
1	Edegem	1970	Claudius Peters	2*3.3	2	28	6.6	dh			ep, d, ff		16,21,48
1 +3	Eeklo	1981	Volund	2*7	2	65	14	N			ep		16,21,43,48
1	Gent	1979	CEC	2*2.5	2	63.5	5	N			ep		16,21,48
1	Harelbeke	1977	CEC	2*5.5	2	63.5	11	el			ep	7.5 MW	16,21,48
1	Heist o/d Berg	1977	Volund	2*3.2	2	32.5	6.4	N			ep		16,21,38,43,48
1	Herstal (Luik:W)	1990		34	1	245	34	Y			ep		16
1	Hoevenen	1976		1*4.5	1	22	4.5	N			ep		16,21,48
1	Izegem	1976	Alberti Fonsar	2*3	2	23	6	N			cy		16,21,48
1	Knokke Heist	1975	Skowzonek	2*2	2	20	4	dh			ep		16,21,48
1 +3	Houthalen	1984	Volund	2*3	2	79.5	6	el			ep,w	36 t st/hr, 6.2 MW	16,21,43,48
1	Lokeren	1973	CEC	2*1.8	2	26	3.6	N			cy		16,21,48
1	Melsele (Beveren)	1978	Alberti Fonsar	2*2.2	2	21	4.4	N			ep		16,21,48
1	Menem	1983	Braun-Sorensen	2*4	2	25.5	8	N			ep		16,21,48
1	Oostende	1982	CEC	2*5.6	2	76	11.2	el			ep, w	29 t st/hr; 5.5 MW	16,21,48
1	Pont de Loup (Charleroi,W)	1978		2*7.5,1*8	3	100	23	N			ep	planned: w	16
1	Roeselare	1976	Volund	2*4	2	53	8	dh			ep, d, ff		16,21,38,43,48
1	Ronse	1977	SBM	2*2.7	2	21	5.4	N			ep		16,21,48
1	St. Niklaas	1977	Volund	2*3.2	2	55	6.4	el,dh			ep,w		16,21,38,43,48
1	Thumaide (W)		SBM	2*5.3,1*5	3	60	15.6	Y			ep	planned: w	16
1	Virginal-Samme (W)	1973		2*5	2	29.5	10	N			ep	energy recovery planned	16
1	Willebroek	1973	De Nayer	2*2.2	2	1.1	4.4	N			ep	closes april 1992	16,21,48
1	Wilrijk (Antwerpen)	1980	CEC	2*10	2	70	20	N			ep		16,21,48

Explanation in appendix, page 5

Table 5.2.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Belgium

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	1390	62	11	44
– No	850	38	14	56
Total	2240	100	25	100
Flue gas cleaning:[1)]				
– unknown				
– none				
– cyclone	70	3	2	8
– esp	1670	75	16	64
– fabric filter				
– dry scrubber	150	7	3	12
– semi-dry scrubber				
– wet scrubber	350	16	4	16
Total	2240	100	25	100
Extended flue gas cleaning:[1)]				
– DeNOx				
– active cokes				

[1)] Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

From this table the following is apparent:
- The 44% of the installations, where energy is recovered, represent 62% of the Belgian MSW combustion capacity. This means that these are relatively large installations.
- The combustors which use dry scrubbers to clean the flue gases are relatively small (12% of the installations represent 7% of the MSW combustion capacity).
- The installations with just cyclones for flue gas cleaning have a relatively low capacity (8% of the combustors represent 3% of the MSW combustion capacity)).
- Only 23% of the flue gases from MSW combustion is cleaned in scrubbers.

It is not known what is done with the residues from Belgian MSW combustors. Probably most of it is landfilled.

No information on the emission monitoring or the actually recovered amount of energy is available. Little is known on steam parameters. In general MSW combustors which recover energy for electricity generation produce steam with 350-360 °C and 34-35 bar. Hot water boilers produce steam of circa 20 bar and 220-230 °C.

5.2.4 Emission guidelines

The current Belgian emission guideline dates back from 1982 (chapter 4). The demands on emission reduction according to this guideline are very low compared to the others. Very soon, however, the emission guidelines will be updated and the MSW combustors will have to comply with the EC guidelines. For combustors with a capacity over 30 tonnss per hour stricter limits are proposed, comparable to the German guidelines (see chapter 4).

5.2.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

In Flanders recently a voluntary agreement has been closed between the secretary of environment and the plastics industry (the same approach as the Liquid Containers Directive 1985) that covers all packaging waste [55]. It consists of a prevention, re-use, recycling concept and setting up a packaging database. The industry undertakes to develop and implement environmentally friendly production processes, continue to lightweight packaging, remove any pollutants and incorporate recyclability into packaging design.
North of Brussels a pilot project will be started (500, 000 inhabitants) early next year, to be evaluated in 1995 [55]. It is an agreement of the recovery of plastic packaging. The Government handles the collection, the industry has a commitment to buy and recycle the plastic waste. Nutrition industries and distribution also contribute to this project. Funding of this project will be done by a sort of tax on every plastic packaging product.
In general the objective is to stop landfilling packaging waste by the year 1995, to encourage waste prevention and develop material recycling [26].

Brussels and Wallonia have drawn up their own (joint) packaging waste program. It sets a recovery target for each packaging material of 70% by the year 2000. Within this 70%, 60% of the plastics are to be recycled (30% by 1995) [26].

Increase of combustor plants is hold back by public opinion. In future the main strategy of reducing waste will be by prevention and recovery. Very ambitious targets are set in the MINA-plan [28] (plan for Environment and Nature in Flanders) concerning prevention and recycling:
- prevention, causing a decrease in total MSW of 8% in 1995;
- 40% decrease in packaging waste in 1995, and 80% in 2000;
- 30% recycling in 1995;
- combustion of the rest: landfilling only the waste which cannot be combusted.

In Wallonia voluntary agreements with the industry are discussed to reduce waste generation.
Overall aims are to decrease landfilling from 70% in 1990 (lower than for the total of Belgium) to 40% in 1995 and 10% in 2000. Recycling will have to take care of 22% of the household waste by the year 2000 [26].

5.2.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

All the MSW combustors currently in operation in Flanders are being shut down one by one in between now and 2010. They will be replaced by 5 or 7 large combustors which will have to combust the waste of an entire district.
At the moment a proposal [56] has been set up to form a basis for discussion on where the combustors will be situated and with what capacity. No information besides the emission guidelines, is known yet on the technical level of the equipment used for the combustion.

5.3 Switzerland

5.3.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Switzerland per year, with elaboration of the plastic fraction

In Switzerland live 6.7 million people, producing the highest amount (550 kg) of MSW per capita per year. In total this adds up to 3700 ktonnes per year for the whole of Switzerland. Table 5.3.1 shows the composition of this MSW, which is assumed to consist of household, bulky and trade waste.

Table 5.3.1 Total amount and composition of Municipal Solid Waste generated in Switzerland per year (1990) [7, 9, 10, 16, 57, 58, 59]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	1110	30
Paper & cardboard	1150	31
Plastic	480	13
Glass	260	7
Metals	220	6
Textiles	110	3
Miscellaneous	370	10
Total	3700	100

There is discussion over the amount of plastic in the Swiss MSW. An analysis of the Secretary of Environment is 13%, but this is too high compared to the consumption. Estimates based on consumption [60] give 7-9% plastics. However, Swiss combustion experts write and talk about the consequences of the high plastic content of the MSW in Switzerland, which they set at 13-14% [47, 61, 62]. Recent analyses of MSW by EMPA report plastic contents of more than 20% [6]. The definitions of MSW belonging to those data is not known, however. We assumed the plastics content to be approximately 13% (table 5.3.1) which amount is split up in table 5.3.2.

Table 5.3.2 Composition of the plastics fraction in the Municipal Solid Waste in Switzerland (1990)

Component	Amount	
	ktonnes/yr	% of total plastics
PE/PP	290 - 340	60 - 70
PVC	25 - 70	5 - 15
PS	50 - 70	10 - 15
Other (PET incl.)	50 - 100	10 - 20
Total	420 - 580	85 - 120

5.3.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Swiss environmental protection legislation is framed in a Federal Law which took effect in 1985. To date ordinances have been issued covering policy for air, environmentally hazardous substances, waste treatment, soil pollution, noise and transport of special wastes [20].

Based on the law relating to the protection of the environment the Technical Ordinance on Wastes (December 1990) contains general technical and administrative prescriptions on the collection, recycling and treatment of wastes. In 1986 the Federal Commission for Waste Management published principles for the treatment and disposal of waste for the near future ('Guidelines for Waste Management in Switzerland', June 1986). The goals of these guidelines are transposed into concrete prescriptions in the technical ordinance on wastes. The main points are [58]:

- Reuse/Recycling have priority to combustion and deposition. As far as possible/practical the waste has to be separated. If possible the separated fractions have to be reused.
- All non reusable, combustible waste has to be combusted in appropriately equipped facilities with recovery of energy.
- Non reusable, non combustible waste has to be transformed into a chemically stable, water insoluble form consisting of inorganic material.
- Standards for waste treatment plants and landfills.
- Prescriptions governing the operation of treatment plants and landfills.
- Planning and authorization procedures.

Until recently waste management and disposal was poorly regulated and operated on an ad hoc, fragmented basis at the Cantonal level. Waste disposal has depended on landfill and export [20].

Table 5.3.3 Municipal Solid Waste treatment per category in Switzerland (1990) [7, 9, 10, 16, 57, 58, 63]

Component	Municipal Solid Waste ktonnes/yr	%
Recycling	800	22
Composting	250	7
Landfill	450	12
Combustion	2200	59
Total	3700	100

Recycling in Switzerland mainly consists of glass and paper. Only recently the amount which is composted has increased.

5.3.3 Overview existing Municipal Solid Waste combustors in Switzerland

In Switzerland 30 MSW combustors with a design capacity of 3 tonnes/hr or more are in operation at the time. Table 5.3.4 gives detailed information on every one of them. How many of these installations is equipped with energy recovery or flue gas cleaning is calculated in table 5.3.5. Also the amount of waste which is combusted in these installations is given. Combinations of scrubbers and dust removing equipment are only counted to the scrubbers.

Table 5.3.4 Municipal Solid Waste combustors in Switzerland 1991

TNO 20/05/92

Incinerator type	Location	Start-up year	Changes	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Steam [bar]	['C]	Flue gas cleaning	Remark	Reference
1	Aire-la Ville (Geneve)	1966		von Roll, Martin	2*6,1*20	3	211	32	Y			ep,w		16,17,37,38
1	Basel	1944	E66,69	von Roll	2*8.3,2*12.5	4	210	41.6	Y			ep,w	fgc: SCR gepland	16,17,45,47
1	Bern	1954	E76;M85	von Roll	2*9.8	2	124	19.6	hw,el			ep		16,17
1	Bioggio	1974		De Bartolomeis	2*2.3	2	36	4.6	N			ep		16,17
1	Brig-Glis	1971		K+K	3.5, N.A.	2	26	3.5	N			ep, w		16,17,38
1	Brügg-Biel	1968	E76	von Roll; K+K	5.0, 3.5	2	43	8.5	Y			ep, w	1 unit on duty	16,17
1	Buchs AG	1974	E84	Alberti Fonser; Martin	3*2.9, 8.3	4	84	17	hw			ep, w		16,17
1	Buchs SG	1975	E82	Alberti Fonser	5.0,8.3,N.A.	3	60	13.3	el			ep,w		16,17,45
1	Colombier	1971		Alberti Fonser	2*3.6	2	45	7.2	el			ep,w		16,17
1	Dietikon	1971		Sulzer/Martin	2*1.6, 0.6	3	25	3.8	hw			ep	fgc: scrubber planned/being built	16,17
1	Hefenhofen	1974		Alberti-Fonser	2*4.2	2	28	8.4	N			ep		16,17
1	Hinwil	1971	E76	Martin	4.3, 7.4	2	12.3	11.7	el			ep	fgc: scrubber planned/being built	16,17
1	Horgen	1968	M74	K+K	7.4, 3.8	2	32	11.2	Y			ep, w		16,17,45
1	Kirchberg	1976	E84	Martin	3*3.5	3	54.1	7	Y			ep	fgc: scrubber planned/being built	16,17
1	La Chaux de Fonds	1972			2*3	2	29	6	Y			ep, w		16,17
1	Lausanne	1958		von Roll	2*2.8	2	52	5.6	el			ep, w		16,17,37
1	Locarno	1969		De Bartolomeis	2*1.6	2	20	3.2	N			ep		16,17
1	Luzern	1971	E83	von Roll	2*16,19	3	68	51	el			ep, w	pilot-plant n2	16,17,47
1	Monthey	1976		De Bartolomeis	2*7	2	63	14	el			ep	fgc: scrubber planned/being built	16,17
1	Müllheim	1974		Alberti-Fonsar	4, 3.6	2	35	7.6	N			ep	Energy recovery under consideration	16,17
1	Niederurnen	1973		von Roll	4.0, 9.0	2	45	13	Y			ep, w		16,17
1	Oftringen	1974		OFAG, Buckau-Wolf	3.3, 3.6	2	34	6.9	hw			ep	fgc: scrubber planned/being built	16,17
1	Sion	1971	E77	De Bartolomeis	1*3,1*4	2	45	7	N			ep	fgc: scrubber planned/being built	16,17
1	St. Gallen	1972	E87; M87	von Roll	3.3, 3.5	2	61	6.8	Y			s, ep		16,17,38
1	Trimmis	1975		Alberti-Fonsar	2*4.4	2	42	8.8	N			ep, w		16,17,38
1	Turgi	1970	E83	Alberti-Fonsar	2*3.6, 5.8	3	70	13	hw			ep, w		16,17,38
1	Winterthür	1965	E77	von Roll; Martin	12.5	1	97	12.5	Y			ep	fgc: scrubber planned/being built	16,17
1	Zermatt	1964		Martin	1.3	1	4.8	1.3	Y			ep		16,17
1	Zuchwil (Emmenspitz)	1976	M87	von Roll	2*10.0	2	140	20	el,hw			ep,w,n2	E90 3rd unit; n2 in "pilotplant"	16,17,45,47
1	Zürich/Hagenholz	1969	M82	Martin; W+E	1*15.2,1*13.0	2	214	28.2	el	37	420	ep,w	pilot SCR-plant	16,17
1	Zürich/Jozefstrasse	1978		Martin	1*15.2	1	110	15.2	Y	40	420	s,ep,n1		16,17,39,47

Explanation in appendix, page 5

Table 5.3.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Switzerland

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	2560	89	23	77
– No	300	11	7	23
Total	2860	100	30	100
Flue gas cleaning:[1)]				
– unknown				
– none				
– cyclone				
– esp	1310	46	16	53
– fabric filter				
– dry scrubber				
– semi-dry scrubber	50	2	1	3
– wet scrubber	1500	52	13	43
Total	2860	100	30	100
Extended flue gas cleaning:[1)]				
– DeNOx	250	9	2	7
– active cokes				

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

From table 5.3.5 it is apparent that the combustors which do not recover the energy are relatively small. Furthermore only slightly more than half the combustors clean their flue gases with a (mainly wet) scrubber.

The bottom-ash from MSW combustion is partly reused in road construction and partly landfilled (normal landfill). The fly ashes and flue gas cleaning residues are to be solidified before landfilling in a sanitary landfill (especially for toxic waste). However, still some combustion residues end up in ordinary landfills which are not well suited for this.

No information on the emission monitoring or the actually recovered amount of energy is available. Little is known on steam parameters. In general steam parameters are said to be 42 bar and 400 °C, and approximately 15% of the energy content of the waste is recovered [61].

5.3.4 Emission guidelines

Swiss guidelines set the emission limits for MSW combustion a little higher than the Germans do, except for NO_x. The limits, however, are considerably lower than the EC-regulations (see chapter 4).

5.3.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

There is an agreement between government and industry to ban PVC from short life applications. PVC bottles for mineral water, alcohol-free beer and soft drinks have been replaced by glass bottles (this has increased the waste stream on weight basis). By the end of 1993 90% of the beverage containers for the mentioned drinks should be refillable or recyclable [26].
The average plastic consumption growth is 7.2% a year. Legislation has no influence on plastic consumption (except PVC).
Switzerland has no plastics manufacturing industries (except PVC) therefore legislation requiring return systems is not possible, prohibition will be the answer. However, plans exist to buy recycling plants abroad (for instance an EVC plant) [60].

In 1995 only chemically inert material will be landfilled. Putrescibles may not exceed 5%. Combustion capacity will increase slightly. An increase in recycling is required.

Governmental plans exist for putting a recycling tax on several products [60]:

Al-industry	0.05 sFr (Swiss Francs) per can.
batteries	0.02 - 0.03 sFr.
refrigerator	60-70 SFr.
cars	100 dollars (around 140 sFr).
plastics	soon to be several centimes (0.01 SFr) per kilo.

The taxes will be used to fund recycling plants.

According to the Government in the near future 30-35% of the total MSW arising has to be recycled, but 20% seems attainable. The Government has also plans to build specific plastic waste combustors in the next 10 years.

Table 5.3.6 Expected treatment schemes of Municipal Solid Waste in Switzerland in the year 2000 [57, 58]

Component	Municipal Solid Waste ktonnes/yr	%
Recycling	1100	29
Composting	300	8
Landfill	0	0
Combustion	2400	63
Total	3800	100

5.3.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

In table 5.3.4 it can be seen that a lot of combustors which do not use scrubbers at the time are planning to retrofit their installation with scrubbing equipment. Due to the low NO_x-emission limit in the new Swiss 2guideline (80 mg/Nm^3) a lot of combustors are also planning to build DeNOx-installations.

Switzerland is building 1 new combustor near the city of Geneva. This will be in operation in 1993.

5.4 Germany

5.4.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Germany per year, with elaboration of the plastic fraction

In Germany (former West-Germany or FRG) 61.1 million people live, which is the largest population of the countries considered in this study. A lot has changed in Germany since the reunification with the former East-Germany (DDR) but not much information is available on the eastern part of the new Germany yet. Therefore this part is left out in this study. (From now on Germany is considered to be the former West-Germany).

In Germany 25000 ktonnes of MSW is produced every year, which is around 410 kg per capita per year. Municipal Solid Waste is in Germany considered to be household and bulky waste and around 50% of the trade waste. As one of the few countries Germany succeeds to keep the amount of household waste nearly constant: from 1979 to 1985 there even was a decline in the amount of waste produced of 5 Wt% [64, 67]. Table 5.4.1 shows the main components of the German MSW.

Table 5.4.1 Total amount and composition of Municipal Solid Waste generated in Germany per year (1990) [7, 9, 10, 16, 67]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	11000	44
Paper & cardboard	6000	24
Plastic	1750	7
Glass	2250	9
Metals	1500	6
Textiles	500	2
Miscellaneous	2000	8
Total	25000	100

Since 1984 no analysis has been done on the plastics fraction of household waste. All more recent numbers (like the ones in Table 5.4.2) are estimates [68].

Table 5.4.2 Composition of the plastics fraction in the Municipal Solid Waste in Germany (1989) [69, 70]

Component	Amount	
	ktonnes/yr	% of total plastics
PE/PP	1140	65
PVC	175	10
PS	260	15
PET	90	5
Other	90	5
Total	1750	100

5.4.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

About 25 million tonnes of municipal wastes are to be disposed off annually in Germany. Packaging wastes compose up to 50% in volume and 30% in weight of this. 36% of the municipal wastes is combusted, 2% composted, 16% recycled and the rest is landfilled. It is estimated that in 1995, given a continuous waste generation, about 50% of the current landfill capacity in Germany will be used up. New sites will not be available at that point of time.

The waste management in Germany is based on the following sequence [24]:
- avoidance of waste;
- material recovery and reuse of waste incl. wrappings;
- treatment (thermal) of the remaining waste and residues from waste recovery combined with energy recovery;
- reuse or dumping of the treated, mineralized, inorganic residues from waste and waste treatment.

Table 5.4.3 Municipal Solid Waste treatment per category in Germany (1990) [7, 9, 10, 16, 24, 67, 71]

Component	Municipal Solid Waste	
	ktonnes/yr	%
Recycling	4000	16
Composting	500	2
Landfill	11500	46
Combustion	9000	36
Total	25000	100

Table 5.4.4 Municipal Solid Waste Combustors in Germany 1991

TNO 20/05/92

Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Total capacity Units	[kton/yr]	[ton/hr]	Energy system	Steam [bar]	['C]	Flue gas cleaning	Remark	Reference
1 r ss	Bamberg	1978	VKW/VKW	3*7	3		21	st/chp	26	227	ep, w		31
1 d	Berlin	1967	Borsig/VKW	7*12	7	400	84	st	75	470	ep, d, ff		31
1 r hw	Bielefeld-Herford	1982	W+E/Baumgarte;Fröling-Siegofa	3*16	3	287	48	st/chp	40	400	ep, w		31
1 d	Bremen	1969	Dürr-Werke/Bremer Vulkan	3*15,1*20	4	287	65	st/chp	21	215	s, ep	fgc: ci planned	31,45
1 f	Bremerhaven	1977	von Roll/Seebeck-Werft	3*15	3	242	45	st/chp	40	400	ep, w, n2		31,45
1 r ss/hw	Coburg	1989	Martin/Wehrle	2*11	2	141	22	st/chp	40	400	ep, w	waste water free	31
1 f	Darmstadt	1967	von Roll/MAN;von Roll/Wamser	2*8.4,1*11	3	140	27.8	st/chp	38	350	ep, w		31
1 d	Dusseldorf	1972	VKW/Dürr-Lentjes	6*12.5	6	295	75	st/chp	112	500	s,ep,c,n1		31,41,45
1 d	Essen/Karnap	1987	VKW/VKW	3*22	3	550	66	st/chp	41	400	ep, w		31
1 f	Frankfurt/M.	1966	von Roll/Baumgarte	4*15	4	420	60	st/chp	60	500	s, ep	fgc: ci planned	31,45
1 f	Geiselbullach	1970	von Roll/Baumgarte	2*6	2	107	12	st/chp	40	400	d, ff	pilotplant fgc:c; ci planned	31,45
1 d	Goppingen	1975	VKW/VKW	2*12	2	169	24	st/chp	39	410	ep, w		31
1 d	Hagen	1966	VKW/VKW	3*6	3	122	18	st/dh	14	196	s, ep		31
1 r	Hamburg (Borsig.)	1958	Martin/Walther;HDW	2*18	2	162	36	st/chp	18	340	s, ep	fgc: n2 planned 93	31
1 r	Hamburg (Stell.)	1973	Martin/Walther	2*18	2	217	36	st	41	410	ep, w		31
1 d	Hameln	1977	VKW/VKW	2*10	2	110	20	st, dh	40	450	d,ep,c,n1,n2	cokes desorbed; extension	31,45
1 f	Hamm	1986	K+K/Lentjes	4*9.5	4	245	38	st/chp	40	400	s, ff		31
1 f	Heidelberg	1974	Lambion	1*5	1	40	5	cd			ep, w		31
1 f	Herten	1982	Steinmüller/Steinmüller	1*5	1	126	5	st/chp	32	320	ep,d,ff,n3(c)		31,45
1 r,f ss	Ingolstadt	1978	Alberti Fonser, W+E/Wamser	2*7, 1*10	3	140	24	st/chp	40	400	ep,w,ci,ff		31,45
1 f,d	Iserlohn	1970	K+K;VKW/VKW	2*8, 1*16	3	150	32	st/chp	17	250	ep, w		31
1 d	Kassel	1968	Dürr-Werke/Dürr-Werke	2*10	2	120	20	st/chp	42	450	s, ff		31
1 f	Kempten (Allgau)	1975	von Roll/Wamser; Baumgarte	1*4,1*5,1*7	3	130	16	st/dh	25	225	d, ff		31
1 d	Kiel-Sud	1975	VKW/VKW	2*5, 1*10	3	150	20	st/dh	14	197	ep, w	fgc: n1, HCl/CaSO4 prod.	31,45
1 d ss	Krefeld	1976	VKW/Lentjes	3*12	3	210	36	st/chp	23	375	ff, w, n1, c	HCl-production fgc-residues	31,42,45
1 f	Landshut	1972	von Roll/Wamser	2*3, 1*6	3	39	12	st	20	380	ep, w		31
1 f	Leverkusen	1970	von Roll,K+K/MAN,Lentjes	2*10, 1*12	3	166	32	st/chp	18	320	s, ep		31
1 f,d	Ludwigshafen	1967	von Roll,Babcock/Baumgarte,VKW	3*12	3	180	36	st/chp	43	450	ep, w		31
1 t+f	Mannheim	1965	EVT/EVT	2*12, 1*20	3	210	44	st/chp	120	500	ep, w	fgc planned: cokesfilter	31
1 s	Markt-Oberdorf	1974	Dr.Pauli/Loos	1*3	1	16	3	st/dh	17	180	d, w, ff		31
1 r ss/hw	Munchen-Nord	1962	Martin/VKW	2*20	2	228	40	st/chp	40	400	s, ep	1992: 2*35 t/hr,ep,w,n2,st,dh	31,44
1 r	Munchen-Sud	1969	Martin/Babcock	2*40	2	326	80	st/dh	20	300	s, ff, n1		31,45
1 r	Neufahrn/Freising	1970	Keller-Peukert,Steinmüller/Wamser	2*3	2	25	6	st/dh	16	250	d, ff		31
1 r	Neunkirchen	1970	Martin/Wamser	1*5, 1*10	2	114	15	st/chp	28	350	ep, w		31
1 f	Neustadt/Holstein	1984	von Roll/Baumgarte	1*8	1	74	8	st/chp	42	420	s, w, cy		31
1 f,r	Nurnberg	1968	von Roll/MAN; Martin/EVT	3*12, 1*19	4	250	55	st/chp	80	450	ep, s, ff	fgc: ci planned	31,45
1 d	Oberhausen	1972	VKW/Babcock	4*22	4	550	88	st	60	480	ep, w		31
1 d	Offenbach	1970	VKW/VKW	3*10	3	185	30	st/chp	16	300	ep, w		31
1 f	Pinneberg	1974	K+K/Baumgarte	2*5	2	95	10	st/chp	40	400	ep, w		31

Table 5.4.4 Municipal Solid Waste Combustors in Germany 1991

TNO 20/05/92

1	d	Rosenheim	1964	VKW/VKW	1*4.5,1*6,1*10	3	80	20.5 st/chp	70	500 ep, s, ff	steam:16/200 & 70/410; fgc:ci	31,45
1	r	Schwandorf	1982	W+E/Steinmüller	3*18.7	3	332	56.1 st/chp	73	410 s, ep		31
1	f	Solingen	1969	von Roll/MAN; Baumgarte	1*10, 1*7.6	2	83	17.6 st/chp	42	450 s, ep		31
1	f	Stapelfeld	1978	Steinmüller/Steinmüller	2*21	2	325	42 st/chp	28	370 ep, w	pilotplant fgc:c; n1 93	31,45
1	r,d	Stuttgart	1965	Martin/KSG;VKW/VKW;VKW/EVT	3*20	3	250	60 st/chp	64	510 ep, w	fgc: n1 planned 92	31,45
1	d	Wuppertal	1976	VKW/VKW	4*15	4	320	60 st	29	350 ep, w		31
1	r	Wurzburg	1984	Martin/EVT	2*12.5	2	174	25 st/chp	42	415 d, ff		31,45
1	f	Zirndorf	1971	von Roll/EVT;W+E/Baumgarte	1*4, 1*4.6	2	52	8.6 st/dh	20	200 ep,w,ci,ff	steam: 5 & 150:cokes back	31,45

Explanation in appendix, page 5

5.4.3 Overview existing Municipal Solid Waste combustors in Germany

In Germany 47 MSW combustors are in operation (table 5.4.4). There are no combustors with a capacity under 3 tonnes per hour. All of the combustors have energy recovery and clean their flue gases with scrubbers. The total design capacity of the combustors is 11230 ktonnes/year although only 9000 ktonnes/year is in fact combusted [31]. Wet scrubbers are the most often applied (table 5.4.5). At the time the first extended flue gas cleaning techniques like DeNOx and active cokes adsorption are installed. Some are operating already, some more are planned.
The purpose of the energy recovery is also given in table 5.4.5.

Table 5.4.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Germany

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	11230	100	47	100
– No				
Total	11230	100	47	100
Flue gas cleaning:[1]				
– unknown				
– none				
– cyclone				
– esp				
– fabric filter				
– dry scrubber	1180	11	7	15
– semi-dry scrubber	4290	38	14	30
– wet scrubber	5760	51	26	55
Total	11230	100	47	100
Extended flue gas cleaning:[1]				
– DeNOx[2]	1790	16	5	11
– active cokes	1180	11	6	13

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

2) One small installation (35 ktonnes/year) applies active cokes adsorption also to reduce NO_x. This is not implied in the data for 'DeNOx' but only in the data for 'active cokes'.

Most of the recovered energy is used for electricity production with usage of remaining heat (combined heat & power). In table 5.4.6 the purpose of the energy recovery is given. The actual recovered amount is not known per installation but the average amount recovered is:
- if only electricity is produced: 1.1-1.4 GJ/tonnes MSW;
- combined heat and power: 4.5-6.1 GJ/tonnes MSW.

Related to an average heating value of 8 MJ/kg for regular MSW, this would mean energy recovery efficiencies of 14-18% (just electricity) and 56-76% (combined heat and power), which are commonly accepted values.

Table 5.4.6 Purpose of energy recovery in Germany

Energy recovery	MSW combusted		Installations	
	ktonnes/year	%	number	%
– Combined heat & power	8040	72	33	70
– District heating	1060	9	7	15
– Compost drying	40	0.3	1	2
– Electricity	2100	19	6	13
Total	11230	100	47	100

From the residues of MSW combustion 80% of the bottom-ash is reused. The remaining 20%, as well as fly-ash and flue gas cleaning residues, is landfilled in different landfill sites. Depending on the composition and the leaching behaviour there are several classes of landfill. Bottom-ash is usually landfilled in normal landfill spaces, fly-ash in specially cared landfills (mono-fills: only one kind of waste in a landfill space) and flue gas cleaning residues in special landfills underground.

No information is available on emission monitoring applied in German MSW combustors.

5.4.4 Emission guidelines

The German emission guideline for MSW combustors (17.BImSchG) is internationally recognized as one of the strictest existing guidelines. Only the Dutch guideline has lower limits for some of the components (dust, NO_x, SO_x) and equal limits for the rest, except for the total of heavy metals other than Hg and Cd (see chapter 4).

5.4.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

Germany intends to keep the total amount of waste constant, like they did the last few years. To realise this prevention is promoted strongly. Besides that landfill is to be reduced and for that recycling (especially packaging waste) and combustion are to be increased.
For example: 80% of primary plastic waste must be recovered, and 80% of this (or 64% total) must be recycled into material [72].

For the packaging waste minister Töpfer has introduced a directive which is put into practice in the so-called 'Dual System'. This system puts full responsibility for the reuse or recycling of primary and secondary packaging outside the public waste disposal system to the private industry (raw material producers, converters, merchants and distribution). Besides putting the responsibility with the private industry a number of collection and sorting quota are defined with realisation dates [73]:

- Starting 1-1-93 at least 50% of all packaging are to be collected by the Dual System. From 1-7-95 this must have increased to 90%.
- By 1-7-95 90% of all the glass, aluminium and ferrous materials in packaging and 80% of all the other packaging materials have to be sorted. A first step towards these percentages has to be reached by 1-1-93, with sorting percentages between 30 and 70%, depending on the material.
- There is an obligation to recycle all sorted materials as secondary raw materials. Combustion as an option for treatment is excluded.
- The present returnable bottle systems are maintained at the same level. The percentage returned bottles may not drop below 72%, except for milk (17% lower limit).

The Dual system is not entirely succesful yet. The collection is working well, but the recycling processes are a bit behind in development.

Other aspects/effects of the 'Töpfer-law' are [26, 72]:

- Since 1-12-1991 transportation packaging must be collected and reclaimed by producers/distributors.
- Starting from 1-4-1992 the consumer is permitted to leave secondary packaging at the point of sale. January 1993 the retailers are obliged to collect primary sales packaging within or in the immediate locality of the stores. This material is then to be reclaimed.
- From January 1993 a mandatory deposit of 50 pfg is to be charged for beverage containers larger than 200 ml, washing agents and detergent containers more than 200 ml and for emulsion paints containers by 1995.

The regulations under the 'Töpfer-law' will in the near future (1992/3) be expanded with the following regulations [26]:

- All fast food is to be packed in bio-degradable packaging material.
- Ecologically questionable packaging materials will be banned.
- Beverage container recycling quotas will be redefined.

5.4.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

In Germany at first the total capacity of MSW combustion was to be expanded enormously. From todays operating 47 installations, which dispose of the waste of 35% of the population, the total number had been planned to grow to 84 installations combusting the MSW from 65% of the Germans by the year 2000 (15000 ktonnes per year in total). This original plan has been altered because of enormous opposition from the public, led by the environmental groups (Die Grünen). What the capacity will be in future is not sure.

In table 5.4.4 already a lot of plans to extend the flue gas cleaning systems of existing installations are mentioned. Besides that a number of new MSW combustors are being planned or built:

- In Bonn a new MSW combustor has started operation in April 1992. It is equipped with an extended flue gas system: esp, spray dry adsorber, wet scrubber, SNCR-DeNOx, dry scrubber with active cokes injection and a fabric filter.
- In Burgkirchen a combustor with a capacity of 40 tonnss per hour (2 units) is being built. This installation is equipped with: electrostatic precipitator, wet scrubber, SCR-DeNOx and a fabric filter with active cokes injection.
- In Schweinfurt an MSW combustor is being built in combination with a coal-fired power station. The MSW part is equipped with a K+K-moving grate and also burns sewage sludge. The flue gas cleaning system consists of: a cyclone, spray dry absorber, fabric filter with active cokes injection, wet scrubber and possible SNCR-DeNOx. The waste capacity will be 24 tonnes per hour (3 units) and the steam production will be 22.7 tonnes per hour (65 bar, 450 °C).
- The installation in Berlin (Ruhleben) will be extended with a fluidized bed combustor with a capacity of 8.5 tonnes per hour. Steam of 470 °C and 75 bar will be generated. The flue gas cleaning system will consist of a cyclone, spray dry absorber, fabric filter and a wet scrubber.
- In Ulm/Weißenhorn an MSW combustor with a capacity of 13 tonnes per hour (2 units) is coming into operation soon. This installation is equipped with a semi-dry scrubber, a wet scrubber, SNCR-DeNOx and a fabric filter with active cokes injection to clean the flue gases.
- Finally there are plans to build MSW combustors in Augsburg, Esslingen, Pirmasens, Velsen, Böblingen and Rems-Mürr. It is, however, not certain that all these installations will be build, and in what time frame.

5.5 Denmark

5.5.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Denmark per year, with elaboration of the plastic fraction

The Danish population consists of 5.1 million capita, producing around 510 kg MSW per capita per year. In different reports the Danish MSW is defined differently making the comparison of data sources very difficult. Data in table 5.5.1 represent household, bulky, trade and garden waste.

Table 5.5.1 Total amount and composition of Municipal Solid Waste generated in Denmark per year (1990) [7, 9, 10, 16, 2474, 75, 76, 77]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	1040	40
Paper & cardboard	910	35
Plastic	130	5
Glass	100	4
Metals	130	5
Textiles	80	3
Miscellaneous		
combustibles	130	5
non-combustibles	80	3
Total	2600	100

The last analysis of the plastics in MSW dates back from 1985 (table 5.5.2). More recent data are not known.

Table 5.5.2 Composition of the plastics fraction in the Municipal Solid Waste in Denmark (1985) [18]

Component	Amount	
	ktonnes/yr	% of total plastics
PE	69	53
PP	9	7
PVC	16	12
PS	10	8
Other (incl. PET)	26	20
Total	130	100

5.5.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

In Denmark household waste collection and disposal is carried out by the municipalities. In general terms waste collected in cities has traditionally been combusted (with heat recovery) and waste collected in small towns has been landfilled [76].

Operation of landfills and combustors have particular requirements under the 1974 Environment Protection Act. In common with other 'specially polluting activities' defined in the Act, combustors and landfills could not be established until a thorough evaluation of planned measures for pollution control from the facility were made and approved [76].

As already mentioned there is great difference in the understanding of what is considered to be MSW in Denmark. Often (if no definitions are given) it is claimed that 70% of the Danish MSW is combusted. This, however, is based just on household and trade waste. The data given in table 5.5.1, 5.5.2 and 5.5.3, however, are based on not only household and trade waste, but also bulky and garden waste. Of these last two waste streams approximately 10% is combusted. Calculation of the combustion percentage for the total MSW (household, trade, bulky and garden waste) gives the 48% which is mentioned in table 5.5.3.

In section 5.5.3 we will see that the total capacity for MSW combustion is 1800 ktonnes/year and not 1250, like in table 5.5.3. This 1800 ktonnes per year, however, implies industrial, construction waste and waste from energy production and treatment facilities besides household, trade, bulky and garden waste. If all this waste is taken into account a total amount of 8600 ktonnes per year is obtained. Of this amount 1800 ktonnes per year (21%) is combusted.

Table 5.5.3 Municipal Solid Waste treatment per category in Denmark (1990) [7, 16, 24, 74, 75, 76, 77]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	500	19
Composting	100	4
Landfill	750	29
Combustion	1250	48
Total	2600	100

The concept of recycling of waste in Denmark was introduced in 1978, originally on a voluntary and experimental basis, but from 1987 recycling of certain waste materials (paper, metals and glass) were given a priority over combustion and landfill disposal [76].
This priority was supported by introduction of a tax on waste combusted or landfilled. In 1987-89 this tax was 40 DKK/t and was raised to 130 DKK/t on 1 January 1990 [20]. Waste which is recycled, composted, or used for biogas production is exempt from the tax. On the contrary, heat recovery from combustion of MSW is, in these terms, not considered as recycling or reuse and therefore subject to tax.

5.5.3 Overview existing Municipal Solid Waste combustors in Denmark

In Denmark there are 29 MSW combustors with a capacity of 3 tonnes per hour or more. The design capacity of these installations is 2060 ktonnes per year, although only 1250 ktonnes MSW per year (1990 is burned. On top of that, however, also 550 ktonnes/year of industrial, construction waste and waste from energy production and treatment facilities is combusted in these installations. In table 5.5.4 details on the Danish installations are given, whereas in table 5.5.5 the flue gas cleaning of the installations is summarized.

Table 5.5.4 Municipal Solid Waste Combustors in Denmark 1991

TNO 20/05/92

Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Energy output [10^12 J]	Flue gas cleaning	Emissions continuous	Emissions sampled	Remark	Reference
1 +3	Aalborg	1980	Volund	2*8	2	121	16	hw	740	s, ep		D,CL,S,F,N:2 FA,SL:4	E91: 1*12 t/h	5,24,29,30
1	Aarhus	1978	B&S	2*7.6	2	100	15.2	hw	560	ep	D,CL,S,TOC WW	D,CL,S,TOC,FA,SL:1	Extension with 1*9.3 t/h	5,24,29,30
1 o	Ärs	1986	B&S	1*3.5	1	30	3.5	hw	189	ep	D	D,CL,S,TOC,F,N,M:1 FA,SL:?		5,24,29,30
1	Albertslund	1969	B&S	1*4,1*3.5	2	17	7.5	hw	220	ep		D,FA,SL:1	Closes 1/6/92	5,24,29,30
1 +3	Amagerforbrænding	1971	Volund	3*12	3	280	36	hw	1560	s, ff	D,CL	D,CL,S,TOC,F,N,M:3 FA,SL:6	E91:1*12 t/h; el,dh	5,24,29,30,3
1	Brondby	1971	B&S	2*4	2	28	8	hw	210	ep	D	D,P:1 FA,SL:4	Closes 1/6/92	5,24,29,30
5	Frederikshavn	1965	B&S	2*4	2	21	8	hw	135	ep		D,CL,S,F,N,FA,SL:?	2nd unit type 1; rebuilt:1*5	5,24,29,30
1	Haderslev	1966	Volund	1*3,1*4.5	2	20	7.5	hw	150	cy	D		will be rebuilt 2*4 t/h	5,24,29,30
1	Herning	1973	B&S	1*3,1*4	2	17	7	hw	140	cy		D,FA,SL:?	Closes 1/6/92	5,24,29,30
1	Hjorring	1986	Volund	2*3	2	30	6	hw	150	ep	D	D,CL,S,M,FA,SL:2		5,24,29,30
1	Hobro	1981	B&S	1*3	1	15	3	hw	100	ep		D,CL,S,F,N,M,FA,SL:1		5,24,29,30
1	Holstebro	1971	B&S	1*3,1*4	2	12	7	hw	80	w, cy		D,CL,S,F,M:1 FA,SL:2 WW:26	rebuilt: energy chp, 2*9 t/h	5,24,29,30
1	Horsens	1974	B&S	2*5	2	43	10	hw	260	ep		D,CL,S,TOC,F,N,M:1 FA,SL:2		5,24,29,30
5	Kolding I	1969	B&S	2*3	2	27	6	hw	170	ep		D,CL,S,F,N,M:6 FA,SL:4	will probably be closed	5,24,29,30
1	Kolding II	1982	B&S	2*4	2	38	8	hw	240	ep		D,CL,S,F,N,M:6 FA,SL:4		5,24,29,30
1	Middelfart	1972	B&S	2*2	2	13	4	hw	70	d, ff				5,29,30
1	Nordforbrænding	1969	Volund	3*3	3	50	9	hw	350	d, ff	D,CL	S,TOC,F,N,M,P:? FA,SL:12		5,24,29,30
1	Nyborg	1970	B&S;Volund	1*3,1*3.2	2	24	6.2	hw	110	ep		D,CL,S,F,N,M,FA,SL,WW:2	will probably be closed	5,24,29,30
1	Nykobing F.	1983	Volund	2*3.5	2	56	7	hw	350	d, ep	D,CL	D,CL,S,TOC,F,N,M:4 FA,SL:1	planned: 1*7 t/h 1992	5,24,29,30
1	Næstved	1983	Volund	2*4.5	2	48	9	hw	310	ep	D,CL	D,CL,S,F,N,M:1 FA,SL:6		5,24,29,30
1 +3	Roskilde	1966	Volund	2*3.5,2*7	4	91	21	hw	560	d, ep	D,CL,S	TOC,F,M:2 FA,SL:4		5,24,29,30
1	Skanderborg	1983	B&S	1*4	1	30	4	hw	200	d, ep	D,CL	S,TOC,F,N,M,P:1 FA,SL:?	Extension 1*5 t/hr	5,24,29,30
1	Slagelse	1970	B&S	1*3,1*4	2	30	7	hw	170	d, ff		D,CL,S,TOC,F,N:? FA,SL:1-2	Extended to 1*4+1*6 t/h	5,24,29,30
1	Sonderborg	1969	B&S, Volund	1*2,2*4	3	55	10	hw	320	ep		D,CL,S,F,N,FA,SL:3	fgc: s considered	5,24,29,30
1	Svendborg	1978	Volund	1*3.5,1*4	2	25	7.5	hw	180	ep	D,CL	D,CL,S,F,N,M,WW:2 FA,SL:6		5,24,29,30
1	Taastrup	1967	Volund	2*2.5	2	40	5	hw	344	d, ff	D,CL	FA,SL:6		24,29,30
1	Thisted	1978	Volund	1*3	1	30	3	hw	200	ep,w		D,FA,SL:1	Expanded to 1*6.3 t/h	5,24,29,30
1	Vejen	1989	Lambion	1*3	1	6	3	hw	130	d, cy			11 kton/yr other fuel	5,24,29,30
1 +3	Vestforbrænding	1971	Volund	3*12,1*14	4	350	50	hw	1950	ep,w	D	D,CL,S,TOC,F,N,M:0.25 FA,SL:6		5,24,29,30

Explanation in appendix, page 5

Table 5.5.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Denmark

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	2060	100	29	100
– No				
Total	2060	100	29	100
Flue gas cleaning:[1)]				
– unknown				
– none				
– cyclone	100	5	2	7
– esp	760	37	14	48
– fabric filter				
– dry scrubber	420	20	8	28
– semi-dry scrubber	360	18	2	7
– wet scrubber	420	20	3	10
Total	2060	100	29	100
Extended flue gas cleaning:[1)]				
– DeNOx				
– active cokes				

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

All the energy which is recovered is used for district heating.
From table 5.5.5 it can be seen that relatively large combustors apply either semi-dry or wet scrubbing technique (7% and 10% of the installations burning 18% respectively 20% of the waste). Furthermore 42% of the installations does not use scrubbing techniques to clean their flue gases.

From the residues out of Danish MSW combustors the biggest part is landfilled. Only one third of the bottom-ash is reused at the time in building and construction works, but the quality requirements for this reuse are currently under investigation.

Very little information on the combustors in Denmark is missing: only some data on emission monitoring.

5.5.4 Emission guidelines

Danish emission guidelines are very similar to the EC regulations (see chapter 4). Only the conditions at which the flue gases have to remain (temperature, oxygen concentration, residence time) are slightly different and the emission limit for Hg and Cd is stricter.

5.5.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

In 1989 the government published an Action Plan on Environment and Development, the follow-up to the recommendations of both the Brundtland Commission and the UN Perspective to the year 2000. It outlines Denmark's commitments and intentions on cross-sectoral policies to achieve sustainable development.
In future (up to 2000) Denmark aims to reach a recycling quorum of 50%, which can be regarded as very ambitious [20]. The total amount of waste is expected to grow with approximately 1% per year [77]. The total combustion capacity will increase to about 2000 ktonnes per year, in which construction and industrial waste and waste from energy production and treatment facilities is included (see also section 5.5.2). For what is meant here by MSW (household, trade, bulky and garden waste) the amount combusted will be approximately 1375 ktonnes per year (table 5.5.6).

Table 5.5.6 Expected treatment schemes for the Municipal Solid Waste in Denmark in the year 2000 [7, 16, 24, 74, 76, 77]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	1455	50
Composting	80	3
Landfill	0	0
Combustion	1375	47
Total	2910	100

In April 1991 the Danish government has set up a stringent agreement with the industry to reduce the use of PVC in packaging by 52% in 1993, an additional 10% in 1995 and a total 85% in 2000 [26].

5.5.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

In table 5.5.4 already some remarks are made concerning the future of some installations. In total 3 of these installations are being closed down right now (per 01/06/92), and two more are very likely to be closed soon. In total 10 of the remaining combustors will be extended and/or rebuild. The planned capacity (fro MSW incl. industrial waste, construction waste, etc.) will be approximately 2360 ktonnes/year.

Until now all the combustors recover energy for district heating. Two installations are planning to start producing electricity as well (combined heat and power stations).

Finally one combustor (Sonderborg) is planning to extend the flue gas cleaning system with a semi-dry scrubber.
The Danish government does not expect that any active cokes adsorption techniques are applied in flue gas cleaning systems for MSW combustors in the near future. There are no plans for new MSW combustors.

5.6 Spain

5.6.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Spain per year, with elaboration of the plastic fraction

In Spain 38.9 million people live. They produce a total amount of MSW of 13300 ktonnes per year (circa 340 kg per capita per year). It is not known which categories of waste (household, bulky, etc.) are included in this.

Table 5.6.1 Total amount and composition of Municipal Solid Waste generated in Spain per year (1990) [7, 9, 10, 16, 24, 27, 78]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	6520	49
Paper & cardboard	2660	20
Plastic	930	7
Glass	1060	8
Metals	530	4
Textiles	270	2
Miscellaneous:		
combustibles	930	7
non-combustibles	400	3
Total	13300	100

Table 5.6.2 Composition of the plastics fraction in the Municipal Solid Waste in Spain (1990) [79]

Component	Amount	
	ktonnes/yr	% of total plastics
PE/PP	620	67
PVC	110	12
PS	90	10
PET	40	4
Other	70	8
Total	930	100

5.6.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

At present there is a trend toward the working out of Provincial Master Plans for the overall resolution of municipal solid waste disposal problems. In the majority of cases this entails the grouping of municipalities so that facilities can be large enough both technically and economically [24].

- The aims of the present policy are as follows [24]:
- Virtual disappearance of uncontrolled dumping.
- Recycling of recoverable raw materials, such as paper, cardboard, glass, plastics and scrap iron.
- Increasing the technological potential of compost plants.
- Greater exploitation of landfills tip biogas.
- Strong trend toward combustion as a viable alternative and with greater participation in MSW-disposal.

Table 5.6.3 Municipal Solid Waste treatment per category in Spain (1990) [7, 16, 24, 27, 78]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	1700	13
Composting	2200	17
Landfill	8650	65
Combustion	750	6
Total	13300	100

The recycling level in Spain is quite good compared to the other countries (higher than for instance Austria and France). This is not caused by government legislation but simply by the economics of recycling; it's profitable. Not only paper and cardboard are recycled, but also plastics and metals. As a result the country's waste is low in calorific value and high in organic matter.
The non-plastics organic matter content is 45% to 60%. This high putrescibles content encourages composting [78].

5.6.3 Overview existing Municipal Solid Waste combustors in Spain

In Spain there are 7 large (>= 3 tonnes per hour) MSW combustors in operation (table 5.6.4). The design capacity of these combustors is 680 ktonnes MSW per year. In table 5.6.5 the energy recovery and flue gas cleaning is summarized.

From tables 5.6.4 and 5.6.5 it becomes clear that the larger plants have energy recovery (electricity generation) and an electrostatic precipitator. The one without flue gas cleaning is small.

Table 5.6.4 Municipal Solid Waste Combustors in Spain 1991

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Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Flue gas cleaning	Emissions sampled	Remark	Reference
1	Moncada y Reisachs (Barcelona)	1975	von Roll,Volund/Maquineria	2*2.5	2	51	5	el	ep	D,CL,S,F,M:12 FA,SL:4	el: 2.5 GWh & st: 2.87 ton/yr	16,24,27
1	Mondragon (Guipuzcoa)	1982	Steinmuller	2*3.5	2	40	7	N	cy			16,24,27
1	San. Adria De Besos .(Barcelona	1975	von Roll/Maquinaria	3*15	3	255	45	el	ep	D,CL,S,TOC,F,M:12 FA,SL:4	el: 94 GWh	16,24,27
1	Son Reus (Palma de Mallorca)	1979	Volund/Vulcano	1*8	1	40	8	el	ep	D,S:1	el: 4.4 GWh	16,24,27
1	Tarragona	1991	DBA/Vulcano	2*9.6	2	144	19.2	el	ep		el: 26 GWh	24,27
3	Ubrique (Cadiz)			2*1.5	2	9	3	N				16,24,27
1	Vigo (Pontevedra)	1972	Alberti Fonser, Steinmuller	2*5	2	58	10	N	cy			16,24,27

Explanation in appendix, page 5

The bottom-ash of the combustors in Moncada y Reisach and San Adriá de Besós is reused for respectively 4% and 22%. The rest as well as the residues from the other facilities is landfilled.

Table 5.6.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Spain

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	540	79	4	57
– No	140	21	3	43
Total	680	100	7	100
Flue gas cleaning:[1)]				
– unknown				
– none	20	3	1	14
– cyclone	120	18	2	29
– esp	540	79	4	57
– fabric filter				
– dry scrubber				
– semi-dry scrubber				
– wet scrubber				
Total	680	100	7	100
Extended flue gas cleaning:[1)]				
– DeNOx				
– active cokes				

[1)] Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

The information on the Spanish combustors is nearly complete. Steam parameters are missing and some data for the installations (see table 5.6.4).

5.6.4 Emission guidelines

At the time the only Spanish emission limit is for dust. Depending on the capacity and the location of the combustor towards housing the emissions must be below 120-500 mg/Nm^3. Furthermore a limit is set to the opacity of the plume (20% or 1 on the scale of Ringelmann).
Very soon Spain will adopt the EC regulations (chapter 4).

5.6.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

Some of the trends are already mentioned in section 5.6.2.

In Spain politics are mainly focused on toxic waste more than MSW. For MSW they have the same point of view as most of the other countries: prevention first, then materials and/or energy recovery and, when nothing else is possible, safe disposal.

Packaging waste management directives are expected to be drawn up on a voluntary basis [79]. Separate waste collection of MSW is promoted in Madrid, Barcelona and Pamplona and in Sevilla (agricultural plastics film).

For plastic waste targets are set: 30% recycling, 30% combustion with energy recuperation and 40% landfill. According to the Spanish Foundation of the Plastics for the Environment the main objectives are: the promotion of the best use of the plastics for the environment and the improvement of the waste management methods (more plastics recycling, mechanical and/or energy recycling).

5.6.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

In Spain 6 new MSW combustors are planned (located in Madrid, Santander, Valencia, Bahia de Cadiz, Palma de Mallorca and Maresme). The total design capacity for these 6 will be 1640 ktonnes per year and all of them will recover energy (electricity production). It is not known what flue gas cleaning will be applied.
Furthermore for 5 locations feasibility studies are executed (Sevilla, Barcelona, Extremadura, Consermancha, Las Palmas/Tenerife).

5.7 France

5.7.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in France per year, with elaboration of the plastic fraction

In France 56.2 million people live, producing circa 360 kg MSW per capita per year. In total this is approximately 20000 ktonnes per year. In this amount of MSW also 1500 ktonnes of bulky waste is included. The composition of French MSW is given in tables 5.7.1 and 5.7.2.

Table 5.7.1 Total amount and composition of Municipal Solid Waste generated in France per year (1990) [7, 9, 10, 16, 24, 80]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	5000	25
Paper & cardboard	6000	30
Plastic	1200	6
Glass	2400	12
Metals	1000	5
Textiles	600	3
Miscellaneous	3800	19
Total	20000	100

Table 5.7.2 Composition of the plastics fraction in the Municipal Solid Waste in France (1990) [81]

Component	Amount	
	ktonnes/yr	% of total plastics
PE	580	48
PP	70	6
PVC	250	21
PS	160	13
Other (PET incl.)	140	12
Total	1200	100

5.7.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

The French legal context and administrative organization encourage three types of action [24]:

- modifications to manufacturing processes and consumption to reduce waste production at source;
- waste recovery and recycling;
- disposal of non-recoverable or non-recyclable waste under satisfactory conditions for the environment.

Local communities are required to set up a domestic waste disposal department.

Table 5.7.3 Municipal Solid Waste treatment per category in France (1990) [7, 16, 24, 80]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	600	3
Composting	2000	10
Landfill	9000	45
Combustion	8400	42
Total	20000	100

Separate collection primarily concerns glass and paper. It is developing under the impetus of agreements between the state and the professional organizations concerned.

5.7.3 Overview existing Municipal Solid Waste combustors in France

In France there is a large amount of combustors (306). Most of them, however, are very small: 137 combustors have a capacity of 3 tonnes per hour or more. These 137 combustors are listed in table 5.7.4. In table 5.7.5 an overview over energy recovery and flue gas cleaning for these combustors is given, based on the total design capacity (10310 ktonnes per year). Combinations of scrubbers and dust removing equipment is counted to the scrubbers only.

Table 5.7.4 Municipal Solid Waste Combustors in France 1991

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Incinerator type	Location	Start-up year	Manufacturer	Units [ton/hr]		Total capacity [ton/hr]	Energy system	Energy output [10^12 J]	Flue gas cleaning	Emissions continuous	Emissions sampled	Inhabitants connected [*1000]	Remark	Reference
	Agde	1970	Triga	1*3	1	3	N					14	66 t/d	36
3	Agen	1983	Triga	1*4	1	4	Y					75	80 t/d	24,36
	Albertville	1985	Triga	1*3.9	1	3.9	N		ep			46	39 t/d	24,36
1	Ales	1975	Itisa Volund	1*3.5	1	3.5	N					70	86 t/d	24,36
1	Angers	1974	Inor/von Roll	3*5	3	15	st		ep			226	283 t/d	24,36
1	Annecy	1986	Sogea	2*4	2	8	Y							24
1	Antibes (Cannes)	1970	CNIM/Martin	2*9	2	18	N					156	375 t/d	24,36
	Argeles	1975	Triga	1*3	1	3	N					15	35 t/d	24,36
1	Argenteuil	1975	Inor/von Roll	2*7.5	2	15	st		ep			217	260 t/d	24,36
1	Arles	1977	CNIM/Martin	1*3	1	3	N					68	50 t/d	24,36
	Arrabloy (Gien)	1975	Sogea (Alberti)	2*1.8	2	3.6	N							24
1	Arras	1976	Inor/von Roll	1*4	1	4	st		ep	D	D:1	90	106 t/d	24,36
1	Bayet	1982	Itisa Volund	2*5	1	10	Y					71	100 t/d	36
1	Belfort	1988	Stein Ind.	2*4	2	8	st		ep			76	96 t/d	24,36
	Benesse	1972	Sogea (Alberti)	1*3,1*4	2	7	N					39	43 t/d	24,36
	Bernay	1974	Ferbeck (Flynn)	2*2	2	4	N					52	46 t/d	24,36
	Besancon	1971	CEC	2*2	2	4	Y		ep			170	195 t/d	24,36
1	Blois	1971	Inor/von Roll	2*3.7	2	7.4	Y					82	151 t/d	24,36
1	Bordeaux	1984	TNEE-DBA	2*8	2	16	st					341	370 t/d	24,36
1	Brest	1989	Inor/von Roll	2*9	2	18	st	275	sw	D,CL	M,FA,SL:?	283	el:2 GWh; 366 t/d	24,36
1	Brive	1973	Inor/von Roll	3*3.5	3	10.5	st		cy			189	200 t/d	24,36
1	Bruay en Artois	1979	Inor/von Roll	2*5	2	10	Y							24
1	Caen	1972	CNIM/Martin	2*7.5	2	15	Y							24
1	Carpentras	1973	Sogea (Alberti)	2*2	2	4	N		cy			32	70 t/d	24,36
1	Carriere	1977	Luchaire	2*10	2	20	st		s, ep			194	270 t/d	24,36
	Cavalaire	1978	Sefi	2*2	2	4	N					8	40 t/d	24,36
	Chambery	1977	Sogea (Alberti)	2*5	2	10	N					164	223 t/d	24,36
1	Chantelle	1982	Itisa/Volund	1*4	1	4	Y							24
	Chartres	1971	Stein	2*4	2	8	N					108	115 t/d	24,36
1	Chateaudun	1976	Inor/von Roll	1*3.4	1	3.4	N					38	40 t/d	24,36
	Chateauroux	1972	SIC (Ofag)	2*3	2	6	N							24
	Chavanod	1986	TNEE	2*4	2	8	Y					160	200 t/d	36
3	Cholet	1983	LBI	1*5.2	1	5.2	Y							24
	Cluses	1982	Itisa Volund	1*4	1	4	N					40	60 t/d	24,36
1	Colmar	1988	CNIM/Martin	2*6	2	12	st	380	s	D,CL	S,TOC,F,N,M,FA,SL:?	163	280 t/d	24,36
1	Colombelles	1972	CNIM/Martin	1*7	1	7	Y					220	330 t/d	36
1	Concarneau	1989	Inor/von Roll	2*4	2	8	Y		d, ep			106	187 t/d	24,36
	Coulommiers	1981	Triga	1*3	1	3	N					50	25 t/d	36
	Couronne	1973	Sogea	1*5,1*1	2	6	N					102	120 t/d	36

Table 5.7.4 Municipal Solid Waste Combustors in France 1991

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1	Creil	1970	Stein	2*4	2	8	N					75	100 t/d	24,36
2	Creteil	1979	Caliqua	2*8	2	16	st		ep					24
1	Deauville	1974	Inor/von Roll	2*2.5	2	5	Y					19	45 t/d	24,36
1	Denain	1977	CNIM/Martin	2*5	2	10	N					150	260 t/d	24,36
1	Dieppe	1971	Inor/von Roll	2*2.5	2	5	st		cy	D	D:?	38	53 t/d	24,36
1	Dijon	1975	Inor/von Roll	2*12.5	2	25	st		ep			293	322 t/d	24,36
	Dinan	1976	Triga	2*2	2	4	N					53	63 t/d	24,36
1	Douarnenez	1974	Triga	1*3	1	3	N					39	60 t/d	24,36
	Dunkerque	1971	SIC (Ofag)	2*4.4	2	8.8	N					185	220 t/d	24,36
1	Ensues la Redonne	1972	Stein	2*4	2	8	N							24
2	Epinal	1983	BSF	2*4	2	8	Y					123	97 t/d	24,36
1	Evans (Dole)	1974	Triga (Flynn)	1*3.2	1	3.2	N					71	72 t/d	24,36
	Fecamp	1975	Triga	1*3	1	3	N					34	40 t/d	24,36
	Fontainebleau	1966	Triga	1*3	1	3	N					76	60 t/d	36
	Forbach	1976	Koppers Volund	2*3	2	6	N					85	82 t/d	24,36
3	Grenoble	1972	TNEE-VKW	3*6.25	3	18.8	st	580	ep		D,CL,S,TOC,N:1	383	el: 5 GWh; 250 t/d	24,36
	Guingamp	1972	Triga	1*3.5	1	7	N					44	40 t/d	24,36
1	Hagueneau	1990	Itisa/Volund	2*5.5	2	11	st		s					24
1	Halluin (Lille)	1967	Stein	2*5	2	10	N					161	250 t/d	24,36
1	Henin Beaumont	1973	CNIM/Martin	3*3.5	3	10.5	N		ep			187	240 t/d	24,36
	Isere	1986	Itisa Volund	1*5	1	5	Y					139	120 t/d	36
1	Issy-Les-Moulineaux	1965	CNIM/Martin	4*17	4	68	st	3240	ep		D,CL,S,F,N,M:1 FA,SL:12	1273	el:63 GWh;eff. 68.5%;1750 t/d	24,36
1	Ivry-Sur-Seine	1969	CNIM/Martin	2*50	2	100	st	4000	ep		D,CL,S,F,N,M:1 FA,SL:12	1507	el:120 GWh;eff. 75.9%;2584 t/d	24,36
3	Jonzac	1982	LBI	1*3	1	3	Y					59	40 t/d	24,36
1	La Beuvriere	1978	Inor/von Roll	2*5	2	10	st		ep	D	D:1	218	310 t/d	24,36
1	La Rochelle	1988	Inor/von Roll	2*4	2	8	st	190	d	CL	D,M:4 FA,SL:2	135	148 t/d	24,36
	La Teste (Arcachon)	1974	CEC	2*3.6	2	7.2	N					50	70 t/d	24,36
1	Lagny	1985	TNEE-DBA	1*8	1	8	st		ep	D		165	300 t/d	24,36
3	Le Havre	1970	VKW	3*8	3	24	st		ep		D,CL,S,N,M:1	263	260 t/d: enrgy: 1 unit Y, 2 N	24,36
1	Le Mans	1975	Inor/von Roll	1*12	1	12	st		w			242	379 t/d	24,36
1	Le Treport	1972	Luchaire	1*3	1	3	N		cy			47	35 t/d	24,36
	Lescar	1975	Triga	2*3	2	6	N					148	238 t/d	24,36
1	Lillebonne	1975	Sogea	1*1,1*8	2	9	st		cy			84	70 t/d	24,36
1	Limoges	1989	Volund	2*5	2	10	hw		s, ep	D,CL	S,TOC,F,N,M,P,FA,SL:1			24
1	Lisieux	1973	Inor/von Roll	1*3	1	3	N					50	65 t/d	36
3	Lyon Nord	1989	TNEE-DBA	2*12	2	24	st		w	D,CL	D,CL,S,F,M,FA,SL:1			24
1	Lyon Sud	1963	Volund;CNIM/Martin	3*12	3	36	st		w	D,CL	S,F,N,M,FA,SL:1	905	700 t/d	24,36
1	Massy	1986	Inor/von Roll	2*5.5	2	11	st	420	ep, w	D,CL	S,TOC,N,M,P,FA,SL:1	190	0.25 kton/yr fuel;250 t/d	24,36
3	Maubeuge	1980	Stein	2*5.5	2	11	st	250	ep	D	D,CL,S,F,M,FA,SL:1	140	160 t/d	24,36
	Medis	1987	BSF	2*2	2	4	N					43	17 t/d	36
	Messanges	1976	Sogea (Alberti)	1*3	1	3	N					15.5	18 t/d	24,36
1 r	Metz	1970	CNIM	2*6	2	12	st		ep			251	250 t/d; steam param. 16/335	24,36,39

Table 5.7.4 Municipal Solid Waste Combustors in France 1991

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3	Montauban	1986	LBI	1*5	1	5	Y		d, ff			88	85 t/d	24,36
3	Montbeliard	1989	LBI	2*4	2	8	st		s, ff		D,CL,M:12 FA,SL:2	173	140 t/d	24,36
1	Montereau	1973	Sogea (Alberti)	1*4.2	1	4.2	N		ep			60	60 t/d	24,36
1	Mulhouse	1972	Inor/von Roll	2*4.5	2	9	st		ep			190	190 t/d	24,36
1	Nancy	1974	Luchaire	2*6.5	2	13	Y					360	543 t/d	24,36
1	Nantes	1987	CNIM/Martin	2*9.5	2	19	hw	350	s, ep	D,CL	S,TOC,F,N,M,FA,SL:1	480	0.8 kton/yr fuel;400 t/d	24,36
	Nevers	1965	Triga (Alberti)	1*3	1	3	N					53	70 t/d	24,36
1	Nice	1977	CNIM/Martin	3*12	3	36	st	270	s, ep	D,CL	S,TOC,F,M,FA,SL:1	401	el: 45 GWh;18 kton/yr fuel;600 t/d	24,36
1	Niort	1972	Stein	2*3	2	6	N					68	100 t/d	24,36
	Nogent le Rotrou	1976	Triga	1*3.2	1	3.2	N					33	32 t/d	24,36
1	Noyelle	1973	CNIM/Martin	2*6.7	2	13.4	N					250	330 t/d	24,36
2	Oyonnax (Groissiat)	1974	Triga (Barcus)	2*2.5	2	5	N					43	40 t/d	24,36
1	Ozoir la Ferriere	1976	Sogea (Alberti)	1*4.5	1	4.5	N		ep			110	100 t/d	24,36
1	Pavilly	1974	Stein	1*4	1	4	N					41	40 t/d	24,36
	Perpignan	1974	Triga (Ferbeck)	1*4	1	4	N		ep			112	120 t/d	24,36
	Pezenas	1981	Triga	1*3	1	3	N					60	60 t/d	24,36
1	Pithiviers	1985	Inor/von Roll	1*3.5	1	3.5	st		cy	D	D:1	57	el: 19 GWh; 67 t/d	24,36
	Plouharnel	1970	Sogea	1*4.2	1	4.2	N		cy			50	80 t/d	24,36
2	Poitiers	1984	BSF	2*4	2	8	Y					142	125 t/d	24,36
1	Pontcharra	1977	Sogea	1*3	1	3	N		cy			34	33 t/d	24,36
3	Pontivy	1990	LBI	1*4	1	4	Y		d,ff					24
3	Pontmain	1984	Sogea	1*4	1	4	st		ep			92	75 t/d	24,36
	Redon	1975	Comsip (Trummer)	1*3	1	3	N					38	43 t/d	24,36
1	Reims	1989	TNEE-DBA	2*6.5	2	13	hw	160	s, ff	D,CL	S,TOC,F,N,M:? FA,SL:2			24
1	Rennes	1968	CNIM/Martin	2*5	2	10	st	430			D,CL,S,TOC,F,M,FA,SL:1	265	290 t/d	24,36
1	Rochefort	1990	Sogea	2*2.5	2	5	st		ep	D	D:1	53	60 t/d	24,36
1	Rouen	1970	Stein Ind.	2*10	2	20	st		d,ff			300	320 t/d	24,36,37
1	Rungis	1981	CNIM/Martin	2*8.5	2	17	hw	243	ep	D	D,CL,S,TOC,M,FA,SL:1	125	428 t/d	24,36
1	Sarcelles	1978	Stein Ind.	2*10	2	20	Y		s, ep			287	335 t/d	24,36
	Seguinere	1983	LBI	1*4	1	4	Y					113	196 t/d	36
1	Sequedin	1973	CEC; CNIM/Martin	3*10	3	30	N		ep			453	400 t/d	24,36
1	Sillans la Cascade	1972	SEFI	2*2	2	4	Y					30	20 t/d	24,36
3	St Foy l'Argentiere	1985	Sogea	2*1.5	2	3	Y					33	40 t/d	24,36
	St Georges sur l'Aa	1972	SFRIR (Alberti)	1*3	1	3	N					42	55 t/d	36
1	St Jean D'Angely	1981	LBI	1*3.5	1	3.5	Y					58	50 t/d	24,36
	St Omer	1975	Sogea (Alberti)	1*4.2	1	4.2	N					63	60 t/d	24,36
1	St Ouen	1990	Stein Ind.	3*28	3	84	el, dh	4090	ep,w	D,CL,S,N	D,CL,M,FA,SL:12	1066	el: 15 GWh; 1500 t/d	22,24,36
	St Pierre Oleron	1976	Itisa (Brun); BSF	2*2.5	2	5	N							24
1	Strasbourg	1974	Inor/von Roll	4*11	4	44	st	400	ep		D:1	476	el: 13 GWh; 590 t/d	24,36
1	Strazeele	1973	Sogea (Alberti)	2*1.8,1	3	4.6	N		cy			62	83 t/d	24,36
1	Thiverval Grignon	1974	CNIM/Martin	2*11.3	2	22.6	hw		ep	D	CL,S,TOC,F,N,M,FA,SL:?	287	360 t/d	24,36
1	Thonon	1988	Itisa Volund	1*5	1	5	st		ep, s	D,CL	D,CL,TOC,M:1 FA,SL:?	84	0.05 kton/yr other fuel; 110 t/d	24,36

Table 5.7.4 Municipal Solid Waste Combustors in France 1991

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	Thonon	1972	Lillers (Roussau)	1*2,1*4	2	6	N			D,CL	D,CL,TOC,M:1 FA,SL:?		24
	Tignes	1985	Sogea	2*1.5	2	3	N					3 17 t/d	24,36
1	Tinteniac	1984	Sogea	2*1.5	2	3	N					40 41 t/d	24,36
1	Toulon	1985	CNIM/Martin	2*12	2	24	st		s, ep		D,CL,S,TOC,F,N,M,FA,SL:?	440 600 t/d	24,36
1	Toulouse	1969	TNEE-VKW	3*8.2	3	24.6	st		ep	D	CL,S,TOC,F,N,M,P,FA,SL:1	377 400 t/d	24,36
3	Tronville	1983	LBI	1*5	1	5	Y					112 100 t/d	24,36
1	Valenciennes	1977	CNIM/Martin	3*5	3	15	Y					222 250 t/d	24,36
	Vaux Le Penil	1976	Stein	1*4	1	4	N					92 65 t/d	36
	Vedenes	1971	Martin	1*5	1	5	N					154 250 t/d	36
	Vesoul	1968	Sogea (Alberti)	2*1.5	2	3	N					24.5 22 t/d	24,36
1	Villefranche	1984	Itisa Volund	1*4.5	1	4.5	st,dh					118 110 t/d; steam 14/198	24,36,43
1	Villejust	1984	CNIM/Martin	1*5,1*8	2	13	hw	300	s, ep	D	CL,S,TOC,F,N,M,FA,SL:?	158 276 t/d	24,36
3	Vitre	1988	LBI	1*4	1	4	st		d, ff			83 70 t/d	24,36
2	Wasquehal	1975	CEC	3*10	3	30	N		ep			442 400 t/d	24,36

Explanation in appendix, page 5

Table 5.7.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in France

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	7730	75	75	55
– No	2590	25	62	45
Total	10310	100	137	100
Flue gas cleaning:[1)]				
– unknown	3270	32	76	55
– none				
– cyclone	330	3	9	7
– esp	3830	37	29	20
– fabric filter				
– dry scrubber	340	3	6	4
– semi-dry scrubber	1340	13	12	9
– wet scrubber	1170	11	5	4
Total	10310	100	137	100
Extended flue gas cleaning:[1)]				
– DeNOx				
– active cokes				

[1)] Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

From this table it can be seen that the largest installations either have a semi-dry or wet scrubbing system or just an electrostatic precipitator. Real conclusions cannot be drawn because of the lack of information on 55% of the plants (32% of the combustion capacity).

It is not known what is done with the residues of the combustion of MSW. Most likely it is mainly landfilled.

A lot of information is still missing. Not only on 'difficult' categories like emission monitoring, amount of energy recovered or steam parameters but also on the flue gas cleaning used.

5.7.4 Emission guidelines

France has implemented the EC regulations in their own legislation (see chapter 4).

5.7.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

France has expressed the general aims to promote prevention and recycling in the so-called 'Plan Vert'. France aims to reduce landfill of MSW to 25% in the year 2000 [81]. Only 'ultimate' waste (after treatment) will be allowed to be landfilled [82].
A new legislation act on packaging waste is presently under preparation. This will probably put the responsibility for the packaging waste with the manufacturer, a bit like the German packaging law. The main objectives are to collect 75% of the packaging waste by the year 2002 (50% in 1997) and recycle (including energy recycling) over 90% of it [26].

5.7.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

No information is available to us on the future plans for combustion of MSW in France.

5.8 Greece

5.8.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Greece per year, with elaboration of the plastic fraction

In Greece 10 million people live. Not much is known on the Municipal Solid Waste which is produced in Greece. Estimates are that 3150 ktonnes per year in total or 310 kg per capita per year are produced. Not known is which categories are included in this. Table 5.8.1 splits up the MSW in several components.

Table 5.8.1 Total amount and composition of Municipal Solid Waste generated in Greece per year (1990) [7, 9, 10, 16, 24, 83, 84]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	1670	53
Paper & cardboard	570	18
Plastic	220	7
Glass	100	3
Metals	130	4
Miscellaneous (textiles incl.)	470	15
Total	3150	100

No information is available to us on the composition of the plastic fraction in terms of percentage PE, PP, etc.

5.8.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Solid waste management is at an infant stage in Greece. At present, solid wastes generated within municipalities an communities are collected with various means and are transported to final disposal sites that do not conform to sanitary landfill specifications. It is estimated that there are at least 3000 such sites in Greece with serious environmental problems concerning air, water and soil pollution [84].

Public policy concerning solid waste management is fragmented and lacks comprehensive and integrated planning at regional level.

The idea of source separation and recycling of various materials has been tried at an experimental level in a number of municipalities in Attica, Thessaloniki and Heraklion regions. Materials that have been recycled include aluminium cans, paper and glass. There is already a market for such materials in Greece [84]. However, none of the above programs has moved to full operation in spite of the very positive response they had from the general public [84].

No information on composting or combustion of MSW is available. The assumption made here is that 100% (3150 ktonnes per year) is landfilled.

Table 5.8.2 Municipal Solid Waste treatment per category in Greece (1990) [7, 84]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	0	0
Composting	0	0
Landfill	3150	100
Combustion	0	0
Total	3150	100

5.8.3 Overview existing Municipal Solid Waste combustors in Greece

At present there are no MSW combustors operating in Greece. There used to be one small unit, which, however, has been shut down recently [85].

5.8.4 Emission guidelines

No Greece emission guidelines are known. At minimum they have to comply with the European legislation though.

5.8.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

In Greece the (public) opposition towards landfill is growing. Therefore it is expected that in the near future plans will be made to start up other treatment schemes [85].

5.8.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

Nothing is known on (plans for) new MSW combustors in Greece.

5.9 Italy

5.9.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Italy per year, with elaboration of the plastic fraction

57.5 million Italians produce around 300 kg MSW per year, which renders a total amount of 17500 ktonnes MSW per year. Not known is whether this is just household waste or if other waste streams (bulky, trade, etc.) are included in this. The composition is given in table 5.9.1.

Table 5.9.1 Total amount and composition of Municipal Solid Waste generated in Italy per year (1990) [7, 9, 10, 16, 24, 86, 87, 88]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	7000	40
Paper & cardboard	3850	22
Plastic	1230	7
Glass	1400	8
Metals	520	3
Miscellaneous textiles incl.)	3500	20
Total	17500	100

Table 5.9.2 Composition of the plastics fraction in the Municipal Solid Waste in Italy (1989) [16, 18]

Component	Amount	
	ktonnes/yr	% of total plastics
PE	860	70
PP	120	10
PVC	100	8
PS	90	8
PET	40	3
Other	20	2
Total	1230	100

5.9.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Environmental policy did not become an important issue in Italy until the 1970s. Environmental legislation was introduced at this time, in particular, a systematic attempt was made to regulate the water sector through legislation known as the 'Legge Merli'. Implementation was hampered though by inadequate administrative structures, given that there was no specific department for the environment, and by the lack of supporting structures such as monitoring facilities. By the time the Environment Ministry was created in 1986, there was already a significant gap between the state of the environment in Italy and that of other European countries. For this reason much of current environmental policy in Italy is concerned with clean-up of contaminated areas and tackling of existing problems. Preventive actions are only beginning to receive attention [20].

The Environment Ministry has recently announced its priorities for the next ten years [20]:
- Rehabilitation of areas with severe environmental problems such as Seveso; Bormida Valley, Naples and the Venice Lagoon;
- Water resources;
- Waste management;
- Noise.

Table 5.9.3 Municipal Solid Waste treatment per category in Italy (1990) [7, 16, 24, 86, 87]

Component	Municipal Solid Waste ktonnes/yr	Solid Waste %
Recycling	500	3
Composting	1200	7
Landfill	13000	74
Combustion	2800	16
Total	17500	100

5.9.3 Overview existing Municipal Solid Waste combustors in Italy

It has been difficult to obtain information on MSW combustors in Italy. At the moment this report is written the following is known.

In Italy at the moment 43 MSW combustors are in operation, 19 of them are being retrofitted while in operation. Besides these 43, 6 new installations are under construction and finally 5 combustors are temporarily closed for retrofitting. So when all the works are finished there will be 54 combustors operating in Italy. 16 of them are listed in table 5.9.4, however, this is hardly a representative amount to draw conclusions on. On the other combustors no data are available yet.

Table 5.9.4 Municipal Solid Waste Combustors in Italy 1990

TNO 20/05/92

Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Steam [bar]	['C]	Flue gas cleaning	continuous	Emission sampled	Remark	Reference
1	Bergamo	1965	Saronno	2*3.1	2		6.2	st			ep		D,CL,S,F,M,P:4		24
1	Bologna	1970	von Roll	3*8.3	3	140	24.9	st, el			ep		D,CL,S,F,M,P:2 FA,SL:1		24
2	Busto Arsizio	1972	Alberti Fonsar	2*5.7	2		11.4				ep		D,CL,S,F,M,P:4		24
1	Desio	1976	De Bartolomeis	2*5	2		10	st			w		D,CL,S,F,M,P:4		24
1	Ferrara	1975	De Bartolomeis	1*4.2	1		4.2	N			ep		D,CL,S,F,M,P:2		24
1	Forli	1976	von Roll	2*4.2	2		8.4				ep		D,CL,S,F,M,P:2		24
1	Genova	1970	von Roll	3*8.3	3		24.9	st			ep		D,CL,S,F,M,P:2 FA,SL:1		24
1	Livorno	1973	Publ. Consul.	2*4.2	2		8.4	N			ep		D,CL,S,F,M,P:2		24
1	Milano I	1969	Volund	2*5	2		10	st			w		D,CL,S,F,M,P:4		24
1	Milano II	1975	De Bartolomeis	2*12.5	2		25	st			w		D,CL,S,F,M,P:4		24
1	Modena	1980	von Roll	2*6	2		12	st			ep		D,CL,S,F,M,P:2		24
1	Padova	1975	Saronno	1*5.8	1	24	5.8	hw			d, ep	D	CL,S,TOC,F,N,M,P:24 FA,SL:12		24
3	Parma	1975	Tecnitalia	2*6.25	2		12.5	N			ep		D,CL,S,F,M,P:2		24
1	Reggio Emilia	1967		2*4.2	2		8.4	st			d		D,CL,S,F,M,P:2		24
3	Trieste	1972	Tecnitalia	3*5	3		15	N			ep		D,CL,S,F,M,P:3		24
4	Verona			2*12	2	28	24	el, dh	50	380	s, ff			RDF: steam prod. 44 t/h	1

NOT COMPLETE ; SEE TEXT !!

Explanation in appendix, page 5

5.9.4 Emission guidelines

Italy has its own guideline which, however, is very much alike the EC guideline (chapter 4). Only an extra limit is set towards the emission of PCDD/F, and the required flue gas temperature to guarantee complete burn-out is higher (950 °C).

5.9.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

Waste disposal has received considerable attention in the last years. Recent legislation has introduced a register of industrial waste at the regional level. From 1989, anyone producing or treating waste has had to provide information to the regional or provincial authorities on the quantity and characteristics of the waste handled. This will make it possible to identify the need for additional treatment facilities and will form the basis of regional waste disposal plans [20].

Italy plans for a large increase in recycling rates. In order to establish this several laws and legislations have been introduced already and will be introduced in the near future. Also a small increase in combustion capacity is foreseen. The targets are given in table 5.9.5 [87].

National consortia have been set up with specific targets for recycling of glass, metal and plastic containers. The legislation also provides for labelling of products urging the user to recycle rather than simply throw away [20].

Legislation, concerning recycling, which has been issued already [54]:
- During 1988 a beverage packaging legislation was introduced with an option for a taxation system.
- The Italian law no. 475 (November 9th 1988) forced the packaging industries to create consortiums for the recycling of glass, metal and plastic beverage containers. If by the end of 1992 a recycling rate of 40% is not reached, recycling contribution (LIT 100 for 1 litre) will have to be paid on each container sold.
- Starting 1989 the plastics industries will have to pay a recycling contribution representing 10% of the bottle resin sales value. This applies to all plastics.

As for packaging waste recycling targets are set to be realised by the end of 1992: 50% of metals and glass and 40% of plastics and laminated cartons. For plastics half of the target may be realised through energy recovery. The 40% target may be postponed to 1994 due to technical problems [26].

Table 5.9.5 Expected treatment schemes of the Municipal Solid Waste schemes in Italy in the year 2000 [87]

Component	Municipal Solid Wast %
Recycling (composting incl.)	37
Landfill	42
Combustion	21
Total	100

5.9.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

No information on the future of MSW combustion in Italy is available (yet).

5.10 Ireland

5.10.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Ireland per year, with elaboration of the plastic fraction

Ireland is inhabited by 3.5 million people. Municipal Solid Waste amounts to 1100 ktonnes total or around 310 kg per capita per year. It is not known which fractions of waste streams (household, bulky, etc.) are included in this figure. The composition of this amount is given in table 5.10.1.

Table 5.10.1 Total amount and composition of Municipal Solid Waste generated in Ireland per year (1990) [7, 9, 10, 16, 89]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	610	55
Paper & cardboard	220	20
Plastic	110	10
Glass	30	3
Metals	30	3
Textiles	30	3
Miscellaneous	70	6
Total	1100	100

No data are available on the composition of the plastic fraction in terms of percentage PE, PP, etc.

5.10.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Almost all MSW is landfilled in 'controlled' sites although standards vary considerably. Many sites are not sealed to prevent soil and ground water pollution by leachate. However, most new sites are synthetically sealed for leachate collection. A small amount (mainly aluminium cans, glass and paper [89]) is recycled as is shown in table 5.10.2.

Table 5.10.2 Municipal Solid Waste treatment per category in Ireland (1990) [7, 89]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	35	3
Composting	0	0
Landfill	1065	97
Combustion	0	0
Total	1100	100

5.10.3 Overview existing Municipal Solid Waste combustors in Ireland

At present there are no MSW combustors in operation in Ireland. There are some small combustors burning industrial or commercial wastes [90].

5.10.4 Emission guidelines

Ireland does not have any emission guideline. If any combustor would be installed it would have to perform according to the EC regulations at minimum. However, it would be recommended to apply the best international standards like the German regulations (TA Luft and 17. BImSchG, or any subsequent equivalents) [90].

5.10.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

It is very likely that recycling initiatives are increased. First of all the already existing recycling schemes for aluminium cans, glass and paper/cardboard will probably be expanded. At present a study is being executed to establish recycling possibilities in Ireland. Furthermore the environmental awareness among consumers is being promoted by a government agency to reduce the amount of waste and increase the recycling of waste [90].
Combustion of MSW is not foreseen in the next twenty years.

5.10.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

At present it is not anticipated that any MSW combustors will be installed by the year 2010 [90].

5.11 Luxembourg

5.11.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Luxembourg per year, with elaboration of the plastic fraction

Luxembourg is the smallest country considered in this study, having 0.4 million inhabitants. In Luxembourg 180 ktonnes of MSW is produced per year (around 480 kg per capita per year). This MSW probably comprises household and bulky waste. Although the production of MSW per capita is considerably higher than in the neighbour country Belgium (480 versus 350 kg), the composition (in percentages) is assumed to be the same (table 5.11.1) in this study.

Table 5.11.1 Total amount and composition of Municipal Solid Waste generated in Luxembourg per year (1990) [7, 9, 10, 16, 91]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	85	47
Paper & cardboard	50	28
Plastic	13	7
Glass	13	7
Metals	7	4
Textiles	4	2
Miscellaneous	9	5
Total	180	100

Also for the composition of the plastic fraction the percentages for the Belgian waste are copied to Luxembourg (table 5.11.2).

Table 5.11.2 Composition of the plastics fraction in the Municipal Solid Waste in Luxembourg (1990) [53]

Component	Amount	
	ktonnes/yr	% of total plastics
PE/PP	8.6	66
PVC	1.3	10
PS	2.1	16
PET	0.5	4
Other	0.5	4
Total	13	100

5.11.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

The majority of the Luxembourg MSW is combusted in the countries only combustor. Recycling is low. Table 5.11.3 gives the amounts.

Table 5.11.3 Municipal Solid Waste treatment per category in Luxembourg (1990) [7]

Component	Municipal Solid Waste ktonnes/yr	Solid Waste %
Recycling	4	2
Composting	2	1
Landfill	39	22
Combustion	135	75
Total	180	100

5.11.3 Overview existing Municipal Solid Waste combustors in Luxembourg

There is one MSW combustor in operation in Luxembourg at the moment. Data on this combustor are given in table 5.11.4. This combustor has a design capacity of 168 ktonnes per year. Energy is recovered to produce electricity. The flue gases are cleaned with an electrostatic precipitator and a semi-dry scrubber, followed by a fabric filter.

Table 5.11.4 Municipal Solid Waste Combusters in Luxembourg 1991

TNO 20/05/92

Incinerator type	Location	Start-up year	Changes	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Steam [bar]	['C]	Flue gas cleaning	Emissions continuous	Remark	Reference
1 r	Leudelange	1976	E85;M88	Martin	3*8	3	136	24	st	41	385	ep,s,ff	D,CL,S,CO,O	31.3 GWh sold: 44.8 GWh produced	25,39

Explanation in appendix, page 5

Table 5.11.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Luxembourg

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery: – Yes – No	168	100	1	100
Total	168	100	1	100
Flue gas cleaning:[1)] – unknown – none – cyclone – esp – fabric filter – dry scrubber – semi-dry scrubber – wet scrubber	168	100	1	100
Total				
Extended flue gas cleaning:[1)] – DeNOx – active cokes				

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

MSW combustion residues are solidified and landfilled in a landfill, suited for industrial waste.

5.11.4 Emission guidelines

Luxembourg has not got own emission guidelines. Their combustion plant has to comply with the European guidelines, but tries to reach emission levels according to German legislation.

5.11.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

In Luxembourg a tax will be put on non refillables for which no recycling scheme exists. Exemptions for this rule will only be for producers that set up large recycling systems [26].
Composting is expected to increase in the near future [91].

5.11.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

No change in combustion capacity in Luxembourg is anticipated. The existing combustor will remain in operation for the time being.

5.12 Norway

5.12.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Norway per year, with elaboration of the plastic fraction

In Norway 2000 ktonnes of MSW is produced annually by 4.2 million Norwegians, which means 470 kg per capita per year. The Norwegian MSW consists of household, bulky and trade waste and a small fraction of industrial and construction/demolition waste. How this is amount is divided over the different components is showed in table 5.12.1.

Table 5.12.1 Total amount and composition of Municipal Solid Waste generated in Norway per year (1990) [7, 9, 16, 24, 32, 92]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	500	25
Paper & cardboard	640	32
Plastic	140	7
Glass	80	4
Metals	80	4
Textiles	40	2
Miscellaneous:		
combustibles	280	14
non-combustibles	240	12
Total	2000	100

Not much data on the plastic fraction in MSW are known. Table 5.12.2 gives an indication.

Table 5.12.2 Composition of the plastics fraction in the Municipal Solid Waste in Norway (1990) [44]

Component	Amount	
	ktonnes/yr	% of total plastics
HDPE	60 - 85	40 - 60
LDPE	15 - 40	10 - 30
PP	7 - 15	5 - 10
PVC	7 - 15	5 - 10
PS	7 - 20	5 - 15
Other (PET incl.)	7 - 20	5 - 15
Total	140	100

5.12.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Until recently the work of the environmental authorities has been concentrated mainly on the clean-up and repair of the most important damages to the environment.

Along with the continued repair of existing damage to the natural resource base, it is now possible, however, to place more emphasis on preventive environmental protection.

In 1984 the Ministry of Environment presented an action plan for recycling. The Action Plan is based on the idea that by recycling a number of environmental problems can be solved and the resource base for society increased.

The Action Plan is based on the Pollution Control Act which states that waste should be recycled when a combination of environmental considerations, resource conservation and economic factors makes it feasible.

Concerning municipal waste disposal the national authorities has put special emphasis on regional cooperation. This is an attempt to replace many of the small local facilities with modern well-managed treatment plants.

According to the Pollution Control Act the collection of consumer waste is a municipal responsibility. Close to 90% of the population is served by a regular waste collection service. The coverage is 100% in centres with more than 2000 inhabitants [32].

The most common disposal method has been landfilling. The typical pattern has been one landfill in each municipality. During the last 10-15 years several regional disposal facilities has been established. Some of these use combustion, some composting and some are modern landfills. As a result many small disposal sites, with severe environmental impact, have been closed [32].

Source separation at households is practised only a few places as part of a test program. From 1990 on a few municipalities have established a 'green system' [32].
Separate collection of newspapers and magazines has been practised to some extent in the most populated areas.
Also glass and batteries are collected separately at many places.

Table 5.12.3 Municipal Solid Waste treatment per category in Norway (1990) [7, 16, 32, 92]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	140	7
Composting	100	5
Landfill	1330	67
Combustion	430	22
Total	2000	100

5.12.3 Overview existing Municipal Solid Waste combustors in Norway

In Norway there are 5 large (>=3 tonnes/hour) MSW combustors in operation at the time (table 5.12.4). The total design capacity of these combustors is 410 ktonnes/year. The MSW combustion facilities all recover energy which is then used for electricity production and district heating (combined heat and power). Also the applied flue gas cleaning is the same for all the installations: an electrostatic precipitator combined with a wet scrubber.

Table 5.12.4 Municipal Solid Waste Combustors in Norway 1991

TNO 20/05/92

Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Flue gas cleaning	Remark	Reference
	Alesund			1*5	1	22	5	st, dh	ep, w	12 GWh	32,44
	Fredrikstad		W+E	2*4.5	2	69	9	st, dh	ep, w	141 GWh	32,38,44
	Oslo (Haraldrud)		W+E	2*6.5	2	90	13	st, dh	ep, w	78 GWh sold: 231 GWh total	32,38,44
	Oslo (Klemetsrud)		Ma.-Fa. Esslingen	2*10	2	121	20	st, dh	ep, w	183 GWh sold; 285 GWh total	32,38,44
1	Trondheim	1986	von Roll/Generator	2*6	2	60	12	st, dh	ep, w	113 GWh sold; 149 GWh produced; 2*14 MW	32,38,44,50

Explanation in appendix, page 5

Table 5.12.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Norway

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery: – Yes – No	410	100	5	100
Total	410	100	5	100
Flue gas cleaning:[1)] – unknown – none – cyclone – esp – fabric filter – dry scrubber – semi-dry scrubber – wet scrubber	410	100	5	100
Total	410	100	5	100
Extended flue gas cleaning:[1)] – DeNOx – active cokes				

[1)] Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

Besides these large combustors there are a lot of smaller combustors mainly combusting hospital or industrial waste.

Residues from MSW combustion are mainly landfilled in hazardous waste landfills for fly-ash and flue gas cleaning residue and normal landfill for bottom-ash. Bottom-ash is reused to little extent.

Information on combustor type, start-up year and emission monitoring is missing.

5.12.4 Emission guidelines

Emission guidelines in Norway differ for small and large installations. For large installations (>20 ktonnes per year) the emission limits are comparable to the EC regulations: stricter for dust, but less strict for HCl (see chapter 4). Also a limit on the emission of PCDD/F is implemented (2 ng TEQ/m^3). The guideline for small installations is a little less strict (chapter 4).

5.12.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

Norway also has expressed the general accepted views considering increase of prevention and (material or energy) recycling and a decrease of (untreated) landfill of MSW.

To realise an increase of prevention and recycling several measures are considered [32] among which:
- tax on waste generating substances;
- amount related charge for collecting waste;
- tax dispensation for objects out of recycled materials;
- change consumer behaviour towards prevention and recycling;
- subsidize separate collection schemes;
- banning of really harmful (environmentally) substances.

5.12.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

In Norway two permits are given for new installations. However, the cities where these combustors are to be built (Tromsø and Bergen) have not decided yet.

5.13 The Netherlands

5.13.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in The Netherlands per year, with elaboration of the plastic fraction

In The Netherlands 14.8 million people live, producing 7700 ktonnes MSW per year, which is around 520 kg per capita per year. MSW in The Netherlands comprises household, bulky and trade waste. The composition is given in table 5.13.1.

Table 5.13.1 Total amount and composition of Municipal Solid Waste generated in The Netherlands per year (1990) [7, 9, 10, 16, 24, 93, 94, 95, 96, 97, 98]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	2930	38
Paper & cardboard	2700	35
Plastic	540	7
Glass	540	7
Metals	390	5
Textiles	150	2
Miscellaneous:		
combustibles	310	4
non-combustibles	150	2
Total	7700	100

Table 5.13.2 Composition of the plastics fraction in the Municipal Solid Waste in The Netherlands (1990) [99]

Component	Amount	
	ktonnes/yr	% of total plastics
PE	320	59
PP	60	11
PVC	35	6.5
PS	70	13.5
PET	10	2
Other	45	8
Total	540	100

5.13.2 Municipal Solid Waste treatment scheme (recycling, landfill, combustion)

In The Netherlands MSW is to a considerable extent landfilled. Recycling of paper and glass is performed with very high recycling rates (60-70%). Besides that in a lot of cities putrescibles are separately collected and composted. Finally small chemical wastes from household (medicines, paint cans, etc) and batteries also are separately collected. Table 5.13.3 shows the amounts per treatment scheme.

Table 5.13.3 Municipal Solid Waste treatment per category in The Netherlands (1990) [7, 16, 24, 93, 94, 95, 96, 97, 98]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	1200	16
Composting	350	3
Landfill	3450	45
Combustion	2700	35
Total	7700	100

5.13.3 Overview existing Municipal Solid Waste combustors in The Netherlands

In The Netherlands there are 10 MSW combustors currently in operation. All of them have a capacity larger than 3 tonnes per hour. Details are given in table 5.13.4. Only one of these combustors does not recover energy from the flue gases, but this is a small one. The flue gas cleaning used at this moment is summarized in table 5.13.5. Combinations of scrubbers with dust removing equipment is thereby counted to the scrubbers only. The total design capacity of the Dutch MSW combustors is 2800 ktonnes per year.

Table 5.13.4 Municipal Solid Waste Combustors in The Netherlands 1991

TNO 20/05/92

Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Steam [bar]	['C]	Flue gas cleaning	Emissions continuous	Remark	Reference
1 r	Alkmaar	1971	Martin	3*4	3	123	12	N			d, ff	D,CL,S,TOC,F,CO,O		24,40
1 r	Amsterdam-Noord	1969	Martin	4*16	4	370	64	st	43	400	ep	D,CL,CO,O	steam 40 t/h: Closes 1993	40
1 f	ARN (Nijmegen)	1986	K&K	1*9	1	68	9	st, el	40	400	ep, w	D,CL,F,CO,O	el: 58 GWh (8MW); RDF incineration; 40 t/h stoom	40
1 d	Arnhem (AVIRA)	1975	Dusseldorf	1*12,2*15	3	256	42	st, dh	40	400	ep, w	D,CL,S,TOC,F,CO,O	energy: 1 unit st 40 t/h, 1 dh, 1 N	40
1 d	AVR (Rotterdam)	1972	Babcock	6*22	6	975	132	st, hw	29	365	ep	D,CL,S,TOC,F,CO,O	E92 22 t/h;M93 fgc: w, nl, c; dist.water; 55 t/h	24,40
1 f	Den Haag	1968	von Roll	3*12.5,1*15	4	330	52.5	el, dh	37	410	ep	CO,O	el: 23 MW; steam 100 t/h; Ca-inj.; d/w+ff,nl	40
1 f	Eindhoven (Philips)	1986	K+K	1*3.5	1		3.5	el, dh	21	340	ep, w		RDF and ind. waste (20%): cal. value (13-14 MJ/kg)	40,41
1 r	Gevudo (Dordrecht)	1972	Martin	4*7	4	144	28	el, ss			ep, w	D,CL,S,TOC,F,CO,O		24,40
1	Roosendaal	1976	B&S	2*4	2	35	8	sd, dh			ep,d,ff,w	CL,CO,O	fgc: 1 line, other line just ep	24,40
1 r	ROTEB Rotterdam	1963	Martin	4*12.5	4	390	50	st	28	360	ep	CL,CO,O	steam 30 t/h;new fgc planned w,c, nl(end 93)	40

Explanation in appendix, page 5

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Table 5.13.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in The Netherlands

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	2720	97	9	90
– No	80	3	1	10
Total	2800	100	10	100
Flue gas cleaning:[1)]				
– unknown				
– none				
– cyclone				
– esp	2090	75	4	40
– fabric filter				
– dry scrubber	80	3	1	10
– semi-dry scrubber				
– wet scrubber	630	23	5	50
Total	2800	100	10	100
Extended flue gas cleaning:[1)]				
– DeNOx				
– active cokes				

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

From table 5.13.5 we see that strange enough the largest combustors do not have scrubbers yet (see section 5.13.6).

Part of the bottom-ash (80%) and the fly-ashes (40%) produced through combustion of MSW is reused in The Netherlands, mainly for road and water works. The rest is landfilled.

All the information for The Netherlands relevant to this study is available.

5.13.4 Emission guidelines

In The Netherlands the EC guidelines are implemented in the legislation. However, there is a guideline (which is about to become a law) which is lot stricter then the EC regulation: 'Richtlijn Verbranden 1989' [52]. In fact, this guideline is the strictest in Europe (chapter 4). Although this guideline is not a law (yet) it is almost always incorporated in the permit for an MSW combustor. In practice it means that all the Dutch installations have to comply with the 'Richtlijn Verbranden 1989'.

5.13.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

In The Netherlands the amounts of Municipal Solid Waste and the treatment thereof in 1986 is taken as a reference point. Towards this reference point in 2000 no growth should have occurred and preferably a 5% decrease in total amount of MSW should have been realised through prevention. In table 5.13.6 the amounts and treatment schemes for 1986 and 2000 are quantified. Comparison with table 5.13.3 learns that in the meantime (1986-1990) the amount of MSW has increased. To get back at the level of 1986 extra prevention has to be realised.

Table 5.13.6 Expected amount of Municipal Solid Waste including expected treatment schemes in The Netherlands in the year 2000 compared to the situation in 1986 [95]

Component	MSW			
	2000		1986	
	ktonnes/yr	%	ktonnes/yr	%
Recycling[1)]	3850	51	1050	14
Landfill	0	0	4150	55
Combustion	3650	49	2300	31
Total	7500	100	7500	100

1) Composting included

In The Netherlands separate collection of putrescibles has been introduced in a lot of cities. By 1994 this separate collection has to be operational throughout the country.

In June 1991 the Dutch government has set up a voluntary agreement on packaging waste with the packaging industry. The main objectives of this agreement are:

- Reduction of the quantity of packaging waste landfilled: in 1995 landfill should be reduced to 40% with regard to 1986, and no landfill at all by the year 2000.
- Material recycling or reuse of more than 60% of the packaging waste by the year 2000.
- Energy recycling of at maximum 40% of the packaging waste by the year 2000.
- Decrease of the quantity of packaging waste of at least 10% between 1986 and 2000.
- Reduction of 10% of the quantity of packaging used in 2000 with regard to the situation in 1986.

Furthermore the industry will take back 90% of the packaging waste (excluding packaging to be reused), provided it is separately collected.
Furthermore several (recycling) projects will be started up like the dismounting and separate processing of parts of refrigerators, television sets, computers, cars etc.

Due to enormous public opposition to the planned increase in combustor capacity the government is now investigating the possibilities of a combination of separation and anaerobic composting.

5.13.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

From table 5.13.5 it was concluded that the largest combustors in The Netherlands do not have scrubbing techniques incorporated in their flue gas cleaning system, whereas the smaller ones do. Of these 4 large combustors, however, 1 will be closed done in 1993 (Amsterdam-North) and replaced by a new MSW combustion facility (Amsterdam-West). This new facility will have a capacity of 765 ktonnes per year and a flue gas cleaning system consisting of a wet electrostatic precipitator, a semi-dry scrubber followed by another electrostatic precipitator and SNCR-DeNOX.
Two other large combustors (AVR and ROTEB, both Rotterdam) are building a completely new flue gas cleaning system right now. Both will be completed in 1993 and will consist of an electrostatic precipitator, a wet scrubber, SCR-DeNOx and an active cokes filter.
The fourth large combustor (The Hague) without scrubber is either shut down or retrofitted with an extended flue gas cleaning system, which will have a wet or dry scrubber, a fabric filter and DeNOx-equipment.

The only combustor in The Netherlands which does not recover energy (Alkmaar) is shut down in 1995 and replaced by a new facility. This new facility will be a lot bigger (55.5 tonnes per hour, 3 units: total capacity 389 ktonnes/year) and will recover energy. The flue gases will be cleaned by an electrostatic precipitator, a spray dry absorber, a fabric filter, a wet scrubber and SCR-DeNOx. Not sure yet is whether active cokes adsorption will be applied.

Further plans are:
- Extension of the capacity of AVR Rotterdam (1*27 tonnes/hour), ARN Nijmegen (160 ktonnes/year) and Gevudo Dordrecht (70 ktonnes/year);
- New combustors in Buggenum (600 ktonnes/year), Moerdijk (600 ktonnes/year), Wijster (370 ktonnes/year), Boeldershoek (180 ktonnes/year) and one in the centre of The Netherlands (600 ktonnes/year) between now and 2000.

Recently the plans for a new combustor near The Hague were put on ice because of enormous public opposition. It is not certain whether this plan will be executed or not. An alternative would be further extension of the capacity of AVR Rotterdam.

If all the combustors which are planned will be build this will mean an increase in capacity from 2800 ktonnes/year now to nearly 7000 ktonnes/year in the year 2000 (supposing that the installation in The Hague will be closed).

At the time the discussion over extension of MSW combustion capacity is very intense, and estimates of the needed capacity vary from 5000 to 9500 ktonnes/year. The 'Afval Overleg Orgaan' (Waste management committee) estimates a combustion capacity of 5300 ktonnes/year in the year 2000. This is not just MSW but also industrial waste, sewage sludge, etc. which explains the difference with table 5.13.6.

5.14 Portugal

5.14.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Portugal per year, with elaboration of the plastic fraction

Portugal is inhabited by 10.3 million people and produces the lowest amount of waste per capita per year of the countries considered in this study: 260 kg. All together this gives a total of 2650 ktonnes MSW. There is no information available concerning which waste streams are taken into account within the definition of MSW in Portugal. The amounts of putrescibles, paper, etc. are given in table 5.14.1.

Table 5.14.1 Total amount and composition of Municipal Solid Waste generated in Portugal per year (1990) [7, 9, 10, 16, 78, 100]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	1590	60
Paper & cardboard	580	22
Plastic	110	4
Glass	80	3
Metals	110	4
Miscellaneous (textiles incl.)	190	7
Total	2650	100

No information on the composition of the plastic fraction is known.

5.14.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

At present there are no source separation and few recycling schemes in Portugal. Insufficient hazardous waste control and poor landfill management are common problems. Only 60% of MSW is collected, a great deal being dumped illegally. Some 40% of wastes in 1985 were correctly handled, ~15% in composting plants, ~25% to sanitary landfill. The rest went to uncontrolled dumps [78, 100].

Table 5.14.2 Municipal Solid Waste treatment per category in Portugal (1990)

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	0	0
Composting	400	15
Landfill	2250	85
Combustion	0	0
Total	2650	100

5.14.3 Overview existing Municipal Solid Waste combustors in Portugal

At the moment there are no MSW combustors operating in Portugal.

5.14.4 Emission guidelines

Portugal does not have any emission guideline of its own. If any combustor would be installed it would have to perform according to the EC regulations at minimum.

5.14.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

No information available.

5.14.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

No information available.

5.15 Sweden

5.15.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Sweden per year, with elaboration of the plastic fraction

Sweden has 8.5 million inhabitants which produce a total of 3200 ktonnes MSW per year. This is around 380 kg per capita per year. The definition of MSW in Sweden is not known. The composition is known and presented in table 5.15.1.

Table 5.15.1 Total amount and composition of Municipal Solid Waste generated in Sweden per year (1990) [7, 9, 10, 16, 24, 101, 102]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	960	30
Paper & cardboard	1280	40
Plastic	260	9
Glass	220	7
Metals	100	3
Textiles	60	2
Miscellaneous	290	9
Total	3200	100

On the composition of the plastic fraction not much is known, besides the PVC content. This is 4-7% which amounts to 10-18 ktonnes per year [18].

5.15.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

From January 1991 every municipality in Sweden is obliged to draw up a 'solid waste plan' for the handling of all wastes produced in the municipality (domestic waste, industrial waste, hazardous waste, hospital waste etc.) including the survey of the amount of different wastes and its origin [101].

The collection of domestic waste is a municipal responsibility. Most collection schemes include a regular or by-request collection of discarded furniture and other bulky waste from households.
In the cities an important proportion of the waste from offices, shops etc. is collected under the household collection scheme. However, the collection of

commercial and industrial waste is generally left to private enterprises and carried out by direct contracting with the individual producing companies.

Thermal treatment of waste combined with energy recovery is widely used in Sweden. At present almost 50% of the municipal solid waste produced is combusted.

The best example of successful resource recovery is the recovery of newspapers and journals. The activity is nationwide. In 1989 600 ktonnes of newspapers, journals were consumed in the Swedish households. Approximately 380 ktonnes were recovered. At present about 40 ktonnes of glass from the households are recovered per year [101].
In the domestic waste there is a bulky fraction consisting among other things of old refrigerators, ovens, bathtubs etc. Out of this 'metal' waste there is a yearly recovery of approximately 80 ktonnes of metals. Only a small part of this kind of waste is landfilled.

Furthermore a return and reuse scheme for PET bottles and aluminium cans has been set up. The PET bottles are reused for 100% already whereas for the aluminium cans the target is 90% by the year 1993 [26].

Table 5.15.2 Municipal Solid Waste treatment per category in Sweden (1990)

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	500	16
Composting	100	3
Landfill	1100	34
Combustion	1500	47
Total	3200	100

5.15.3 Overview existing Municipal Solid Waste combustors in Sweden

In Sweden 17 large (capacity >= 3 tonnes per hour) MSW combustors are operating at the time. These are listed in table 5.15.3. Besides that also 6 small combustors are in operation. All these combustors recover energy for district heating. Some of them (the 3 largest combustors, combusting 45% of the total combusted MSW) also produce electricity. The total design capacity of the large combustors is 1770 ktonnes per year. On this basis an overview of the flue gas cleaning used in Sweden is made (table 5.15.4). Thereby combinations of scrubbers and dust removing equipment is counted to the scrubbers only.

Table 5.15.3 Municipal Solid Waste Combustors in Sweden 1991

TNO 20/05/92

Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Total capacity [kton/yr] Units		Energy [ton/hr]	Steam system	Steam [bar]	Steam ['C]	Energy output [TJ]	Flue gas cleaning	Emission continuous	Emission sampled	Remark	Reference
1	Avesta	1980	B&S	2*3.2	2	40	6.4	dh				w, d, ff	D,CL	D,CL,S,TOC,F,N,M,P,FA,SL,WW:1		16,23,24
4	Bollnäs	1983	Generator	1*4	1	15	4	dh	16		315	cy, ff	D	CL,S,TOC,F,N,M,P,FA,SL:1	2*10 MW	16,17,24,50
1	Borlange	1982	K+K	1*5-6	1	10	5	dh			230	d, ff		D,CL,S,F,N,M,P,FA,SL,WW:?	11 kton/yr other fuel; 18 MW	16,23,24,50
1	Göteborg	1972	von Roll, B&S	3*15,1*0.2	4	295	45.2	el,dh	20	212	2540	ep, w	D,CL	D,CL,S,TOC,F,N,M,P,FA,SL:2 WW:12	el:55 GWh;oil;E to 400 kton/yr	16,17,23,24,4
1	Halmstad	1971	Martin	2*5	2	70	10	dh	16		620	ep, w	D,CL	S,TOC,N,M,P,FA,SL,WW:1	2.5 kton/yr other fuel;2*11 MW	16,17,23,24,5
1	Karlskoga	1986	K+K	1*5	1	35	5	dh	28	300	226	ep,w	D,CL,N	S,F,M,P:1 FA,SL:2	0.2 kton/yr fuel; 18 t/h steam	16,23,24,50
1	Karlstad	1986	K+K	1*7	1	50	7	dh	28			d, ff	D,CL	S,TOC,N,M,P,FA,SL:1	17 MW	16,23,24,50
1	Kiruna	1984	Volund	2*2.1	2	11	4.2	dh	80	480	330	ep,w		D:4	32 kton/yr fuel; 44 t/h steam	16,23,24
1	Köping	1972	Landsverk	2*5	2	34	10	dh			320	d, ep	D,CL	S,TOC,F,N,M,P,FA,SL:4	7 kton/yr other fuel	16,17,23,24
4	Lidköping	1985	Generator	1*6	1	12	6	dh	16		91	ff	D	D,CL,S,TOC,F,N,M,P,FA,SL:2	35.5 kton/yr fuel; 2*12 MW	16,24,50
1	Linköping	1982	von Roll	1*7,2*12	3	200	31	dh			1650	d, ep	D,CL	S,TOC,F,N,M,P,FA,SL:?	6 kton/yr other fuel	16,17,23,24
1	Malmö	1973	Martin	2*14	2	195	28	dh			1650	d, ff	D,CL,S,N	F,M,P,FA,SL:1		8,23,24
1	Mora	1981	B&S	1*3.15	1	18	3.15	dh			103	d, ff	CL	D,S,TOC,F,N,M,P:1	0.7 kton/yr other fuel	16,17,23,24
1	Stockholm	1970	VKW, Martin	2*11,1*15	3	203	37	el,dh			1490	d, ff	D,CL,S,N	D,CL,S,F,N,M,P:1 FA,SL:?	el: 32 GWh; 8 kton/yr fuel	16,23,24
1	Umea	1970	von Roll	2*4,1*7	3	86	15	dh	28		760	d, ff	D,S,N	CL,F,M,P:1 FA,SL,WW:9	10 kton/yr other fuel,18 MW	16,17,23,24,5
1	Uppsala	1961	Volund,B&S,W+E	2*3,1*10,1*15	4	242	31	st,dh			2440	ep,w,ci,ff	D,CL,WW	S,TOC,F,N,M,P:6 FA,SL:?		11,24,45
4	Västervik	1984	Generator	1*5	1	18.5	5	dh	16		155	cy, ff		D,CL,M,P,FA,SL:1	20 MW	16,17,24,50

Explanation in appendix, page 5

Table 5.15.4 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Sweden

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	1770	100	17	100
– No				
Total	1770	100	17	100
Flue gas cleaning:[1]				
– unknown				
– none				
– cyclone				
– esp				
– fabric filter	100	6	3	18
– dry scrubber	950	54	8	47
– semi-dry scrubber				
– wet scrubber [2]	720	41	6	35
Total	1770	100	17	100
Extended flue gas cleaning:[1]				
– DeNOx				
– active cokes	220	12	1	6

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

2) Included is one installation which has a wet scrubber as well as a dry scrubber. This installation is not calculated under dry scrubber

From table 5.15.4 it can be seen that the 3 combustors which do not use scrubbers to clean the flue gases are relatively small.

Bottom-ash, fly-ashes and flue gas cleaning residues from MSW combustion are landfilled completely, but in separate landfills. Research is being done to reuse some of the bottom-ash in construction works and road building, but this has not been practised yet.

Only a few data are not available on individual installations as is apparent from table 5.15.3.

5.15.4 Emission guidelines

The Swedish emission guideline is somewhat different from the other guidelines. The emission limits are very strict for PCDD/F and Hg, but loose on NO_x and HCl. The rest is intermediate between the EC and the German guideline (see chapter 4). Furthermore the limit values are defined at 10 vol% CO_2, whereas all the other regulations are based on a certain oxygen concentration (mainly 11 vol%) in the flue gases. This prohibits direct comparison although in most cases the differences will not be very large: very often 11% O_2 is considered to correspond to 9% CO_2.

5.15.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

The Government promotes return systems, disposable packaging will be discouraged. Industries have agreed not to use PVC as a packaging material and the Government hopes to eliminate imported PVC. The targets for plastics recycling are set to 40% by 2000, and should increase after that to 60% [26].

The Swedish Parliament approved a governmental bill which will make producers responsible for all waste originating from their commercial activities, including the costs for disposal and of developing new, clean and resource efficient products. The target for refillable and recyclable beverage containers will be increased to 90%, and a governmental committee will investigate the use of economic instruments to stimulate recycling and reclamation.

At the time a proposal is discussed which sets recycling targets to be met in 2000 for packaging materials: glass 60-70%, aluminium 70%, paper/board 70%, corrugated packaging 80%, plastics 40% and steel 50-60% [26].

The government has the possibility to decide upon source recovery of different wastes in the municipalities. Source separation (by the households and the industries) ought to be developed in such a way that [101]:

- From 1994 all wastes delivered to final treatment are separated in categories suitable for proper handling.
- Combustion and landfilling of unseparated waste essentially will cease by the end of 1993. Methane gas from landfilling will be used for energy recovery, alternatively be flared away.

5.15.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

On the future of MSW combustors in Sweden nothing is known, except the planned extension of the combustor in Göteborg from 295 to 400 ktonnes per year.

5.16 Finland

5.16.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in Finland per year, with elaboration of the plastic fraction

In Finland 5.0 million people live, producing in total 2500 ktonnes of MSW per year or 500 kg per capita per year. It is not known what is exactly understood with the term MSW in Finland. Table 5.16.1 shows the composition of the MSW in Finland.

Table 5.16.1 Total amount and composition of Municipal Solid Waste generated in Finland per year (1990) [7, 9, 10, 16, 103, 104, 105]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	750	30
Paper & cardboard	1000	40
Plastic	150	6
Glass	100	4
Metals	80	3
Miscellaneous (textiles incl.)	430	17
Total	2500	100

There is no information available on how the plastic fraction is subdivided in PE, PP, etc.

5.16.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Local authorities are statutory required to arrange for the transport of municipal wastes in urban and semiurban areas, unless the Municipal Council in question has decided to arrange for this to be done on a contractual basis. Approximately 15% of the municipal wastes are recycled, 2% combusted and 83% disposed of at landfills [104].

The recycling of waste paper has been a common practice in Finland. There is also separate collection of glass in 130 municipalities. The deposit-refund system of returnable soft drink, beer and alcohol drink bottles is functioning very well in Finland. The return rates are the following: soft drinks and beer 97%, alcohol drinks 73%.

Table 5.16.2 Municipal Solid Waste treatment per category in Finland (1990) [7, 16, 103, 104, 105]

Component	Municipal ktonnes/yr	Solid Waste %
Recycling	375	15
Composting	0	0
Landfill	2075	83
Combustion	50	2
Total	2500	100

The major problems in waste management are [104]:
- there are too many small landfills;
- a considerable number of landfills are not adequately supervised or are badly managed;
- the profitability of recycling businesses is jeopardized due to the decline in secondary raw material prices;
- the majority of rural municipalities have not yet arranged the collection of hazardous wastes properly.

5.16.3 Overview existing Municipal Solid Waste combustors in Finland

At the moment there is one MSW combustor operating in Finland. Details on this installation are given in table 5.16.3. The design capacity of this facility is 70 ktonnes/year. Energy is recovered in this installation for district heating and the flue gases are cleaned from dust in an electrostatic precipitator. The information is complete.

Table 5.16.3 Municipal Solid Waste Combustors in Finland 1991

TNO 20/05/92

Incinerator type	Location	Start-up year	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	Total capacity [ton/hr]	Energy system	Flue gas cleaning	Emissions continuous	Emissions sampled	Remark	Reference
1	Turku	1975	von Roll	2*5	2	50	10	hw,dh	ep	CO,O,CL	D,TOC,S,F,N,P:1	hw: 2*8.7 MW	34

Explanation in appendix, page 5

Table 5.16.4 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in Finland

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery: – Yes – No	70	100	1	100
Total	70	100	1	100
Flue gas cleaning:[1)] – unknown – none – cyclone – esp – fabric filter – dry scrubber – semi-dry scrubber – wet scrubber	70	100	1	100
Total	70	100	1	100
Extended flue gas cleaning:[1)] – DeNOx – active cokes				

1) Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

5.16.4 Emission guidelines

Finland does not have own emission limits, but follows the EC guidelines (chapter 4).

5.16.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

Future trends will be in separation of various waste. Separate waste streams in the household will be: glass, recyclable paper, hazardous waste, metals, bio mass (wet fraction) and combustible (dry fraction).

The plastics consumption will keep on growing (vehicles, construction and technical end issues) [106]. In packaging the growth will be a constant battle with consumers and legislators. Some plastics (like bottles) will without any doubt win this battle. No recycling for plastics exists (virgin materials are too cheap). For the public there is no real advantage for using recycled plastics (image creation: paper recycling has an extremely good image, people insist on using recycled paper). Waste reduction can be achieved by making packaging increasingly thinner and expanding the use of returnable packaging (this might lead to the German model).

At the time a large scale pilot scheme for collection and recycling of plastics waste is running in the south of Finland [26]. The results will be used for a nationwide plan.

In general Finland is planning to recover 50% (energy recovery included) of the MSW by the year 2000. The targets are given in table 5.16.4.

Table 5.16.5 Expected treatment schemes for the Municipal Solid Waste in Finland in 2000 [107]

Component	Municipal Solid Waste %
Recycling (composting incl.)	37
Landfill	50
Combustion	13
Total	100

5.16.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

There are two combustors planned: one in the region of Helsinki and one in the city of Pori. The first is in preparation and still has some different options for the exact way of treating the waste. The capacity for the time being is aimed at 400-600 ktonnes per year and the flue gas cleaning system will be designed in such a way that the emissions can comply with German standards. However, there is enormous public resistance towards this combustor and it is not very likely that it will be realised. The second combustor (in Pori) will be a fluidized bed combustor, which will be fired with RDF and biogas. Depending on the chosen system the capacity will be 34-60 ktonnes per year. Start-up of this combustor is planned for 1993-94.

5.17 United Kingdom

5.17.1 Total amount of Municipal Solid Waste and the composition (putrescibles/paper/plastics/etc.) thereof generated in the United Kingdom per year, with elaboration of the plastic fraction

In the United Kingdom 57.2 million people live, producing a total amount of approximately 30000 ktonnes Municipal Solid Waste per year. Per capita the amount of MSW produced is circa 520 kg per year. This MSW consists of household, bulky and trade waste for England, Scotland, Wales and Northern Ireland together.

Table 5.17.1 Total amount and composition of Municipal Solid Waste generated in the United Kingdom per year (1990) [7, 9, 10, 16, 24, 108]

Component	Amount	
	ktonnes/yr	% of total MSW
Putrescibles/Fines	12600	42
Paper & cardboard	8400	28
Plastic	2100	7
Glass	2400	8
Metals	2700	9
Textiles	1200	4
Miscellaneous:		
combustibles	300	1
non-combustibles	300	1
Total	30000	100

The plastic fraction of the waste stream is given in table 5.17.2.

Table 5.17.2 Composition of the plastics fraction in the Municipal Solid Waste in the United Kingdom (1990) [109]

Component	Amount	
	ktonnes/yr	% of total plastics
PE	840	40
PP	340	16
PVC	210	10
PS	230	11
PET	100	5
Other	380	18
Total	2100	100

5.17.2 Municipal Solid Waste treatment schemes (recycling, landfill, combustion)

Disposal of collected MSW is currently dominated by landfill; 80% is disposed of by this route. Approximately 2.5 Mtonnes is combusted.
Whilst all countries will make use of landfill to some extent, the UK does so to a greater degree than many. This is mainly caused by the relatively low cost of landfill at this time.

Table 5.17.3 Municipal Solid Waste treatment per category in the United Kingdom (1990) [7, 16, 24]

Component	Municipal Solid Waste ktonnes/yr	Solid Waste %
Recycling	600	2
Composting	0	0
Landfill	27000	90
Combustion	2400	8
Total	30000	100

Recycling of domestic waste has only recently been emphasized. The longest running scheme in the UK was established in 1977 but most of them are much more recent. Bringing systems, where the public segregate individual materials and take them to collection points, have dominated recovery and have been aimed primarily at glass and paper and lately increasingly at steel, aluminium and other materials.

Table 5.17.4 Municipal Solid Waste Combustors in the United Kingdom

TNO 20/05/92

Incinerator type	Location	Start-up	Manufacturer	Unit capacity [ton/hr]	Units	Total capacity [kton/yr]	[ton/hr]	Energy system	Flue gas cleaning	Emissions cont.	Emissions sampled	Remark	Reference
1 s	Altringham	1960-75		2*5	2		10	N	ep				15
1 s	Basingstoke	1969	H&F	1*9	1	40	9	N	ep	D	D,CL,S,TOC,N,M,FA,SL:1		15,24
1 s	Belfast	1960-75		1*4	1		4	N	ep				15
1 s	Birmingham	1977	H&F	2*15	2	139	30	N	ep		D,CL,S,M:0.5 FA,SL:0.25	will be rebuilt on same site	15,24
1 s	Bolton	1974	H&F	1*16	1	41	16	N	ep		D,CL,S,TOC,N,M,FA,SL:1 WW:12		15,24
1 d	Bristol	1960-75		2*15	2	165	30	N	ep		D,CL,S,M,P:?	energy recovery planned; possible ss-incin.	15,24
1 s	Cleveland	1960-75		2*16	2		32	N	ep	D			15
1 r	Coventry	1975	Martin	3*11	3	156	33	hw	ep		D,CL,S,M:0.5 FA,SL:0.25	hw: 36 MW; upgrade with ff, el-generation	3,15,24
1 w	Derby	1969	Int. Comb.	2*7.5	2	75	15	N	cy			will be rebuilt on same site	15,24
1 f	Dudley	1970	John Thom.	2*7	2	86	14	N	ep		D,CL,S,M:0.5 FA,SL:0.25		15,24
1 s,f	Dundee	1978	Heenan	2*7	2	61	14	N	ep	D	D,CL,S,TOC,F,N,M,P:0.5 FA,SL:0.25 WW:3		15,24
1 d	Edmonton	1970		5*11	5	400	55	el	ep			el: 22 MWe, 192 GWh	3,15
1 r	Exeter	1960-75		1*9.5	1		9.5	N	ep				15
1 d	Glasgow			2*8	2		16	N	ep		D,CL,S,TOC,N,M,P,FA,SL:?		15
1 f	Havant	1974	Völund	1*14	1	51	14	N	ep	D	D,CL,S,TOC,N,M,FA,SL:1		15,24
5	Huddersfield	1975	Elisinore	2*6	2	55	12	N	ep		D,CL,S,TOC,F,N,M,P,FA,SL:1 WW:12	el planned; hw incin 1 ton/hr with el(0.5 MW)	3,15,24
1 r	Jersey	1977		2*5	2	62	10	el	ep			el: 3 MWe; replace 7.5 t/h unit with el(3 MW)	15,24
1 o	Mansfield	1960-75		1*6	1		6	hw	cy/ep				15
1 r	Nottingham	1973		2*12	2	105	24	el,dh	ep			el: 2 MW; upgrade with s, ff	3,15,35
1 w	Portsmouth	1976	Int. Comb.	2*10	2	80	20	N	ep	D	D,CL,S,TOC,N,M,FA,SL:1	new plant same site 300 kton/yr with el	15,24
1 s	Rochdale			1*8	1		8	N	ep				15
5	Scillies	1974		1*7	1	1.5	7	N	cy				15,24
1 d	Sheffield	1976	VKW	2*10	2	121	20	hw,dh	ep		D,CL,S,TOC,F,N,M,P,FA,SL:2-3	el planned; hw incin. 5 tpd, w scrubber	3,15,24
	Shetlands			6*1	6		6	N	-				15
1 d	Southampton	1975	VKW	1*9	1	49	9	N	ep	D	D,CL,S,TOC,N,M,FA,SL:1		15,24
	Stoke on Trent	1976		2*11	2	90	22	N	ep		D,CL,S,M,P:? WW:24	extra unit 20 ton/hr with el planned	15,24
1 w	Sunderland			2*10	2		20	N	ep				15
1 s	Tynemouth			2*11	2		22	N	ep				15
1 s	Winchester	1971		1*9	1	39	9	N	ep	D	D,CL,S,TOC,N,M,FA,SL:1		15,24
1 d	Wolverhampton	1973	VKW	2*10	2	126	20	N	ep		D,CL,S,M:0.5 FA,SL:0.25	energy recovery planned	15,24
1 o	Worcester	1972	B&S	2*2	2		4	N	cy				15,24

Explanation in appendix, page 5

5.17.3 Overview existing Municipal Solid Waste combustors in the United Kingdom

At present there are 31 large (>=3 tonnes/hour) MSW combustors in operation in the UK. These plants are listed in table 5.17.4. Energy recovery is only practised at 6 of them. Four of them use the energy for industrial use, two plants generate electricity [8]. All the combustors with capacities of more than 3 tonnes/h are equipped with a moving grate. Most of the combustors use an electrostatic precipitator for flue gas cleaning. Non is equipped with flue gas scrubbing equipment. All this is summarized in table 5.17.5 based on a total design capacity of 3640 ktonnes per year. The actually combusted amount is only 2400 ktonnes per year.

Table 5.17.5 Extent of energy recovery and flue gas cleaning in MSW combustion facilities in the United Kingdom

Extent of energy recovery and flue gas cleaning	MSW combusted		Installations	
	ktonnes/ year	%	number	%
Energy recovery:				
– Yes	1040	28	6	19
– No	2610	72	25	81
Total	3640	100	31	100
Flue gas cleaning:[1)]				
– unknown				
– none	40	1	1	3
– cyclone	180	5	3	10
– esp	3420	94	27	87
– fabric filter				
– dry scrubber				
– semi-dry scrubber				
– wet scrubber				
Total	3640	100	31	100
Extended flue gas cleaning:[1)]				
– DeNOx				
– active cokes				

[1)] Installations which have only a dust removal device and no scrubber are calculated under the dust removing device, installations which have both are calculated only under the scrubber. Most installations with scrubbers also have one of the mentioned dust removal systems. Installations which have dust removal devices, scrubbers and extended flue gas cleaning are counted to the scrubbers and are separately mentioned under the extended flue gas cleaning technique

Fly ash and bottom-ash is disposed of in a controlled landfill, sometimes separately.

Information on the amount of energy recovered as well as emission monitoring is not complete (yet). Also some other data are (still) missing.

5.17.4 Emission guidelines

The United Kingdom is at the time discussing emission legislation. Until now they have no emission limits. The new emission guideline will probably come into effect in August 1992. The emission limits in this guideline are comparable to the EC-guideline with stricter limits for heavy metals and HCl and additional limits for NO_x and PCDD/F (see chapter 4).

5.17.5 Future perspectives for Municipal Solid Waste: developments in waste treatment schemes (recycling, etc.)

With an unchanged waste policy the amount of MSW will grow with 10-15% per year. This results in a total amount of approximately 35 Mtonnes. The Government has set a target of recycling half of the country's recyclable household waste, which is estimated to equal 25% of all household waste [108] (9000 ktonnes per year), by the year 2000. There is currently much debate as to whether the recovery of energy should be counted to recycling or not.

Because of the increasing costs for landfilling, combustion will become more competitive regarding costs.

Plastic waste will be separately collected from households by:
- bringing (bottle banks);
- collecting (curbside, projects in Sheffield, Milton Keynes and Cardiff);
- centralised processing.

Besides recycling a strong growth of combustion or composting is not foreseen so the main treatment scheme will remain landfill.

5.17.6 Future perspectives for Municipal Solid Waste combustors: new combustors, retrofits, closing

At this moment a strong growth of combustion is not foreseen. At the time none of the combustors can comply with the European Directives on MSW Combustion. For existing combustors these will come into force December 1996. In order to remain in operation the MSW combustors will have to make additional investments (flue gas cleaning, process control) to upgrade the plant. A very large proportion (around 20) of the existing plants will not be able (technically or financially) to reach the demanded emission levels and will be shut down. Six of the plants mentioned in table 5.17.4 are planning to incorporate energy recovery,

two plants are planning upgrading with scrubbers; one wet and one semi-dry scrubber.

Also there are a few outlines schemes (see below) emerging for new, modern plants, as well as some existing operators/authorities talking positively about a wish to retain combustion capacity. New MSW combustors with energy recovery are stimulated by a clause written in the electricity programme: the so-called NFFO, Non Fossil Fuel Obligation. Some 20% of the produced electricity is to be provided from other than fossil fuels: coal, oil and gas. Electricity companies are obliged to buy this 20% of their electricity at a fixed price from MSW combustors or other non-fossil-fuel-producers of electricity. The NFFO subsidizes new initiatives on non-fossil-fuel-electricity until 1998.

A number of plans for new combustion capacity have been set up:
- A plant in London will be built with a capacity of 400, 000 tonnes/y, thereby producing 30 MW electricity and hot water for 10, 000 homes. The plant will have acid scrubbing equipment. The combustor is based on the Martin grate system and will meet the latest European standards.
- Another similar plant for combustion of the MSW of London is planned. The plant will have a capacity of 1, 200, 000 -1, 500, 000 tonnes/y. The plant will have a power generation of 80-100 MW [110].
- Other plants are foreseen in Leeds (capacity 300, 000 tonnes/y; acid scrubbing) and on the Isle of Man (capacity 24, 000 tonnes/y; acid scrubbing; energy recovery for district heating).

Possible rebuilds, all with energy recovery, on old sites:
- Birmingham.
- Birkenhead: 18 tonnes/h FB, planned for 1994.
- Derby.
- Portsmouth: capacity: 300, 000 tonnes/y.

6 References

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Survey of municipal solid waste combustion in Europe
– Data for 17 European Countries –

Appendix

Alphabetical list of abbreviations and keywords

bottom-ash ..... part of the ash content of the waste which remains on the grate or falls through the grate

bulky waste ..... waste consisting of large items like electrical appliances (refrigerators, TV-sets, etc.), furniture, but also large pieces of wood, etc.; usually this is separately collected

combustor ..... installation in which material is burned

DeNOx-technique ..... NO_x-emission reducing technique

dioxin ..... PCDD: polychlorinated-dibenzo-para-dioxin

dry scrubber ..... scrubber which uses a dry powder as adsorbent: the residue is also dry

ESP ..... Electrostatic precipitator

excess air ..... the amount of air used for combustion which exceeds the amount of air needed for stoichiometric reaction

excess air level ..... lambda; the total amount of air used for combustion divided by the stoichiometric amount of air (e.g. if 5000 Nm^3 are required stoichiometrically and 9000 Nm^3 are supplied the excess air level is 1.8)

fgc ..... flue gas cleaning

fixed carbon (matter) ..... part of the combustible fraction of a fuel which burns (reacts with oxygen) in the solid phase: opposite from volatile matter

flue gas ..... stack gas; gases resulting from the combustion process

flue gas cleaning ..... series of equipment in which pollutants are removed from the flue gas

fly-ash ..... part of the ash content of the waste which does not remain on the grate but is transported with the flue gases and removed in the flue gas cleaning system (mainly in dust collecting equipment)

fuel-NO_x ..... NO_x formed from reaction of fuel-bound nitrogen with oxygen (during combustion of a fuel)

furan ..... PCDF: polychlorinated-dibenzo-furan

garden waste ..... waste from gardens and parks

HDPE ..... high density polyethylene

heating value ..... heat released upon combustion of a compound: see 'higher heating value' and 'lower heating value'

higher heating value ..... the heat which is released if a compound is burned and the resulting products are cooled back to the reference temperature (inclusieve condensation of water)

household waste ..... waste collected in bags or containers from households

lambda ..... excess air level; the total amount of air used for combustion divided by the stoichiometric amount of air (e.g. if 5000 Nm^3 are required stoichiometrically and 9000 Nm^3 are supplied the excess air level is 1.8)

LDPE ..... low density polyethylene

lower heating value	the heat which is released if a compound is burned and the resulting products are cooled back to the reference temperature but the water in the flue gas does not condensate but remains in the gas phase: lower heating value = higher heating value – condensation heat of the water (from moisture content but also from combustion of hydrogen)
market waste	waste from street cleaning by the municipality
MSW	municipal solid waste: generally consisting of household waste, bulky waste, trade waste and market and garden waste as collected by the municipalities
Nm^3	Normal cubic metre: cubic metre at stp
NO_x	the total concentration of NO and NO_2 expressed as if all NO was converted to NO_2; in the atmosphere the NO/NO_2 ratio varies with temperature variation and to eliminate confusion all the NO is expressed as NO_2 too
PCB	Polychlorinated biphenyls
PCDD/F	Polychlorinated-dibenzo-para-dioxines and –furanes
PE	Polyethylene
PET	Polyethylene-terefthalate
PP	Polypropylene
primary air	air needed for the combustion which is supplied through the grate (blown through the grate from below)
PS	Polystyrene
PVC	Polyvinylchloride
quench	reactor in which water is sprayed in the flue gases to cool them quickly
RDF	Refuse Derived Fuel
SCR	Selective Catalytic Reduction
scrubber	reactor in which a fluid or a solid ab- or adsorbent is dispersed in the flue gas stream; wet, dry or semi-dry scrubber
secondary air	air needed for the combustion which is supplied through nozzles which are generally located near the exit of the combustion chamber and in the beginning of the boiler
semi-dry scrubber	scrubber which uses a solution or suspension as absorbent: through contact with the flue gas the fluid evaporates: the residue is dry
SNCR	Selective Non-Catalytic Reduction
stoichiometric air	the amount of air containing just enough oxygen for complete combustion of a material: the needed amount of O_2 is calculated from the C, H, S-content of the material assuming complete reaction of C to CO_2, H to H_2O, S to SO_2, diminished by the O-content of the material itself.
stp	Standard temperature and pressure: 273 K, 101.3 kPa

TEQ	Toxicity Equivalent Quantity: a toxicity factor relating the toxicity of the specific PCDD/F-congeners to the toxicity of 1, 2, 7, 8-tetraclorinated-dibenzo-para-dioxin and –furan
thermal NO_x	NO_x formed from reaction of atmospheric nitrogen with oxygen (only at very high temperatures: >1200 °C)
TOC	Total Organic Carbon
tpd	tonnes per day
trade waste	waste from small commercial or industrial enterprises with comparable composition to household waste
Vol%	percentage by volume (m^3/m^3)
volatile (matter)	part of the combustible fraction of a fuel which first is transferred to the gas phase before combustion (reaction with oxygen) takes place: opposite from fixed carbon matter
wet scrubber	scrubber which uses a liquid absorbent: though some fluid evaporates upon cooling the flue gases the residue is also a liquid
Wt%	percentage by weight (kg/kg)

Explanation of tables

In the table where the technical data on the combustors are given (usually table ?.4) a lot of abbreviations are used. These are explained below.

Combustor type

1 moving grate:
- d rotary drum
- r reverse acting reciprocating grate
- f forward acting reciprocating grate
- s rocking grate
- w travelling grate(continuous grate)

2 fixed grate
3 rotary kiln
4 fluidized bed
5 other

Flue gas cleaning

- \- no flue gas cleaning
- cy cyclone
- ep electrostatic precipitator
- ff fabric filter (bag filter)
- w wet scrubber
- d dry scrubber
- s semi-dry scrubber
- n DeNOx-installation
  - 1 SCR
  - 2 SNCR
  - 3 active cokes adsorption
- c cokesfilter
- ci cokes injection before dust separator (usually fabric filter)

Energy system

- hw hot water
- st steam
- el electricity
- chp combined heat & power
- dh district heating
- cd compost drying
- sd sludge drying
- Y energy recovery (unspecified)
- N no energy recovery

Emissions (continuous or sampled)

- D dust
- CL HCl
- S SO_x
- TOC total organic carbon
- F HF
- N NO_x
- M heavy metals
- P PCDD/F
- FA fly ash (% unburnt)
- SL bottom-ash (% unburnt)
- WW waste water
- CO CO
- O O_2
- ..:6 6 times a year

n.b. open spaces indicate that the information is not known