The Evolution of WTE Utilization - The European Perspective

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The ECO-Society

Everyone involved in the protection and proper use of raw materials, natural resources and the environment and in the daily operation of solid waste management aims to reach the "Eco Cycle Society". That means that each of us, in our present and future handling of raw materials, products, residues and waste will minimize the use of terminable resources and bring back as much as possible of them in the closed cycle after being used. The idea of the "Eco Cycle Society" is showed in **graph nr l.**

The Producer´s Responsibility

To reach the "Eco Cycle Society" it is necessary to reduce the amount of waste and to significantly increase the reuse and recycling of different materials and products. It is important to understand that wastes are simply discarded products and the design of a product can have a very significant impact on the nature of the waste that is produced. Recycling and reuse can be enhanced by designing products so that components and materials can be easily separated, by eliminating contaminating materials that inhibit recycling, and by using more recycled materials in the original products. Eliminating certain materials from products can also reduce the release of toxic materials to the environment during waste treatment.

We are beginning to see the implementation of the concept of the "Producer´s Responsibility" in laws that are being passed in various European countries requiring manufacturers to take back discarded products and packagings for reuse or recycling. In Sweden the Swedish Government in 1993 decided about guiding principles for packagings and some other products in order to reach the "Eco Cycle Society". The "Producer´s Responsibility" means both physical and economical responsibilities. The same principle will step by step be introduced for more products. The "Producers" have been given the economical and physical responsibility for the collection, recovery and recycling of used packagings. Requirements and goals have been settled for the recovery and recycling of these packagings. For news-papers, journals and old tyres there is also a "Producer´s Responsibility" from the 1st of July 1994 in Sweden.

The consequences of the "Producer´s Responsibility" for the future handling of waste will most probably be decreased amounts of Municipal Solid Waste/MSW to be treated as compared with today. For example the amounts of MSW being incinerated in Waste-to-Energy plants will decrease but it opens at the same time up the possibilities for an increased amount of burnable industrial waste being incinerated with energy recovery instead. Besides, there is or being planned a ban or very strong restrictions of landfilling organic and burnable MSW in many European countries, which will increase the need for incineration.

Establishment of Environmentally Sound Treatment and Disposal Facilities - A Combination of Methods.

Even with maximum feasible rates of waste reduction and recycling, there will still be a need for waste treatment. The state of the art of waste treatment has advanced rapidly in recent years. Today, technologies are available to effectively treat wastes in an environmentally sound manner. For example, standards for solid waste incineration units incorporate emissions monitoring and highly efficient air pollution control systems to control organic emissions, metals, acid gases and other pollutants. Today´s state-of-the-art landfills meet with similar tough standards, most of them are equipped with leachate collection systems, groundwater monitoring, systems for control of landfill gas and recovery of its energy content, and closure and post-closure care. The objective is to ensure that landfilling, when used, is performed in a manner that greatly reduces the chance of environmental degradation and also ensure that any release that does occur is quickly detected and remedied.

Solid waste management in practice must be based on **integrated systems** with **a combination of many different methods.** There should not be any contradiction between the different methods, on the contrary they should be regarded as complement to each other:

- Recovery of materials in households and industries, involving direct action by residents and industries in cooperation with those given the resonsibility for the collection, recovery and recycling of different materials and products.
- Increased utilization of the material and energy resources in industrial waste. The conservation of resources should mainly take place within the industry, by the use of low-waste technology, and by internal recovery of the residues and the waste.
- Thermal treatment of waste, with energy recovery.
- Utilization of the easy biodegradable part of the organic waste for the production of biogas and compost
- Landfilling, which always will be needed regardless of other methods utilized, for non-recyclable materials, and for residues from other waste treatment.

Results and experiences today from different countries and different used systems for solid waste management clearly shows the need of attacking the waste problem with an intergrated waste system. In order to fullfill this concept the scheme as shown in **graph nr 2** is already used or will soon be used in most municipalities in Sweden, in order to recover material- and energy resources and to get cleaner products for recycling, cleaner compost and less emissions from different treatment plants as a result of a cleaner input.

In most European countries the following list of Priority is recommended in order to solve the waste problem:

1 Waste Reduction and Minimization
2 Reuse
Recycling
3 Energy Recovery
4 Landfilling

Municipal Solid Waste Treatment in Europe

In Europe there is a total population of approximately 360 millon people, producing a total amount of Municipal Solid Waste/MSW of about 140 million tons per year (1991). Per capita this is an amount of about 400 kg per year. The total amount of MSW produced in each country is presented in **graph nr 3** as well as the production per capita. Also the composition of the MSW per country is listed. An average composition for the whole of Europe is given as a reference.

In Europe Municipal Solid Waste/MSW is disposed of in mainly four different ways: Recycling, Composting, Incineration and Landfilling. In **graph nr 4** is shown the treatment of MSW per country in Europe. All figures in the graph are in % of the total MSW per country. The figures are from 1991 and some changes have taken place since then, the recycled amount has increased and the landfilled amount has decreased in many countries. However, it is very difficult to find up-to-date figures covering all the changes that are taking place for the moment.

The effects of the introduction of the Producer´s Responsibility, the increased source recovery in households and industries and the very heavy restrictions on landfilling in many countries will most certainly dramatically change the use of different methods for treating MSW in a few years. For example, in France it will be prohibited after the year 2002 to landfill other waste than residues from other treatment, in Germany it will only be allowed after 2005 to landfill waste with a very low content of organic materials, in Sweden there is currently a proposal to prohibit landfilling of burnable waste from the year 2000 and waste with an organic content from the year 2005, in Switzerland and The Netherlands there are very heavy restrictions on landfilling, similar to those restrictions mentioned above. This means that there will be an increase in recycling, biological treatment and incineration of waste just within a few years in Europe. In many countries there are plans and measures taken to meet with this new situation.

Energy from Waste

Waste incineration is an old and established method for treating MSW in Europe. The first plant was built already during the 1890´ies. By that time waste incineration was used for hygienic aspects, not least to solve the enormous problems with cholera in the densely populated cities of Europe. Still being a method to tackle the hygienic problems it also during the 1900´ies became a method for reducing the increasing volumes of waste being generated. Incineration was not associated with any form of recovery. An objective like that is relevant for a society with linear material flows where raw materials are provided from virgin materials and the waste dumped without any recycling. This is not in accordance with a society of sustainable development. Today we are aiming at a cyclic flow. There is only one objective for waste incineration that is relevant in the eco cyclic society and that is energy recovery. Volume reduction is no more an objective but still an important parameter when comparing environmental impact. Furthermore incineration is only justified when the method is at least as favourable as other recycling or recovery alternatives. In many European countries you will not even get a permission today to build a new waste incineration plant without recovering the produced energy. Besides, the operation costs in a modern plant with advanced flue gas cleaning and a strict handling of the residues will be too high without any incomes from energy recovery.

The situation in Europe when coming to waste incineration is today actually a little bit difficult to overlook. In some countries there are a number of old, small incineration plants not meeting the EU-directives on waste incineration. Of course they have to be closed down, probably replaced with new, larger plants, but there is an uncertainty about the future amounts of waste to be incinerated due the effects of the increased recycling activities, the effects of the producer´s responsibility and of the ban or restrictions on landfilling of organic and burnable waste. Will the amounts for incineration increase, decrease or remain at today´s level? At some larger plants in Europe there is to-day an overcapacity, due the increased amounts of waste being recycled or composted. The restrictions on landfilling will probably change this situation into the opposite and there will probably soon be a demand for increased incineration capacity in many European countries.

Number of plants and capacity

In Europe there are between 450-500 MSW incineration plants with a total nominal capacity of more than 6000 tons per hour. All together there is an annual capacity of about 45 million tons, based upon 7000 hours of operation. **Graph nr 5** shows in which countries the incineration plants are located and how much of the total amount of MSW is incinerated in these plants. As already mentioned there have probably already been some changes in the figures presented in the graph and there will be even more changes in the future - less small plants, more larger plants with an increased incineration capacity and equipped with advanced flue gas cleaning systems.

In graph 5 it can be seen that France has the most incineration plants by far. However, these 225 incineration plants are relatively small as they represent 46,4% of the number of incineration plants in Europe but only incinerate 26,1% of the total amount of MSW in Europe. On the contrary the installations in Germany and in The Netherlands are relatively large: 10,1% (Germany) and 2,1% (The Netherlands) of the incineration plants incinerate respectively 27, 9% and 7,3% of the European MSW.

Energy Recovery

In Europe there is some kind of energy recovery from most of the incineration plants (56% by number representing 82% of the MSW incineration capacity in 1993, probably even more today). **Graph 6** gives an overview of the energy recovery per country. In general 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 production, mostly without usage of the remaining energy which has to be cooled off. However, there is a change towards better use of the produced heat outside the Scandinavian countries as well as there is a very significant tendency in the Scandinavian countries of more and more combined production and use of as well heat as electricity.

Emission Guidelines and Flue Gas Cleaning Systems

Almost every country in Europe has its own legislation concerning emissions from MSW incineration. 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 emission of dust, HCl, HF and CO, whereas others also include SO_2, No_x, total organic carbon (TOC), heavy metals, PCDD/F as well as certain performance demands, other than emissions.

Graph 7 gives an overview of the emission limits according to the different regulations existing in Europe. For comparison the latest EU directives on Hazardous Waste Incineration (HWC) have been included. The values in the table are related to an oxygen concentration in the flue gases of 11vol%(dry, at standard temperature and pressure: 273 K, 101,3 kPa), except for Norway (10vol% O_2) and Sweden (10vol% CO_2). An oxygen concentration of 11vol% is corresponding with 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 air injection. For example the German regulation requires that the flue gases, after the last injection of air remain at a temperature of at least 850 degrees centigrade and a concentration of 6 vol% O_2 for at least 2 seconds. This is done to guarantee the destruction of combustible matters in the flue gases. Besides the limit values it is very important to specify the time period during which the measurements have to be averaged to meet the limit values. For example a limit value as a half hour average is more difficult to meet with as the same value over a longer period of time (time to even out peaks).

Member countries of the European Union have to comply with the EU-directives at minimum, but can have stricter limits. This is the case for example for Germany and The Netherlands, see **graph 8**. In this graph the EU Draft Directives for incineration of waste are also shown. However, it is still a draft. In **graph 9** the needed removal efficiency to reach the Dutch guidelines is shown, in relation to the raw flue gas concentration.

To reach the EU guidelines and most national guidelines advanced fluegas cleaning systems have to be installed. In **graph 10** all the different steps that could be included in such a system is shown. Of course all the steps in the graph can be used, or combinations of the different steps, to reach the different guidelines. The strictest emission guidelines (Germany, Austria, Netherlands) can be reached by using state-of-the-art cleaning techniques, but not without considerable effort. In newly designed flue gas cleaning systems the following sequence of equipment is in principle often used:
- Electrostatic Precipitators
- Multi-staged wet scrubber with waste water evaporation
- Active cokes/lime injection with fabric filter
- SCR-$DeNO_x$.

Residue treatment

Of the residues in general only the bottom-ash (slag) can be reused for the moment. Before re-use the bottom-ash can be crushed and/or sieved and iron scrap is removed and in many cases recycled. Several processes are under development to improve the bottom -ash quality to ensure disposal of the bottom-ash when the regulations are toughened. The bottom-ash which is not re-used is landfilled, but because of the large amounts of bottom-ash which are produced from waste incineration there is a pressure to reuse as much of the bottom-ash as possible. In some countries the "gravel" fraction of the bottom-ash is used in road constructions.

Fly-ash reuse is in fact not possible for the time being: it is landfilled in a secure way - stacked in big bags, stabilized with cement or binders or in some other way safely land-filled.

As the emissions to the air to a large extent are controlled, the research is more and more focusing on the safe handling and better use of the residues.

Costs of MSW Incineration

In a TNO Environmental and Energy Research Report from 1993 the costs (the investment cost and the cost per ton) are calculated for an incineration plant which basically has the follwing equipment:

- moving grates
- boilers in which steam is produced
- a turbine and electricity generator
- a flue gas cleaning system which consists of: an ESP, a 2-staged wet scrubber and an entrained flow adsorber (reactor with subsequent fabric filter) with active cokes addition.
- a waste water treatment system which neutralizes the waste water and precipitates a gypsum sludge and heavy metals.

The costs are given with and without evaporation of the waste water. The latter is done because it is not certain whether discharge of waste water will be allowed. For the moment at most locations which are close to the sea or to a river, discharge of waste water is allowed. Both options are considered. Waste water evaporation results in a solid salts residue which has to be landfilled. The evaporated waste water is condensed and used again in the first step of the wet scrubber.

The investment and operating costs were determined for different capacities in a range from 9 tons per hour to 115 tons per hour. With an availability of the facility of 80% this is equal to an annual capacity from 63 000 tons to 806 000 tons. Each plants is calculated for a minimum of 2 separate units. The investment costs are shown in **graph 11**.

Besides investments costs also the costs per ton of MSW processed are important. These are calculated with the following assumptions:

- the availibility of the plant is 80%
- the depreciation period for a new MSW incineration plant is 25 years and the interest is 10%
- maintenance of the building/construction part is 1% of the investment for this part, maintenance for the electro/mechanical part is 5% of the investment for this part.
- personel costs 40 000 ECU per year per person.
- insurance 1% of the total investment

Besides there are of course costs for chemicals and utilities. It is assumed that the bottom-ash can be reused and that the cost for disposal of the bottom-ash equals zero. Disposal of the other residues (fly-ash, sludge, salts, used active coal mixture) is assumed to cost 182 ECU/ton. The costs per ton are shown in **graph 12**.

The net cost will of course vary very much due to the price for the produced electricity and, as in the Scandinavian countries, if the produced heat can be sold and not cooled off.

The Swedish Example

Modern waste incineration with energy recovery got its break through in Sweden during the sixties and seventies, not only because of hygienic aspects and volume reduction, but also because the energy content could be utilized for district heating purposes. Waste incineration is still a very important method for handling the waste problem and for energy recovery and will remain so in the future handling of waste in Sweden. Today about 1,8 million tons of waste are being incinerated in 21 Waste-to-Energy plants, with in all 38 furnaces - including about 1,4 million tons of MSW (of a total amount of about 3,3 million tons before a material recovery of about 0,7 million tons) and about 0,4 million tons of industrial waste. 18 of the plants produce heat and 3 of the plants are combined heat and power facilities. There will most probably be an increased production of power in the future.

Waste contains mostly materials of biological origin, only 10% have fossile origin. The waste do contain materials which should be separated from the waste before incineration. By efforts to eliminate hazardous waste from the market (for example Mercury-batteries) and by separation at the source in accordance with the scheme in graph nr 2, the remaining waste becomes cleaner and also the emissions.

During the last ten years the waste incineration system has gone through a considerable technical development. Originally the Swedish waste incineration plants were only equipped with cyclones or electrostatic precipitators for the reduction of emissions, especially dust. Nowadays all Waste-to-Energy plants in Sweden have installed advanced flue gas cleaning systems to meet with the more stringent emission standards set up by EU and the Swedish Environmental Protection Agency. From an environmental point of view, waste incineration in Sweden with advanced flue gas cleaning is a very clean way to produce energy.

Swedish Plants - capacities, type of furnaces, flue gas cleaning equipment

Plant	Capacity (tons /year)	Grate/FB	Flue gas cleaning
Avesta	45 000	Grate	ESP, Dry+Wet,FF
Bollmora	13 000	Grate	FF
Bollnäs	20 000	FB	FF
Borlänge	26 000	Grate	ESP, Wet
Eksjö	8 000	FB	FF
Göteborg	400 000	Grate	ESP, Wet
Halmstad	90 000	Grate	ESP, Wet
Karlskoga	35 000	Grate	ESP, Dry, FF
Karlstad	50 000	Grate	ESP, Dry, FF
Kiruna	18 000	Grate	FF
Köping	33 000	Grate	ESP, Dry, FF
Lands-krona	5 000	FB	Dry, FF
Lidköping	65 000	FB	Dry, FF
Linköping	230 000	Grate	ESP, Dry, FF
Malmö	220 000	Grate	Dry, FF
Mora	20 000	Grate	Dry, FF
Stock-holm	300 000	Grate	Dry, FF
Sundsvall	17 000	FB	ESP, Dry, FF
Umeå	120 000	Grate	Dry, FF
Uppsala	250 000	Grate	ESP, Wet+Dry, FF
Västervik	30 000	FB	Dry, FF

FB=Fluidized Bed   ESP=Electrostatic Precipitator   FF=Fabric Filter
Wet=Wet cleaning   Dry=Dry cleaning.

At twelve of the twentyone plants steps have been taken to reduce the emissions of No_x.

The annual emissions from the the Swedish Waste-to-Energy plants have been reduced as follows from 1985:

Substances	Unit	1985	Today	Reduction
Dust	tons/year	420	40	90%
HCl	tons/year	8400	290	96%
SO_x	tons/year	3400	820	76%
NO_x	tons/year	3400	1600	53%
Hg	kg/year	3300	100	97%
Cd	kg/year	400	15	96%
Pb	kg/year	25000	300	99%
Dioxins	g/year	90	1,7	98%

In all 5 TWh of energy are produced from waste incineration in Sweden. All energy is used and delivered to the district heating systems and the power systems in the cities concerned. The produced energy covers almost the heating of 250 000 apartments or 15% of the district heating in Sweden every year, corresponding to the saving of 500 000 tons of oil annualy. In some cities the waste incineration stands for 30-40% of the district heating. Due to the development of the incineration technology, the high energy value of the waste and due to a very professional staff at the incineration plants, the energy efficiency in average is as high as 85%.

The incinerated amount of waste has been more than doubled since 1980. During the same period the production of energy from the Swedish Waste-to-Energy plants have been almost quadrupled. This is due to the fact that the energy content of the waste has increased but most of all because the introduction and use of a more efficient technique for energy recovery. Less energy has been cooled off since 1980. In 1986 about 1,5 million tons of waste were incinerated with an energy production of 3, 4 TWh. Today about 1,8 million tons are incinerated with an energy production of 5 TWh.

While the incinerated amount has increased with 20% since 1986, the energy production has increased with 47%, and different emissions have decreased between 54% to 99%.

After energy recovery the waste incineration treatment costs in the Swedish Waste-to-Energy plants vary somewhere between 200-400 Swedish Crowns/ton, depending upon age, size and equipment of each plant. Without energy recovery the cost would have been doubled.

Waste incineration with energy recovery will even in the future be one of the more important methods in Sweden to reduce the waste amount, to protect the environment and to take care of energy resources.

Conclusion

Waste-to-Energy is an established and well functioning method for waste treatment and energy recovery and the most effective way of taking care of the energy content of waste. Waste is to a very large extent to be considered as a bio-fuel and the incineration of waste decreases the need of fossil fuels to be burned, resulting in a decrease of the emissions of green-house gases.Due to far-reaching restrictions on landfilling of MSW in Europe there will most probably be an increased need for waste incineration with energy recovery, as a complement to recycling and biological treatment of waste. New plants will be equipped for using the produced energy for heating purposes as well as for electricity production. The strict emission guidelines already implemented in for example Germany and The Netherlands will most probably, at least to some extent, be introduced in the other EU-countries, resulting in the installation of very advanced flue gas cleaning systems.

There is only one objective for waste incineration that is relevant in the eco cyclic society and that is energy recovery. Volume reduction is no more an objective but still an important parameter when comparing environmental impact. Furthermore incineration is only justified when the method is at least as favourable as other recycling or recovery alternatives. □

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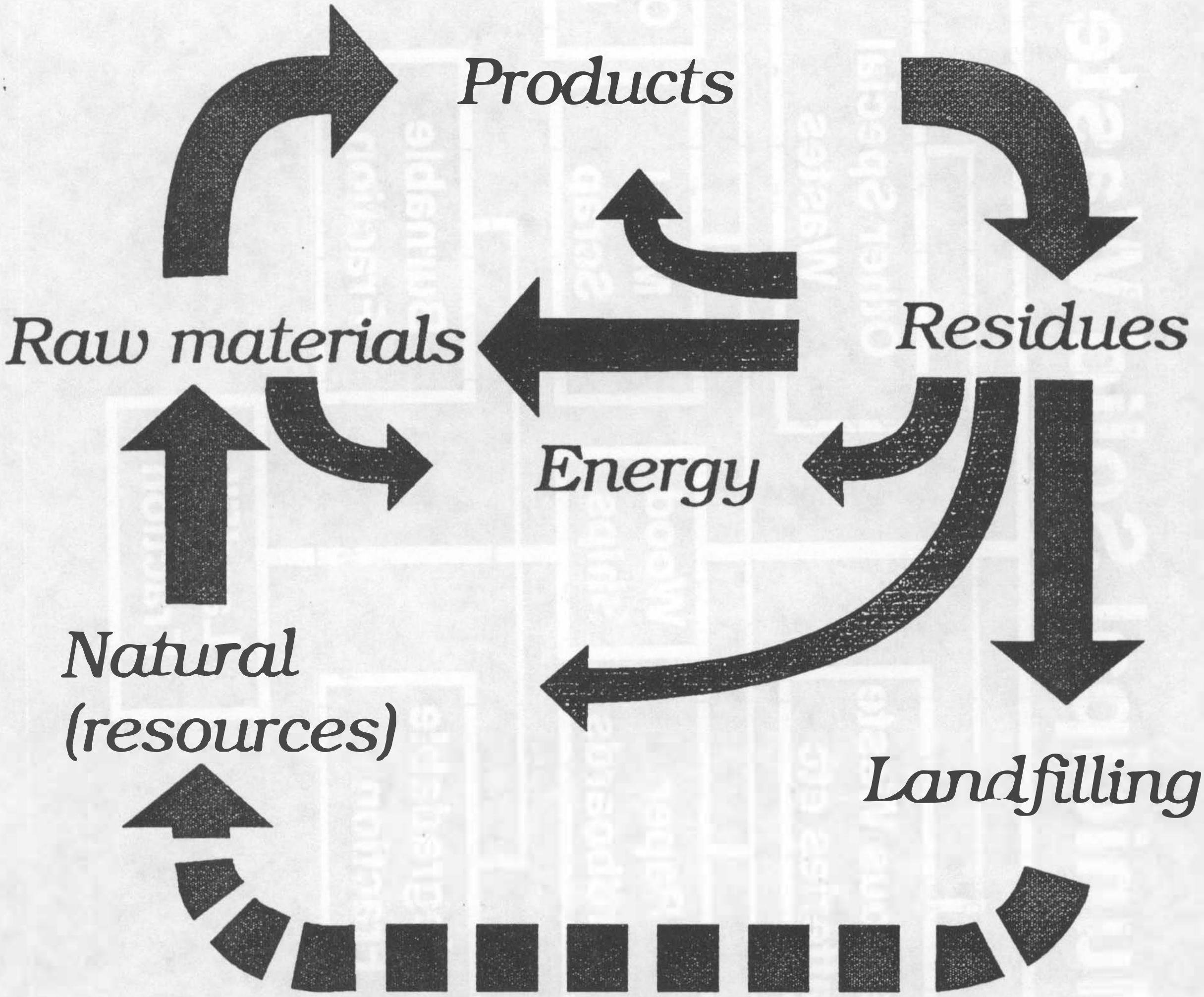
" Closed Cycle Society"



Graph 2


Municipal Solid Waste
Hazardous Waste Batteries etc
Other Special Wastes
Packagings
Paper Cardboards
Wood Ships
Metal Scrap
Other clean Fractions
Biodegradable Fraction
Burnable Fraction
Landfill Fraction

Composition of Municipal Solid Waste per country in Europe
All figures consider total MSW per country

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	2,800	370	30	30	9	10	4	17
B	3,500	350	47	28	7	7	4	7
CH	3,700	550	30	31	13	7	6	13
D	25,000	410	44	24	7	9	6	10
DK	2,600	510	40	35	5	4	5	11
E	13,300	340	49	20	7	8	4	12
F	20,000	360	25	30	6	12	5	22
GR	3,150	310	53	18	7	3	4	15
I	17,500	300	40	22	7	8	3	20
IRL	1,100	310	55	20	10	3	3	9
L	180	480	47	28	7	7	4	7
N	2,000	470	25	32	7	4	4	28
NL	7,700	520	38	35	7	7	5	8
P	2,650	260	60	22	4	3	4	7
S	3,200	380	30	40	9	7	3	11
SF	2,500	500	30	40	6	4	3	17
UK	30,000	520	42	28	7	8	9	6
Europe	140,880	395	40	27	7	8	6	13
min-max[1)]		260-550	25-60	18-40	4-13	3-12	3-9	6-28

Treatment of Municipal Solid Waste per country in Europe

Country	Amount ktonnes/yr	Incineration	Landfill	Composting	Recycling
A	2,800	11	65	18	6
B	3,500	54	43	0	3
CH	3,700	59	12	7	22
D	25,000	36	46	2	16
DK	2,600	48	29	4	19
E	13,300	6	65	17	13
F	20,000	42	45	10	3
GR	3,150	0	100	0	0
I	17,500	16	74	7	3
IRL	1,100	0	97	0	3
L	180	75	22	1	2
N	2,000	22	67	5	7
NL	7,700	35	45	5	16
P	2,650	0	85	15	0
S	3,200	47	34	3	16
SF	2,500	2	83	0	15
UK	30,000	8	90	0	2
Europe	140,880	24	63	6	8

Graph 5

MSW Incinerators in Europe

Country	Number of incinerators per country	% of total number of incinerators in Europe (%)	Incineration capacity per country (ktonnes/yr)	%of total incineration capacity in Europe (%)
A	2	0.4	340	0.8
B	24	4.9	2.240	5.2
CH	30	6.2	2.840	6.6
D	49	10.1	12.020	27.9
DK	30	6.2	2.310	5.4
E	15	3.1	740	1.7
F	225	46.4	11.330	26.1
I	28	5.8	1.900	4.4
L	1	0.2	170	0.4
N	18	3.7	500	1.2
NL	10	2.1	3.150	7.3
S	21	4.3	1.860	4.3
SF	1	0.2	70	0.2
UK	31	6.4	3.670	8.5
Europe	485	100.0	43.140	100.0
EU	413	85.2	37.530	87.0

Level of energy recovery in the different countries in Europe

Country	Number of incinerators per country	% of total number with energy recovery (%)	Incineration capacity per country (ktonnes/yr)	% of total capacity with energy recovery (%)
A	2	100	340	100
B	24	46	2,240	64
CH	30	80	2,840	90
D	49	100	12,020	100
DK	30	100	2,310	100
E	15	27	740	73
F	225	42	11,330	70
I	28	64	1,900	76
L	1	100	170	100
N	18	28 [1)]	500	83
NL	10	90	3,150	97
S	21	100	1,860	100
SF	1	100	70	100
UK	31	16	3,670	32
Europe	485	56	43,140	82
EU	413	54	37,530	80

1) On 13 small incinerators it is assumed that no heat is recovered

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 MSW	EC Haz. waste	Component
Dust	mg/Nm^3	15	100	10	10	30	30	10	5	20	30	30	5	Dust
HCl	mg/Nm^3	10	100	20	10	50	50	100	10	100	30	50	5	HCl
HF	mg/Nm^3	0.7	5	2	1	2	2	-	1	1	2	2	1	HF
SO_2	mg/Nm^3	50	-	50	50	300	300	300	40	200	300	300	25	SO_2
CO	mg/Nm^3	50	1000	50	50	100	100	100	50	100	100	100	50	CO
NO_x (as NO_2)	mg/Nm^3	100	-	80	200	-	-	-	70	400	350	-	-	NO_x (as NO_2)
TOC (as C)	mg/Nm^3	20	-	20	10	20	20	-	10	-	20	20	5	TOC (as C)
Heavy metals														Heavy metals
Hg	mg/Nm^3	0.05	-	0.1	0.05	-	-	0.1	0.05	0.03	0.1	0.2	0.05	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	0.2	-	-	-	-	-	-	Hg+Cd
Cd+Tl	mg/Nm^3	-	-	-	0.05	-	-	-	-	-	-	-	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	-	-	-	-	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	-	0.5	Tot.rest
PCDD/F	ng TEQ/Nm^3	0.1	-	-	0.1	-	4000 1)	2	0.1	0.1	1	-	0.1	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	11% O_2	Conditions
Temperature	°C		800		850	850	950	800	850		850	850	850	Temperature
Residence time	s		1		2	2	2	1.5	2		2	2	2	Residence time
Oxygen conc.	vol%		6		6	6	6	-	6		6	6	6	Oxygen conc.

Emission levels for waste incineration plants in Europe

Pollutants			
mg/nm^3	Germany 17.BlmSchV	Netherlands, BLA (1 hour average)	EU *)
Hydrogen chloride	10	10	10 (60)
Hydrogen fluoride	1	1	1 (4)
Sulfur oxides	50	40	50 (200)
Nitrogen oxides	200	70	200 (400)
PCDD/PCDF (ng/m_o^3 TEQ)	0.1	0,1	0.1 ng/m_o^3 (6-16 hours)
Dust	10	5	10 (30)
Cd + Hg	0.05 + 0.05	0.05 + 0.05	0.05+0.05
Heavy metals (remainings)	0.5	1	0.5
CO	50	50	50 (daily average)

*) Draft Directive Incineration of Waste, 20.08.94, GH016
daily average values for new plants: > 3 ton/hour
between ( ): half-hourly average values.

All values are related to 11% O_2 and dry flue gas

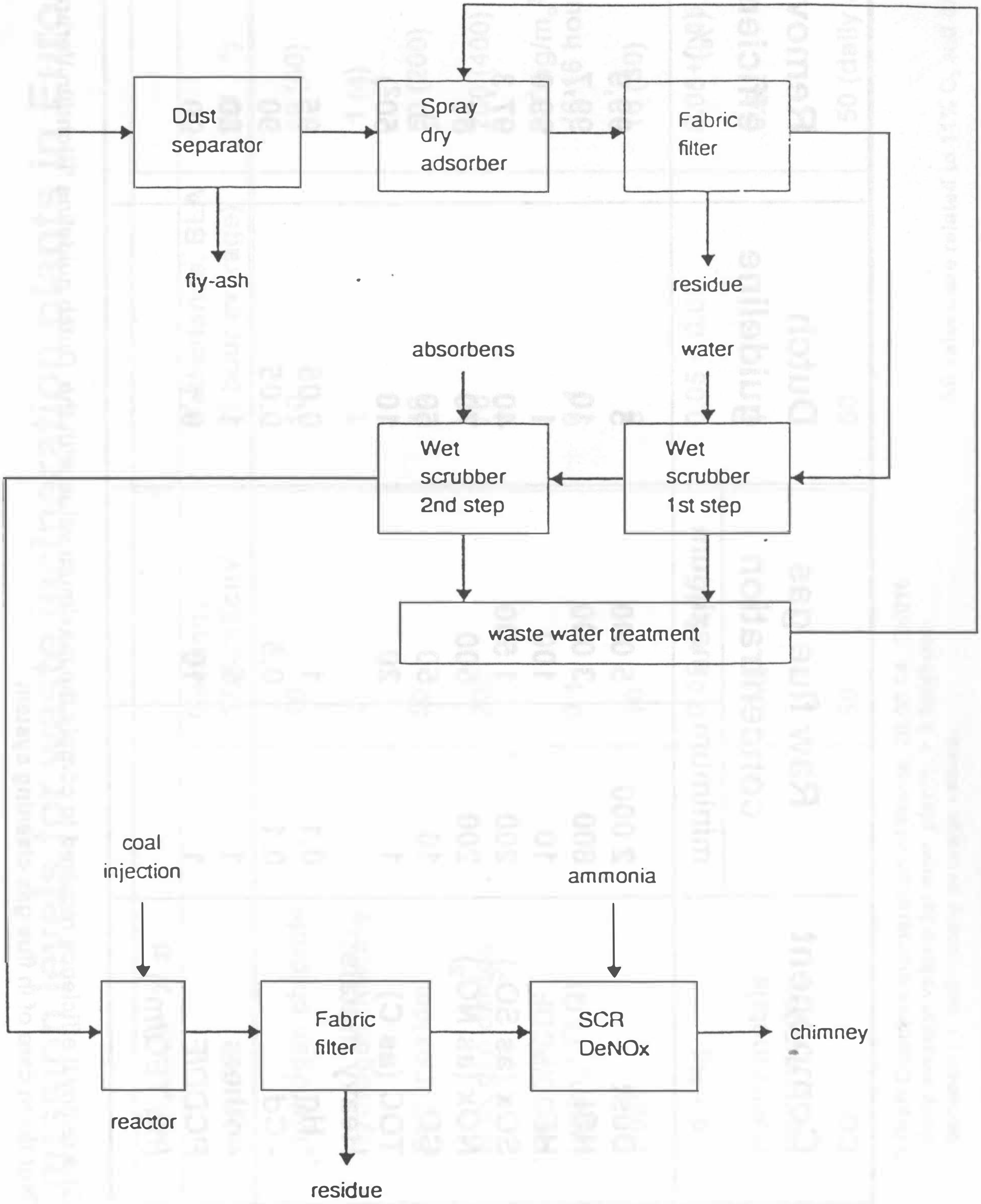
Component	Raw flue gas concentration		Dutch guideline	Removal [1)] efficiency (%)
	minimum	maximum		
Dust	2 000	5 000	5	99,9
HCl	800	3 000	10	99,7
HF	10	100	1	99,0
SOx (as SO_2)	200	1 500	40	97,3
NOx (as NO_2)	200	500	70	86
CO	10	50	50	[2)]
TOC (as C)	1	20	10	50[2)]
Heavy metals:				
- Hg	0.1	1	0.05	95
- Cd	0.1	0.5	0.05	90
- others	1	5	1	80
PCDD/F (ng TEQ/m^3) [3)]	1	10	0.1	99

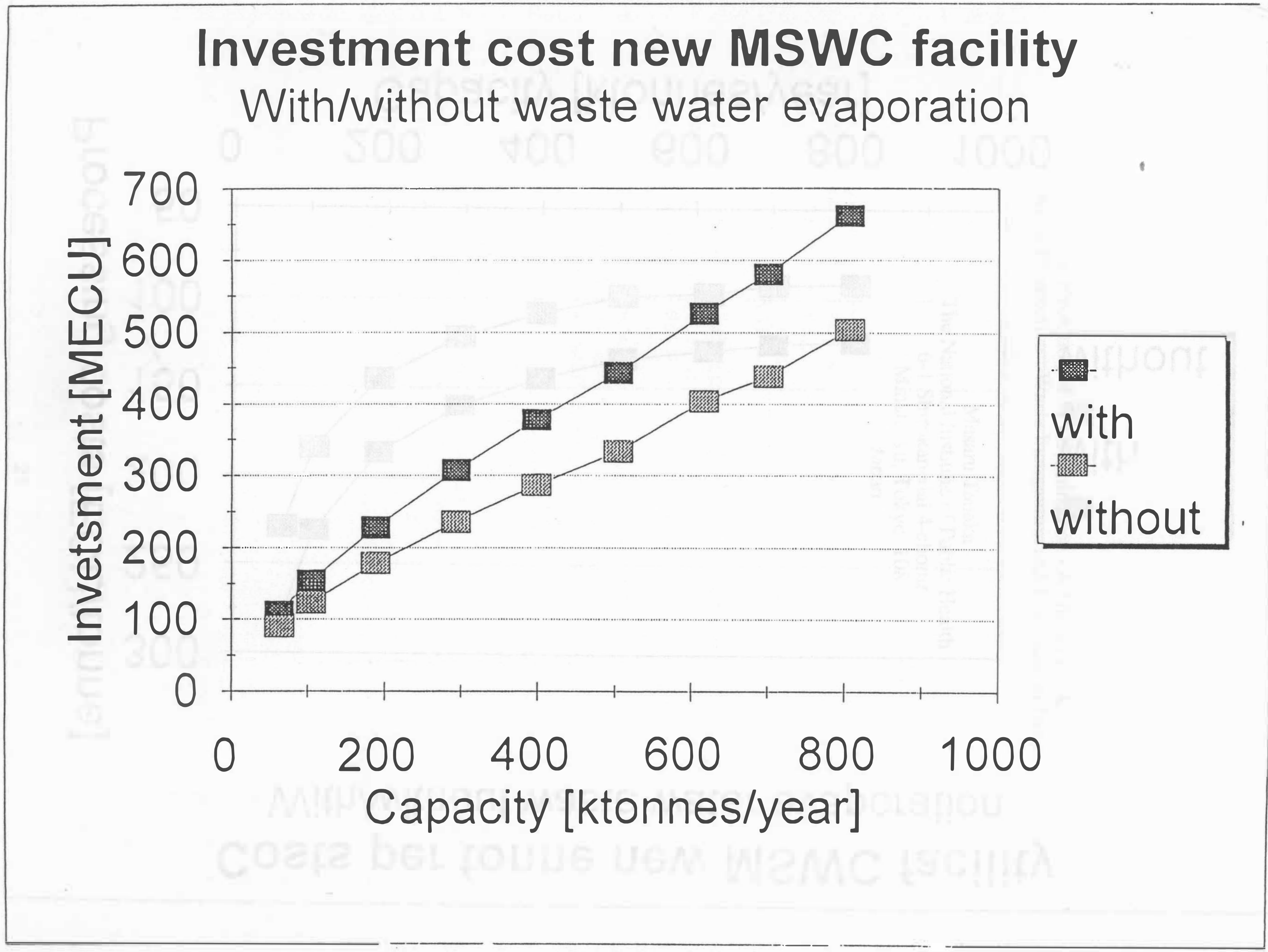
[1)] The removal efficiency required to comply the maximum value with the Dutch guideline 'Richtljin Verbranden 1989'

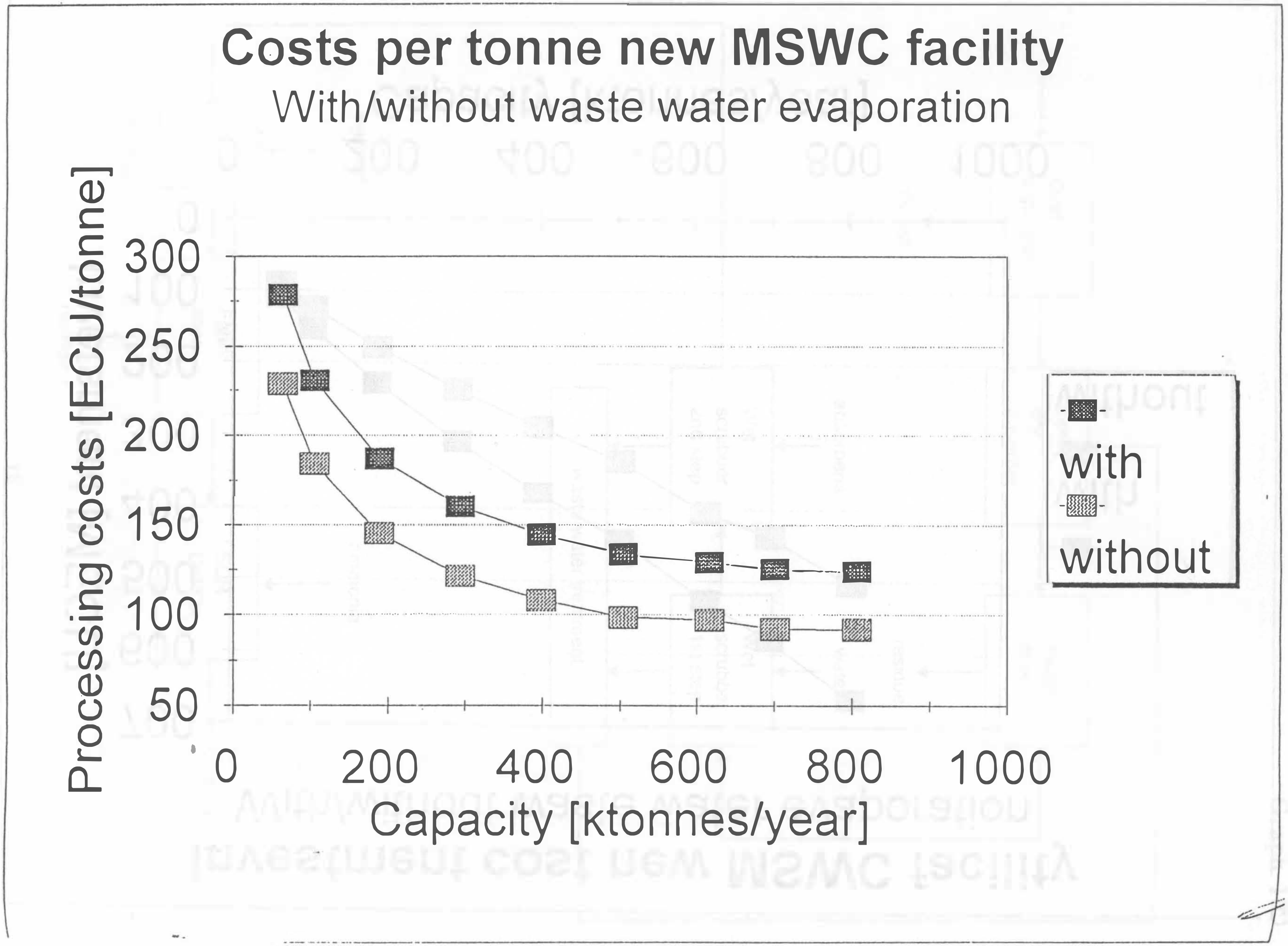
[2)] Not taken care of in flue gas claening system

[3)] TEQ = Toxicity Equivalent Quantity (related to 1,2,7, 8-TCDD)

Graph 10


Dust
separator
Spray
dry
adsorber
Fabric
filter
fly-ash
residue
absorbens
water
Wet
scrubber
2nd step
Wet
scrubber
1st step
waste water treatment
coal
injection
ammonia
reactor
Fabric
filter
SCR
DeNOx
chimney
residue


Investment cost new MSWC facility
With/without waste water evaporation
Invetsment [MECU]
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
Capacity [ktonnes/year]
with
without


Costs per tonne new MSWC facility
With/without waste water evaporation
Processing costs [ECU/tonne]
300
250
200
150
100
50
0
200
400
600
800
1000
Capacity [ktonnes/year]
with
without