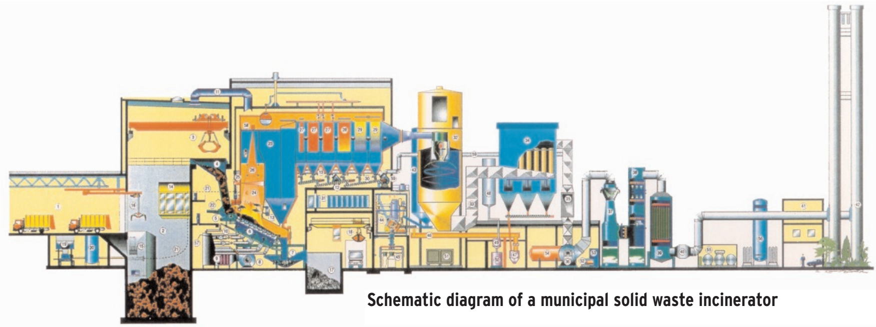
THE ROLE OF WASTE INCINERATION IN GERMANY



Schematic diagram of a municipal solid waste incinerator

Contents:

Umwelt Bundes Amt
For our Environment

Imprint

Published by: Umweltbundesamt

Press officer: Martin Ittershagen (responsible)

Adress: P.O. Box 1406, 06813 Dessau-Roßlau
Telephone: 0340/21 03-2122
E-Mail: pressestelle@uba.de
Internet: www.umweltbundesamt.de

Status: October 2008

1. Waste Incineration in the Course of Time

In the late 19th century, the lack of appropriate waste collection and disposal systems in Europe along with public health issues – the outbreak of epidemics such as the cholera – raised the question: How can waste volumes be reduced and how can waste be managed more hygienically? This marked the beginning of the age of "technical waste incineration". The first waste incineration plant known as Destructor was built in Nottingham, England in 1876. Following experience with waste incineration in Manchester, the introduction of this technology was also discussed in Germany.

The first waste incineration plant in Germany was built in 1894/95 in the wake of the last major cholera outbreak in Hamburg. This so-called "waste incineration works" took up operation in Bullerdeich, Hamburg on 1 January 1896, disposing of the waste of the city's 300,000 inhabitants.

Thus, the foundations had been laid for a new method of waste treatment which proved to be viable not only from health and environmental aspects but also economically.

Even at that time, the construction of waste incinerators faced intense public opposition. The duration and ferocity of the political controversy over the construction of the Hamburg waste incineration plant more than 100 years ago bears close resemblance to today's public debates in connection with construction decisions and permitting processes. The massive air pollutant emissions and the resulting environmental burden were, however, not an issue at that time. In the age of industrialization, the "smoking stack" used to be a symbol of technological progress and still had positive connotations.

The twenties and thirties of the 20th century saw a significant further development of the incineration technology as well as the first use of an electrostatic precipitator for flue gas cleanup. Technical advances allowed fully automated plant operation with continuous waste feed to the combustion chamber and continuous slag removal. The technology developed for these second-generation plants constituted the basis for modern waste incinerators.

Further development of the technology – from the point of view of environmental performance - led to the "Municipal Solid Waste Incinerator (MSWI[1]) of the Modern Age" equipped with fully developed firing technology and powerful flue gas cleaning systems (3rd generation), a development that was accelerated in particular by the stringent emission control standards of the Waste Incinerator Ordinance (17. BImSchV[2]) passed in 1990. The late nineties of the last century saw the advent of the fourth-generation plants characterized by slimmed yet equally efficient flue gas cleaning systems[3].

These days, waste incineration is on its way towards the 5th plant generation - and the development of the technology has not reached its end by far. This applies in particular to energy efficiency improvements (see also sections 5 and 6).

The development of thermal waste treatment facilities in terms of number and capacity is depicted in Tab. 1.

Tab. 1 Development of thermal treatment facilities for municipal solid waste in Germany[4]

Year	Number of plants	Waste throughput in 1000 t/a	Average throughput per plant in 1000 t/a
1965	7	718	103
1970	24	2.829	118
1975	33	4.582	139
1980	42	6.343	151
1985	46	7.877	171
1990	48	9.200	191
1995	52	10.870	202
2000	60	13.900	230
2005	66	16.000	242

2. The Controversy over Waste Incineration in the Eighties

With growing public awareness of environmental issues, waste incinerators were increasingly viewed as sources of critical air pollutants and became the subject of controversial public debate. As measurement and analysis methods were being continuously further refined, pollutant groups like dioxins and furans[5]-[6] that had hitherto been largely unknown and were to go down in history as a synonym for major industrial accidents were also identified in incinerator flue gases. In view of the dramatically increasing waste volumes produced by the affluent society, MSWIs – at that time termed "poison spewers" or "omnivores" – epitomised the uncontrolled growth of consumption in the industrial society at the expense of the environment. Prompted by fears over dioxin emissions, the citizens started to take on waste incinerators. And they did so with success: public opposition to pollutant emissions from waste incinerators fuelled the further development of the firing, air pollution control and monitoring technologies, thus reducing pollutant emissions and improving the environmental compatibility of the plants without regard to cost and energy consumption.

At the same time, the German Waste Management Act of 1986 introduced the waste management hierarchy "Prevention before Recycling before Disposal", thereby paving the way for a more environmentally sound waste disposal strategy. With the ensuing federal implementation regulations, waste management was taken one step further towards the resource-conserving closed-cycle economy.

In Germany, more than 60 percent of the municipal solid waste is currently recycled, e.g. biowaste, paper, glass or packaging waste. Landfilling of untreated municipal solid waste has been banned since 1 June 2005[7].

These days, approx. 18 million t/a of waste are thermally treated in just under 70 MSWIs. Thanks to stringent emission control standards, dioxin, dust and heavy metals emissions from waste incineration are no longer an issue, a fact that is all the more impressive as the waste incineration capacity has more than doubled since 1985.

3. Environmental Relevance of Waste Incineration

3.1 Emissions and regulatory requirements

On 1st December 1990, Ordinance No. 17 on the Implementation of the Federal Immission Control Act governing Incineration Plants for Waste and Similar Combustible Substances (17. BImSchV) took effect, further tightening emissions from MSWIs. This Ordinance established the most stringent emission limits worldwide, notably for carcinogenic and toxic substances such as dioxins and heavy metals.

The introduction of emission control regulations had become necessary in view of the very high concentrations of specific air pollutants encountered in waste incinerator flue gases prior to the passage of 17. BImSchV. In individual cases, dioxin concentrations of up to 400 nanograms of toxicity equivalents (TEQs) per cubic metre had been measured in the flue gas. This is 4000 times higher than the current limit mandated by 17. BImSchV. Furthermore, there was the problem of dust and heavy metals emissions. Under these circumstances, waste incineration merely shifted the pollutant burden from the waste to the atmosphere.

Within a given transition period all existing waste incinerators had to be retrofitted with sophisticated flue gas cleaning technology or else they had to be closed down. New facilities had to meet the prescribed emission limits from day one of their operation. In addition, 17. BImSchV imposes strict requirements for emission monitoring. These days, virtually all pollutant emissions – including dust and heavy metals such as mercury (Hg) - are continuously monitored. To ensure complete pollutant destruction, 17. BImSchV prescribes minimum temperatures and residence times for the combustion products in the combustion zone. These requirements have remained in force up to the present day, in both the German and the European legislation.

Since 2000, the EU Waste Incineration Directive has been in force (RL 2000/76/EEC). The basis for this Directive was the 17. BImSchV of 1990. The transposition of this Directive into national law led to the amendment of 17. BImSchV[8] in August 2003. As a result, emission limits have been further tightened and more stringent requirements apply to the co-incineration of waste in industrial firing systems such as cement kilns or coal-fired power plants.

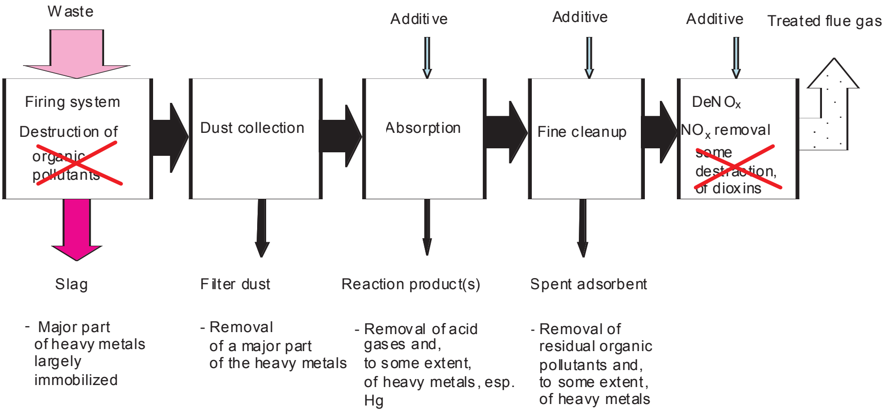


Fig. 1 Simplified schematic of a MSWI flue gas cleaning system, taking into account pollutant destruction and removal

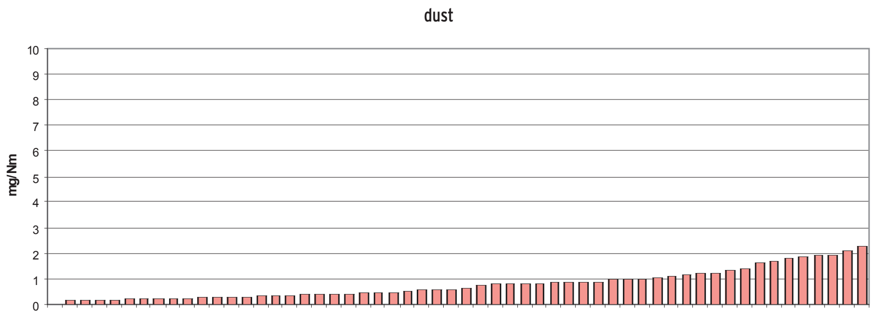
Since 1996 at the latest, all German waste incinerators have been operating in compliance with the rigid emission levels mandated by 17. BImSchV. Dioxin and furan concentrations are limited to 0.1 nanograms TEQs per cubic metre of flue gas. In a similar way, emission limits for heavy metals, dusts and acid gases such sulphur dioxide, hydrogen chloride and others have been severely tightened so that emissions of these components are these days no longer health-relevant (see also section 4).

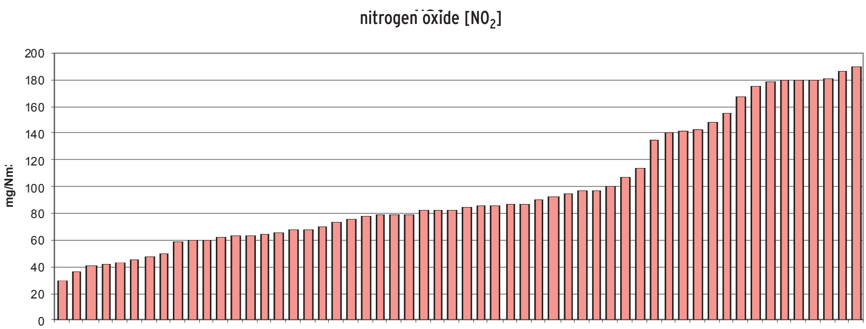
On the contrary – without waste incinerators, ambient air pollutant levels would be much higher than with waste incinerators. After all, electricity and heat generated in MSWIs substitute fossil energy sources in conventional (heat and) power plants which typically release higher specific pollutant levels than waste incinerators. For the carcinogenic substances arsenic, cadmium, nickel, benzo(a)pyrene, benzene, PCB and dioxins/furans, for instance, the MSWIs operated in Germany deliver a credit of around 3 tonnes of arsenic equivalents[9] per annum. In other words, if the energy produced by MSWIs were generated by conventional coal-fired power plants, the ambient air concentration of these pollutants would increase by 3 tonnes. This is the result of a study undertaken by “Institut für Energie und Umweltforschung” (IFEU)[10] Heidelberg in 2004 on behalf of the German Federal Environment Agency (UBA).

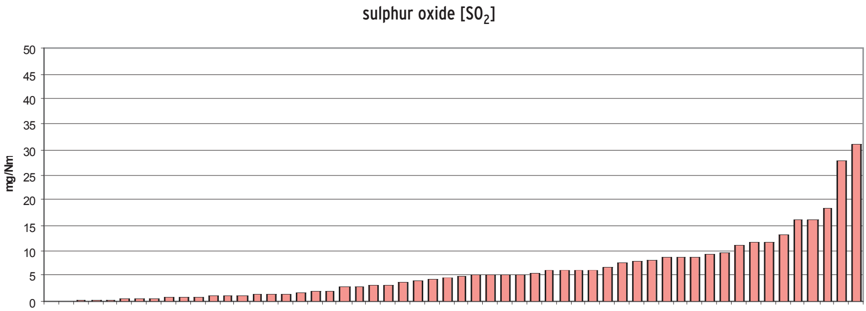
As part of a further research project[11] commissioned by the Federal Environment Agency, a study was undertaken to investigate current emissions from MSWIs.

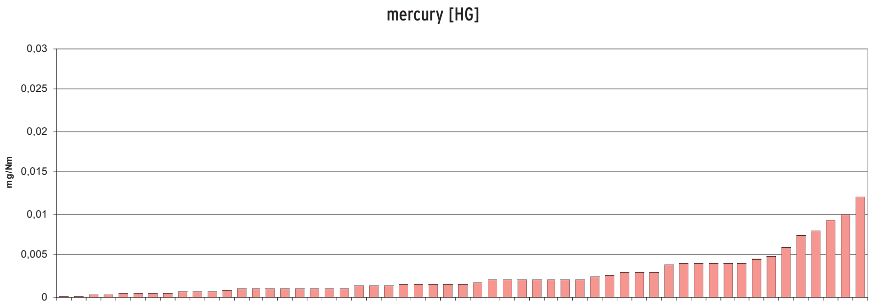
The following diagrams (Fig. 3) show the ranges of dust, nitrogen oxides (NO_2), sulphur dioxide (SO_2), Hg as well as dioxin/furan emissions for the plants evaluated. All evaluated plants are plotted along the abscissa; the emission concentrations measured in the flue gas are plotted along the ordinate. The ordinate scales are in each case standardized to the respective emission limit, i.e. the highest concentration on the ordinate corresponds to the respective emission limit of 17. BImSchV. In this way, it can be readily seen that all plants consistently meet the prescribed emission limits. As can be seen, the emission concentrations attained during plant operation are well below the allowable limits. In the case of dust, for instance, no more than 10 % of the emission limit is exploited.

Solely nitrogen oxide appears to be a parameter for which the emission limit is exploited to a relatively large extent. While approximately 25 % of the plants are in the range of over 120 milligrams per cubic metre (mg/m3) – corresponding to 60 % of the limit value – the greater part of the plants remains in the range of 60 to 100 mg/m³.









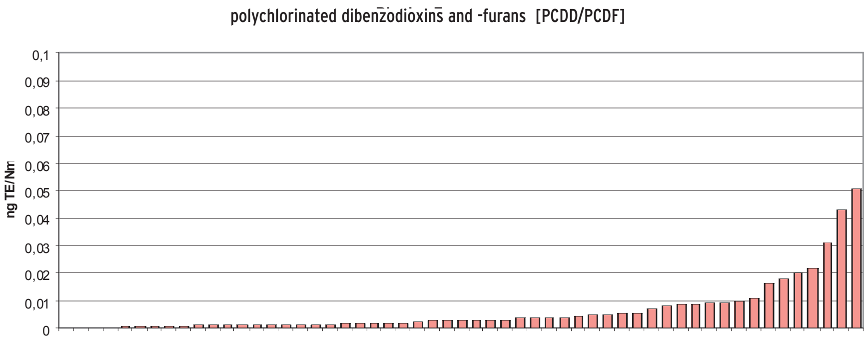


Fig. 2 **Emissions of dust, NO_X (expressed as NO_2), SO_2, mercury and dioxins; emission concentration ranges of German MSWIs; data source: publicly available data from MSWI operators and assumptions of the IFEU (2007)**

The development of the Waste Incineration BREF[12] - Reference Document on the Best Available Techniques for Waste Incineration – on the basis of Directive 96/61/EEC concerning Integrated Pollution Prevention and Control (IPPC Directive) marked a further step in the direction of integrated cross-media environmental protection for waste incinerators. Using the best available techniques – synonymous with state-of-the art technology - all German waste incinerators meet the environmental standards for emissions to air, water and soil there stated, taking into consideration waste disposal aspects and energy efficiency.

Tab. 2 Attainable emission levels for waste incineration facilities (Excerpt from the Waste Incineration BREF, Table 5.2 "Operational Emission Levels associated with the use of BAT" for Air Pollutants expressed in mg/m³STP)

Substance	Non-Continuous samples	Half-hour mean value	Daily mean value	Notes
Dust		1-20*	1-5	Lower levels achieved with fabric filters
Hydrogenchloride (HCl)		1-50	1-8	Use of wet processes preferred
Sulfurdioxide (SO_2)		1-150*	1-40*	Use of wet processes preferred
Nitrogenoxides (NOx) with SCR1[1]		40-300*	40-100*	Additional energy demand and costs
Nitrogenoxides (NOx) with SCR2[2]		30-350	120-180	At high raw gas NOx levels, NH_3-slip to be taken into account, preferred method in conjunction with wet processes
Total organic compounds (TOC)		1-20	1-10	Optimum combustion conditions
Carbonmonoxide (CO)		5-100	5-30	Optimum combustion conditions
Mercury (Hg)	<0,05*	0,001-0,03	0,001-0,02	Input control, carbon-based adsorption processes
Dioxins and furans (PCDDs/PCDFs)	0,01-0,1*			Optimum combustion conditions, temperature controls to reduce de-novo synthesis, carbon-based adsoption processes

3.2 Reuse of incineration residues

However, even state-of-the-art German MSWIs offer potential for further development. This applies in particular to energy efficiency and the quality of the slag, even so it must be said that MSWI slag reuse has already reached a high level. The following Figure (Fig. 4) depicts the percentage distribution of incinerator slag uses. According to information from MSWI operators, some 50 % of the total of 3.7 million t/a of slag was routed to reuse in civil engineering (excluding landfill construction). At just above 45 %, the predominant reuse is in roadway construction while about 13 % is reused as structural fill in deep mines and 10 % in landfill construction. Another 12 percent is reused without any further specification. No more than 3 percent of the slag volume (3 mentions) was explicitly landfilled. Nevertheless, there remains a gap of some 12 percent (11 mentions) for which no information on the disposal route is available. Assuming that this 12 % volume is landfilled, this would result in a reuse level of 85 % which would already be very high.

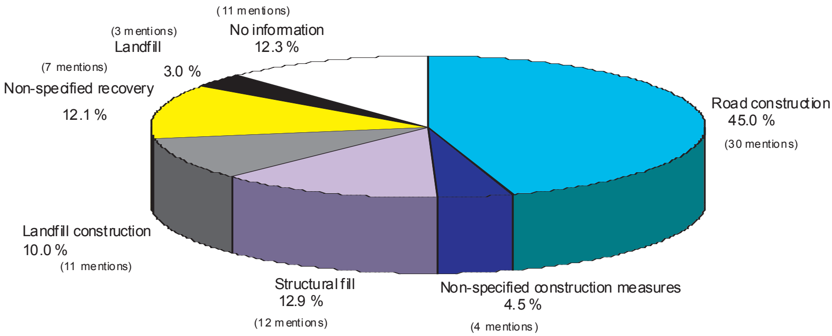


Fig. 3 **Evaluation of the slag reuse criterion for 65 MSWIs in Germany; percentage figures weighted by mass; number of mentions including multiple mentions per plant; data source: publicly available data from MSWI operators and assumptions of the IFEU (2007)**

Incineration technologies with integrated slag treatment allow the production of a largely inert granulate featuring a significantly improved quality as against conventional slag and bottom ash. However, these technologies have failed to gain a commercial foothold so far for reasons of both cost and energy efficiency losses.

The slag contains metals which can be recovered. The following Figure (Fig. 5) depicts the number of MSWIs recovering metals from the incinerator slag. The figures stated also include external treatment for the recovery of ferrous and, where applicable, non-ferrous metals (NF metals). The study reports only eight

MSWIs not practising metal recovery. The slag from 57 MSWIs is further processed to recover at least ferrous metals, frequently at external recovery plants. Moreover, 14 operators state non-ferrous metals extraction.

Regarding these data, it should be noted that IFEU conducted this survey in 2006. Spurred by rising scrap metal prices, metal extraction and recycling has since been expanded.

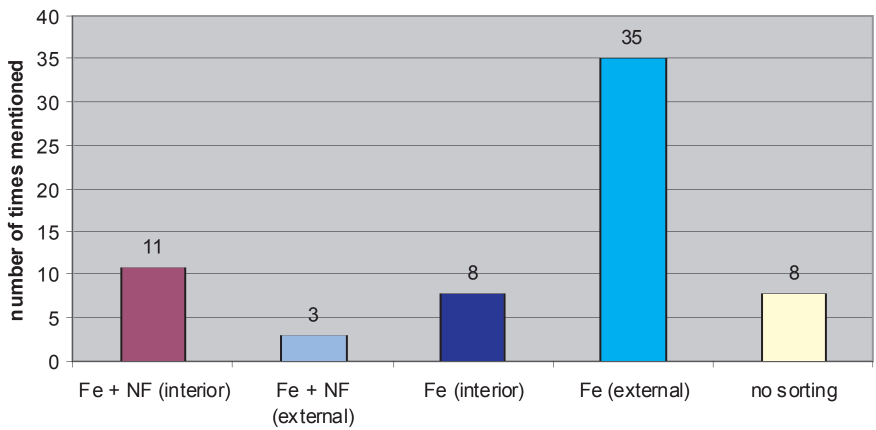


Fig. 4 **Evaluation of the metal recovery criterion for 65 MSWIs in Germany; number of times mentioned; data source: publicly available information from MSWI operators and assumptions of the IFEU (2007).**

3.3 The contribution to climate protection

Waste incineration not only serves the purpose of environmentally sound waste disposal but also generates significant amounts of energy in the form of electricity and heat. In this way, it contributes to climate protection and helps preserve natural resources. As well as the usable energy from combustion which is for the greater part CO_2-neutral – the biogenic fraction of residual waste accounts for 50 to 60 %-ferrous and non-ferrous metals like copper and aluminium recovered at MSWIs deliver credits for the climate balance. The extraction and reuse of the scrap metal require a significantly lower energy input than metal recovery from primary resources and hence, reduce carbon dioxide emissions (CO_2).

The bulk of the residual waste volume – more than 17 million tonnes in 2006 – is treated in waste incinerators. On average, German MSWIs operate at a gross electrical efficiency of 13 percent and a thermal efficiency of 34 percent. They export approximately 6.3 terawatt hours (TWh) of electricity and 17.2 TWh of heat. The energy so produced replaces fossil energy, translating into the avoidance of approximately 9.75 million t/a of CO_2 equivalents. Taking into account the fossil content of the waste and energy imports of the waste incinerators, the net amount of CO_2 emissions avoided is just under 4 million tonnes.

Significant additional potential for CO_2 emission reductions could be tapped by optimizing the energy efficiency of existing MSWIs (see also sections 6 and 7).[15] However, due to the capital cost involved and the poor revenue potential, MSWI operators are reluctant to implement the optimization measures needed for maximizing energy recovery. In many cases, MSWIs also have to compete with other energy generation plants sited in the same area. Another impediment to increased energy recovery are the locations of many waste incinerators. In most cases, political enforceability was the prime siting criterion. Only in very few cases was the optimum use of the energy generated a key consideration in the sitting of the plant.

(Co-)incineration of refuse-derived fuels:

The incineration and co-incineration of pre-processed waste streams – so-called Refuse-Derived Fuel (RDF) – likewise make a contribution to climate protection. Production of RDF from municipal solid waste not only reduces the waste volumes to be disposed of, but also provides a low-cost fuel, especially for energy-intensive industries.

Pre-processing municipal solid waste, similar-type commercial waste and production-specific wastes/residues – e.g. scrap tyres, spent oil, plastics processing and paper mill waste - generates up to 8 million t/a of high-calorific waste fractions that would lend themselves for use as RDF[16]. Of this volume, approx. 3 million tonnes stem from the treatment of residual waste in mechanical-biological treatment (MBT[17]) plants.

However, the RDF co-incineration capacities of industrial firing systems (especially power plants and cement mills) are limited and to some extent already used for production-specific waste streams. In Germany, these plants currently co-incinerate some 2 million t/a of RDF derived from municipal and commercial waste including sewage sludge. Given the lack of acceptance on the part of the plant operators, any major capacity extensions for RDF co-incineration in coal-fired power plants are not to be expected. The reasons for the reticence of the operators - notably of coal-fired power plants – are twofold. On the one hand, RDF producers are frequently not able to supply a fuel quality comparable to that of conventional fuel – such as coal, for instance - and on the other, operators fear losses in plant availability (due to corrosion problems) as well as adverse impacts on the byproducts generated such as ash, slag and gypsum. A take-off price that could compensate for these risks would not be accepted by the market. As a result of this situation, approx. 50 dedicated RDF combustion projects are currently in the planning stage[18], not all of which – in the opinion of the Federal Environment Agency (UBA) – will have a chance of being realized.

Unlike many conventional MSWIs, dedicated RDF combustion plants offer the advantage that they can be designed for and operated with maximum energy efficiency. This applies all the more so, if these plants are configured for combined electricity and heat production. However, not all projects provide for such a concept. RDF combustion plants generating electricity only offer no advantages over MSWIs operated in the combined heat and power mode.

There are currently around ten RDF-fired power plants in operation in Germany, corresponding to a capacity of approx. 1 million tonnes per annum. Another ten plants are under construction or in the permitting stage (status July 2008). Yet, secured plant capacities have not contributed to reducing the stokkpiles of roughly 1 million tonnes of high-calorific waste currently on interim storage (status April 2008)[19].

The realization of further RDF-fired power plants is associated with major uncertainties. For many projects, a contractually agreed long-term supply of the RDF volumes necessary to ensure minimum capacity utilization will be the key prerequisite for implementation. This is the only way to secure cost-effective plant operation and security of energy supply. The construction of major overcapacities that might lead to dramatic changes in the waste management sector is not likely with this approach. On the contrary, minor overcapacities are even necessary to ensure disposal reliability so that the existing RDF volumes on interim storage can be reduced within reasonable time and fluctuations in the waste volumes or the temporary outage of individual plants can be made up for. Securing fuel supply for the RFD-fired power plants through imported RDF would have no adverse effect on the environmental balance, since Germany generally has more stringent environmental standards than many of its neighbour countries. Nevertheless, equivalent environmental standards provided, the disposal of waste at or close to its point of generation is the preferable option.

4. Do Waste Incinerators Pose a Human Health Hazard?

Waste incinerators are regulated by the 17. BImSchV which requires pollutant emissions to the atmosphere to be minimized to such an extent as to rule out hazards to human health and the environment. The performance of the air pollution control equipment is subject to continuous monitoring - for mercury, for instance.

Carcinogenic Substances from Municipal Solid Waste Incineration (MSWI):

Like all combustion processes, waste incineration generates carcinogenic substances. Which specific substances are involved in the individual case cannot be predicted. To rule out adverse health impacts, stringent emission limits apply to extremely hazardous substances such as dioxins and furans, polycyclic aromatic compounds and potentially carcinogenic metalloids and heavy metals. These substances are also used as surrogate parameters for a great variety of carcinogenic or potentially carcinogenic compounds that cannot be exactly determined.

Unlike combustion processes which occur uncontrolled and without flue gas cleanup - in open fire places or camp fires, for instance – the specific emissions of MSWIs related to the material burnt are extremely low. This is due to sophisticated flue gas cleaning technology that ensures compliance with rigorous regulatory emission control standards. Given the very minor contributions of the monitored surrogate parameters for carcinogenic substances – e. g. dioxins and furans (PCDDs/PCDFs), benzo(a)pyrene, cadmium, arsenic - to background levels of air pollution in the surroundings of waste incinerators, an increased cancer risk for children or adults is unlikely. Even in rural areas, a potential increase in the cancer risk is not quantifiable because of the very minor contribution to existing background levels. This statement was confirmed as far back as in 1993 by a review on the health effects of 17. BImSchV-compliant waste incinerators published by an expert advisory committee of the German Medical Association. Judging from current knowledge, a waste incinerator operating in compliance with the regulatory requirements is not likely to lead to adverse impacts on the health of the surrounding population due to the emission of air pollutants including carcinogenic metals or organic compounds.

Dioxin releases to the environment, health effects and regulatory measures:

Dioxins may be present as impurities in chemical products or formed under defined conditions in combustion processes. In Germany, pentachlorophenol, polychlorinated biphenyls and certain herbicides containing dioxin impurities have been banned for about 20 years. For waste incineration facilities, an emission limit of 0.1 nanograms per cubic metre (ng/m_3 STP) has been in place for these compounds since 1990. This emission limit meanwhile also applies to all other combustion systems. As a result of these regulations, which apply Germany-wide, it has been possible to drastically reduce dioxin emissions in Germany. Dioxin emissions from waste incinerators are virtually negligible these days[20].

Pollutants in the surroundings of waste incinerators:

The waste incinerators operated in Germany not only serve the hygienic disposal of municipal solid waste but act at the same time as a classic pollutant sink. This means that they lead to a reduced ambient air concentration of specific pollutants in a defined local area.

Nevertheless, an environmental impact assessment should always include a potential long-term accumulation of pollutants as a result of deposition[21] in the surroundings of the waste incineration facility. More recently, emission studies and ambient air quality assessments have been undertaken for hazardous waste incinerators (HWIs) in Biebesheim, Hesse and Ebenhausen, Bavaria. These did not reveal any health-relevant accumulation of pollutants due to deposition in the different environmental media, even though these plants had been in operation for decades. These findings correlate well with the results of previous environmental impact assessments for a HWI in Bavaria where the pollutant concentrations in soil and plant samples were above the background level of air pollution in rural areas, yet still far below the air pollution levels encountered in urban areas. No health-relevant limit concentrations were exceeded. The crop plants examined did not exceed the applicable reference values for pollutants in food. If the emission limits prescribed by 17. BImSchV are complied with, the contribution of municipal solid waste and hazardous waste incinerators to the existing background levels of air pollution is virtually negligible.

Unknown pollutants and the "zero-risk" problem:

An objection frequently raised by critics of MSWI within the scope of the permitting process and in public debates over proposed or existing waste incinerators is that the pollutants listed in 17. BImSchV (and also the substances regulated by 22. BImSchV[22] and the Technical Instructions for Air Pollution Control (TA Luft)) are insufficient for an assessment of MSWI emissions in terms of the characterization and the assessment of the exposure of the surrounding population. In this connection, critics often present comprehensive pollutant lists, demanding that these should also be included in the exposure assessment. The position of the Federal Environment Agency (UBA) on this issue is as follows:

> Waste incineration - like other combustion processes – generates a great variety of different chemical substances as products of combustion. Waste incinerators emit these substances at very low concentrations. The spectrum of released (and detectable) substances that can be included in a monitoring program is limited by analytical constraints (complicated and labour-intensive sampling; detection limits achievable with current methods). What is required is therefore a meaningful selection of substance mixtures. The criterion for selection is the potential hazard posed to human health and the flora and fauna in the surroundings of the plant.

Relevant criteria in terms of environmental epidemiology are mainly the (ambient air) pollutant concentration and its potential impacts on humans (chronic and acute toxicity[23], carcinogenicity[24], mutagenicity[25] etc.). The substances selected for regulation by 17. and 22. BImSchV including TA Luft satisfy for the greater part these criteria. Substances not listed in 17. BImSchV and the associated regulations normally play no or only a secondary role in the exposure characterization and assessment. Through the use of efficient flue gas cleaning technologies, German waste incinerators outperform the pollutant emission limits prescribed by 17. BImSchV by far. Emission reductions and removal efficiencies achieved are typically above 60 percent - e.g. for polyaromatic hydrocarbons – and in some cases up to 99 percent – for hydrochlorocarbons and hydrofluorocarbons. This means that flue gas constituents not explicitly considered in the assessment are also reduced to a similar extent.

Due to the complex composition of industrial flue gas streams - e.g. from waste incinerators – a complete eco- and humano-toxicological identification of all the emission components is not feasible in practice. In order to largely rule out hazards to humans and the environment due to the potential presence of minor unknown emission components, expert bodies are investigating scientifically identified “surrogate compounds”.

Despite all efforts made, a zero-risk will not be attainable for waste incinerators, nor for any other industrial technologies releasing emissions to the environment.

What is required is to strike a balance between acceptable and unacceptable risks. No doubt, risks that are deliberately chosen by individuals stand a better chance of acceptance than risks imposed by third parties. Thanks to the 17. BImSchV which sets much more stringent emission limits than any other German air pollution control regulation, the safeguards for waste incinerators are excellent compared to other less regulated industrial activities such as the energy sector, for instance.

Assessment of waste incinerators in terms of public health impact:

Although Germany can draw on many years of positive operating experience with meanwhile more than 100 waste incinerators (including hazardous waste incinerators and RDF-fired power plants), new waste incinerator or incinerator extension projects continue to spur public concern over potential health impacts. However, so far, no adverse health effects could be identified among citizens living in the impact range of a waste incineration facility. Nevertheless, these fears must be taken seriously, all the more so since a potential health risk can only be ruled out largely but never completely.

To largely minimize health impacts from waste incinerators, a series of studies was initiated worldwide. These arrive at different results. While some identified a correlation between waste incineration and (different) health problems, others did not confirm such a causal link. In this connection, it should, however, be noted that many of these studies relate to waste incinerators that meet neither the criteria of the European Waste Incineration Directive nor the requirements of 17. BImSchV. In many cases, the studies relate to foreign facilities which are outdated from today’s perspective. In Germany, there is currently no evidence for an increased prevalence of certain diseases like cancer, asthma or allergies in the surroundings of MSWIs. According to current knowledge, there is no causal association between such diseases and the ambient air quality. Nor is there any valid evidence to suggest that other diseases occur more frequently in the surroundings of MSWIs than in other areas. From today’s perspective, there is no need to change the selection of the substances to be assessed. There are to date no indications that substances not listed would have proved to be relevant for an assessment. Should, however, future findings show the necessity of a re-assessment of specific emissions, the existing regulations will be revised accordingly.

5. Central Challenges for Waste Incineration Today

Boosting energy efficiency and optimizing energy use are the central challenges faced by state-of-the-art waste incineration.

Soaring energy prices, in particular, have called the public's attention to the necessity to rethink our methods of energy production and supply. Given the limited supply of fossil primary energy sources, the globally rising energy demand cannot be met in the current form over the long run. In parallel with intensive efforts to boost energy efficiency and realize energy savings, it is imperative to make use of all available energy sources that help conserve limited resources, are environmentally benign and contribute to climate protection. This also applies to high-calorific waste streams.

While the waste management sector is already making relevant contributions to energy supply, there is still vast untapped potential for energy recovery. Current waste-to-energy applications span a broad spectrum such as:

- **electricity and heat generation in municipal solid waste incinerators,**
- **co-incineration of RDF and sewage sludge in power plants and cement mills,**
- **combustion of wood waste,**
- **anaerobic digestion of liquid manure and biowaste in biogas plants,**
- **anaerobic digestion and incineration of sewage sludge,**
- **use of landfill gas**

Of these, MSWIs offer major potential for optimizing energy efficiency. Below options for expanding energy recovery in MSWIs and the use of the energy so produced are discussed and suitable policy instruments for stimulating investment in energy efficiency upgrades explored.

To begin with, an overview of the current situation of thermal residual waste treatment and the associated regulatory framework is presented:

Waste volumes:

The Federal Statistical Office reports a total waste volume of some 341 million tonnes[26] for Germany in 2006, of which municipal solid waste accounted for a share of around 46 million tonnes. According to the Waste Committee of the German Lander (LAGA), the residual waste volume routed to disposal amounts to approx. 22 million tonnes (excluding the high-calorific fraction from mechanical-biological treatment). Municipal solid waste routed to recycling accounts for over 50 % of the total waste volume. The proportion of waste routed to energy recovery cannot be exactly determined due to the lack of reliable statistical data. In Germany, the permitted co-incineration capacities in power plants and industrial plants (e.g. cement mills) amount to approx. 3.5 million t/a, of which only about 2 million t/a are currently used. These days, Germany's 68 MSWIs burn approx. 17.8 million t/a of residual and commercial waste.

Provisions of the Waste Avoidance, Recycling and Disposal Act for energy recovery from municipal solid waste:

Pursuant to Art. 6, § 1 of the German Waste Avoidance, Recycling and Disposal Act (KrW-/AbfG), priority is to be given to that form of recovery – i.e. materials or energy recovery – that is more environmentally compatible. A statutory ordinance regulating the priorities has so far not been issued by the Federal Government. In the absence of such a regulation, Art. 5, § 2 of KrW-/AbfG permits energy recovery only if:

1. **the waste has a calorific value of more than 11 megajoules per kilogram (MJ/kg),**
2. **a combustion efficiency of not less than 75 % is achieved,**
3. **the heat generated is used on site or sold to third parties and**
4. **the residues from the recovery process can be landfilled without further treatment.**

If a secondary fuel having a calorific value of more than 11 MJ/kg is derived from the high-calorific fraction of the residual waste, it may be routed to energy recovery. Processing residual waste to produce refuse-derived fuel not only reduces the waste volumes to be disposed of but also provides a low-cost fuel for energy-intensive industries. The key to success lies in securing a low-pollutant and uniform fuel quality. So far expectations for a greater use of RDF through co-incineration have only come true in part, even though RDF offers a cost-attractive alternative to fossil fuels in the current climate of high energy prices. Moreover, energy generation from RDF creates CO_2 certificates for emissions trading because of the high biogenic fraction of municipal solid waste.

Pursuant to Art. 5, § 2 of KrW-/AbfG, waste recovery has priority over waste disposal. This priority rule may only be omitted if recovery cannot be carried out in a proper and environmentally sound manner or would not be economically reasonable or is not technically feasible (see KrW-/AbfG Art. 5 §§ 3 and 4).

The incineration of residual municipal waste may qualify as energy recovery. Art. 4, § 4 of KrW-/AbfG distinguishes between energy recovery and thermal treatment – depending on the primary purpose of the measure. Accordingly, “*(for a given waste stream ....) the type and extent of its pollutant load and the additional waste and emissions occurring as a result of its treatment are the criteria for determining whether the primary purpose is energy recovery or treatment*“.

Here, it should be noted that following a ruling of the European Court of Justice (ECJ), this primary purpose clause is to be interpreted in conformity with EU legislation. The ultimate criterion is whether the waste is used to substitute primary fuels. The pollutant load or calorific value of the waste is not a criterion (see ECJ C-228/00). From this, it follows that residual municipal waste can basically be routed to energy recovery.

However, there is a restriction with regard to energy recovery in MSWIs. According to the ECJs Luxembourg ruling (C-458/00), the status of an energy recovery operation presupposes that the waste directly replaces primary fuels in the actual treatment plant (rather than indirectly through heat supply to a district heating grid) or that the plant operator pays for the waste. Under the criteria defined by the ECJ, the main purpose of a MSWI is that of a disposal operation.

For reasons of climate protection and resource conservation, both the German and the European jurisprudence encourage the enhanced use of the waste's energy potential As a result of considerations for a reassessment of waste-to-energy, some German Lander have already reclassified MSWIs with energy recovery as recovery operations - going in some cases beyond the restrictions defined by the Luxemburg ruling. Consequently, these facilities qualify as both waste disposal and recovery operations.

With the revised EU Waste Framework Directive of June 2008, the European Commission – following the line of jurisprudence of the European Court - has for the first time defined uniform criteria for a distinction between thermal treatment (Disposal - D10) and energy recovery (Recovery - Rl) from municipal solid waste in MSWIs. Annex II to the Waste Framework Directive describes a procedure (Rl formula) for the energy efficiency assessment of MSWIs that allows a clear distinction between the types of operation (recovery or disposal) (see also section 7).

6. Energy Recovery through Thermal Waste Treatment – Potential and Barriers

All energy recovered from residual municipal waste and put to effective use replaces fossil energy, thereby preserving fossil energy sources. In addition, energy recovery from waste contributes to climate protection as approx. 50 to 60 % of the residual waste's energy content – related to the calorific value of the waste input – originates from the biogenic fraction and is therefore largely CO_2-neutral.

As the waste management sector will always produce residual waste streams and these must be subjected to continuous thermal treatment in order to accomplish the disposal mandate, the prerequisites for base-load energy generation - primarily for electricity production - by the combined disposal/recovery process are given in principle. In addition, as demonstrated by many years of operating experience in Germany, MSWIs – whether operated with heat generation only or in the combined heat and power (CHP) mode – are also capable to ensure reliable heat supply via process steam or district heat.

A study on the energy efficiency of German MSWIs revealed the following results (see graph below)[27]: Data on energy use are available for 64 of the MSWIs under review. 44 MSWIs and hence, the majority of the plants sell the surplus energy generated to third parties in the form of both electricity and heat (district heat or district steam). Nine MSWIs produce electricity only, another nine export their complete high-pressure steam to an external user – typically a power plant or combined heat and power plant. Two further MSWIs feed exclusively into the district heating grid.

As illustrated in the coming up Figure (Fig. 6), 38 plants – i.e. more than half of all German MSWIs - meet the"energy efficiency threshold" of 0.6 required by the revised EU Waste Framework Directive for existing facilities to qualify as a recovery operation when applying a simplified R1 formula. Only two plants fall short of an efficiency level of 0.4. Eleven plants remain below an efficiency level of 0.5.

An energy recovery survey on thermal residual waste treatment facilities (processing approx. 17 million tonnes of waste in 2006) shows that roughly four fifths - 40 TWh per annum - of the waste's energy content - some 50 TWh per annum – is recovered in the form of steam at standard steam parameters of 400 °C, 40 bar and a mean boiler efficiency of 80 %. However, the energy available in the boiler can never be fully recovered since the conversion into other forms of energy such as electricity, district heat or process steam – is always associated with some losses. At an overall energy efficiency level[28] of 46 percent on average (range: 1 to 22 percent electricity, 5 to 81 percent heat) corresponding to an energy output of 23 TWh and hence, the average electricity and heat demand of roughly 820,000 single-family homes, it must, however, be said that all in all, the energy efficiency of German MSWIs is underdeveloped. One explanation for this situation is the frequent lack of sufficient outlets for the heat produced. According to information from MSWI operators (ITAD[29]), the

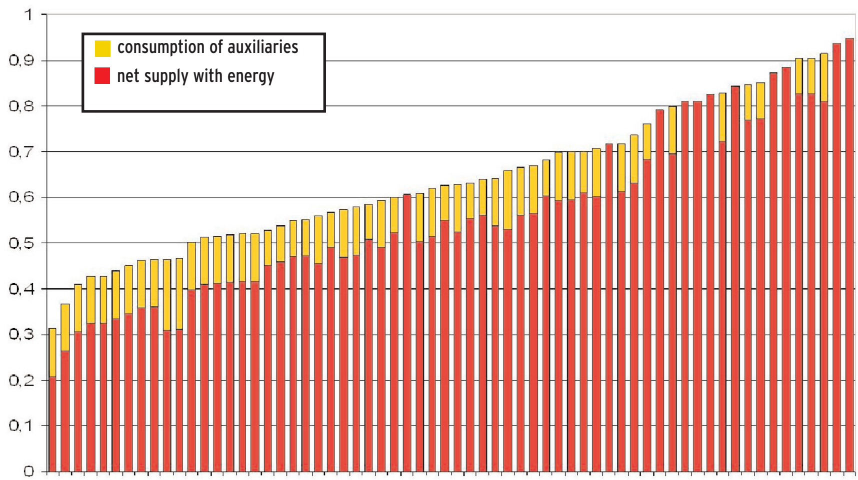


Fig. 5 **Energy efficiency range of German MSWIs; the graph shows the gross efficiency of energy generation determined on the basis of the RI formula plotted against the plants examined; data source: publicly available information from the MSWI operators and assumptions of the IFEU (2007).**

mean overall energy efficiency of the plants could be about 20 percentage points higher. This would correspond to an untapped energy potential of approx. 10 TWh per annum, enough to power and heat another 360,000 single-family homes. In addition, optimizing the energy efficiency of the existing MSWIs would deliver climate change benefits. By increasing the average fuel conversion efficiency to approx. 60 percent (e.g. 18 percent electricity and 42 percent) for instance, another 3 million tpa of CO_2 could be avoided as a result of the substitution of fossil fuels.

Altogether, the energy recovered from residual waste in the form of electricity and heat by MSWIs and the associated substitution of fossil energy sources in conventional (heat and) power plants currently avoids some 9.75 million tpa of CO_2 emissions. Due to the fossil fraction of the waste and the energy imports of the MSWIs, the net relief in terms of avoided CO_2 emissions is, however, lower.

Because of the high capital cost of heating grid extension projects or electrical efficiency upgrades, for instance, and the minor revenues to be expected - tariff rates for MSWI-generated electricity have hovered around 2.5 to 5 Cents per kilowatt hour (kWh) over the past few years - MSWI operators, by their own account, are currently not investing in optimization measures to boost energy efficiency. Increasing the electrical efficiency by 5 percentage point would require a capital investment in the amount of Euro 10 to 20 million per plant. The capital cost of a new district heating grid or a grid extension amounts to some Euro 0.5 to 1 million per kilometre.

7. How can Energy Recovery from Municipal Solid Waste be Optimized?

According to the German Waste Avoidance, Recycling and Disposal Act (KrW-/AbfG), recovery has priority over waste disposal. As the European Court of Justice has broadened the definition of recovery, this term now also includes residual municipal waste to the extent it is used as a fuel substitute. This already offers an incentive for operators of MSWIs to optimize energy recovery. Moreover, the revised EU Waste Framework Directive recognizes only those MSWIs as a recovery operation that operates at a high level of energy efficiency. This as well is bound to open up major potential for MSWIs to improve their CO_2 emission performance. Here, it should, however, be noted that the revised EU Waste Framework Directive places the recovery of materials through recycling higher up in the new 5-step hierarchy than combustion for energy recovery. Yet, the member countries are obligated to encourage the option that delivers the best overall environmental outcome.

Where waste is not routed to recovery but thermally disposed of, Art. 10 para. 2, sentence 3 of KrW-/AbfG mandates the maximum possible use of the energy generated by the treatment process as a basic obligation without, however, specifying any details. Art. 8 of 17. BImSchV requires the use of the heat released by the incineration process *(„...to the extent this is technically feasible and can be reasonably expected given the type and location of the plant...“)* and prescribes electricity generation under defined conditions – if the thermal output is sufficient to produce an electric terminal output of more than 0.5 megawatts (MW) - should there be no uses for the heat generated.

These regulatory and planning constraints have led to the types of energy recovery practices presented above which, from today's perspective, we consider that as insufficient.

Existing residual municipal waste incinerators (MSWIs), in particular, offer potential for optimizing energy recovery from waste. Here the operators' interest in reaching recovery status will be a major driving force which, under the revised EU Waste Framework Directive, presupposes a high level of energy efficiency. Possible incentives for MWSI operators to optimize their plants include:

- **compensation of the electricity / heat generated,**
- **investment grants,**
- **soft loans,**
- **possibility of offsets in emissions trading, monetary benefits, e.g. temporary tax holidays, non-monetary benefits, e.g. simplified planning process**
- **priority regulations for MSWI-generated electricity/heat in connection with an accreditation,**
- **subsidizing heat take-off for investors (if required, temporarily).**

Possible obligations include:

- **regulatory obligation to efficiently use the heat of combustion either directly or for electricity generation, e.g. as part of the permitting/ planning process or by way of a subsequent order,**
- **ban on exporting municipal solid waste amenable to energy recovery,**
- **heat export duty**

In our judgement, funding under the German Combined Heat and Power Act (KWK-G) and the use of the planning legislation are the most promising instruments for MSWIs. In the same way, we consider the funding of energy efficiency upgrade projects under the Federal Government's Climate Protection Initiative to be a suitable instrument in principle.

An extension of the funding scheme for biogenic waste fractions under the German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG) is currently not being considered, mainly because relinquishing the exclusivity principle – which is the prerequisite for funding - would jeopardize public acceptance of the Act.

Nor do we think that including MSWIs in the emissions trading system would be a suitable approach. The participation in emissions trading and hence, the allotment of emission allowances might induce MSWI operators to increasingly accept wastes with biogenic fractions and reject wastes having high fossil fractions in order to generate CO_2 certificates. This is not compatible with the disposal task of the MSWIs and would not make sense from the point of view of an environmentally sound waste disposal strategy.

Promotion through fiscal incentives (German CHP Act; Renewable Energies Heat Act; Market Incentives Program):

The Federal Environment Agency (Umweltbundesamt - UBA) recommended that a special provision should be included in the CHP Act (KWK-Gesetz) in order to secure a premium to MSWIs exporting CHP electricity to the grid.

However, the amended CHP Act passed by the Bundestag in June 2008 contains no special provisions for MSWIs. Funding support under this Act is restricted to high-efficiency CHP plants in terms of the EU Directive on the Promotion of Cogeneration in the Internal Energy Market adopted in 2004[30]. Furthermore, for upgrade projects to be eligible for funding, their capital cost must be at least 50 percent of that of a new CHP project. To what extent these criteria can be satisfied by MSWIs is still to be checked. Given these regulations and the demanding eligibility criteria, especially for upgrades to existing plants, we assume that only very few MSWIs will be eligible for a premium for CHP electricity fed to the grid. Nevertheless, the amended CHP Act provides, for the first time, for the funding of investments in heating grids, both new and extension projects. The Federal Environment Agency (UBA) welcomes this new regulation which applies to all CHP plants exporting useful heat. In this way 20 % of all eligible[31] capital expenditure for the construction of new and the extension of existing heating grids – including grids served by MSWIs – could be funded with up to Euro 5 million per project. Under the amended CHP Act, which entered into force on 1 January 2009, the Federal Government plans to make available a total amount of up to Euro 150 million per year for the promotion of heating grids via a para-fiscal levy scheme.

Although not yet published, the amended CHP Act was adopted by the Bundesrat in July 2008. Consequently, changes in the law text are no longer to be expected.

Since 1 January 2008 local heating grids as well have been eligible for funding under the Market Incentives Program (MIP) for Renewable Energy Sources. The new funding principles for the MIP issued on 5 December 2007 explicitly state the use of MSWI-generated heat as a new eligibility criterion for the new construction and extension of heating grids. Under this regulation, the biogenic fraction of municipal solid waste has for the first time been recognized as a renewable energy source eligible for funding[32]. Funding for local heating grids is limited to Euro 1 million per project.

Furthermore, the Renewable Energies Heat Act (EEWärmeG) of 7 August 2008 may give additional impetus to the greater use of MSWI-generated heat. This Act requires owners of newly constructed buildings with a usable floor space of greater than 50 square metres (m2) to cover a share of their thermal energy demand by renewable energy sources with effect from 2009. This obligation is deemed to be met if the owner covers his thermal energy demand via so-called alternative measures such as heat from a local or district heating grid. The use of thermal energy from a local or district heating grid is deemed to be an alternative measure if

a) a major share of the thermal energy originates from renewable energy sources,
b) at least 50 % of the thermal energy originates from heat recovery systems
c) at least 50 % of the thermal energy originates from CHP plants or
d) at least 50 % of the thermal energy originates from a combination of the measures stated under a) to c). Renewable energy sources as defined by this law also include the biodegradable fractions of municipal and industrial waste streams.

Proposal for an amendment of the planning legislation:

Another option to stimulate greater use of the energy potential of existing MSWIs is the application of planning instruments. We recommend that the zoning legislation should be changed to the effect that municipalities will in future be required to use heat available from existing MSWIs for new developments.

Such an obligation of the municipalities would have to be included in the planning legislation in the form of a so-called planning direction (which sets a mandatory priority rule that cannot be skipped in the individual case). This would also require an amendment of the German Building Code (BauGB). Here, it would be helpful to include a provision mandating the use of MSWI-generated heat in all cases where a MSWI exists and the future occupants of the development can be reasonably expected to use the heat so produced.

The Federal Environment Agency (UBA) is still checking to what extent further administrative regulations – an amended permitting law, for instance - would be helpful in enforcing that new waste incinerators may only be built at locations ensuring sufficient outlets for the heat produced.

8. The Future of Waste Management and the Role of Waste Incineration

Over the past few decades the cross-media approach to environmental protection along with the objective of maximizing the prevention and recovery of municipal solid waste have increasingly shaped our waste management policy. Expanding waste prevention and recovery while constantly improving the environmental performance and the quality of recovery is a challenging task for all parties involved.

Against this background, the Federal Environment Ministry presented in 1999 a strategy paper on the future of municipal solid waste disposal which was to usher in a paradigm change in the waste management policy. This strategy paper provided for

- **landfilling of untreated residual municipal waste to be banned,**
- **pretreatment of the waste by thermal or mechanical-biological methods prior to landfilling,**
- **energy recovery from the high-calorific waste fraction generated by mechanical biological treatment,**
- **the step-by-step closure of existing landfills and**
- **the further development and extension of treatment technologies by 2020,**

so as to ensure a virtually complete and high-quality recovery of all municipal solid waste in Germany.

Bio-degradable waste streams are diverted from landfills in order to prevent municipal waste disposal sites from becoming an environmental liability for future generations.

The so-called "Target 2020" strategy provides for municipal solid waste to be recovered to the maximum possible extent and its disposal in above-ground landfills to be largely abandoned by then. The number of municipal waste landfills has been steadily decreasing over the years. While there were still 562 municipal waste landfills in 1993 (Landfill Class II[33]), their number has gradually dropped via 297 in 2004 to around 160 today.

Banning land disposal of municipal solid waste from 1 June 2005 was the next logical step in the German waste management policy pursued to date. Target 2020 is part of a precautionary and environmental and health impact-based strategy for the further development of waste management to a resource-conserving material management while at the same time supporting the objective of the Federal Government's sustainability strategy to double Germany's resource productivity (raw materials and energy) by 2020.

In order to be able to largely abandon landfilling, the recycling and energy recovery potential of municipal solid waste must be tapped even more comprehensively. This will allow to further increase raw material and primary fossil energy savings, thus making a major contribution to climate protection and the conservation of our natural resources. Here, waste incineration has a central role to play in the future.

Municipal solid waste incinerators have fallen within a definitional limbo between waste disposal and waste recovery for a long time. The revised EU Waste Framework Directive defines the criteria for distinction by the so-called Rl-formula[34]. We support this approach in principle and take the position that waste incineration in a high-efficiency MSWI qualifies as recovery operation and that the energy efficiency of the plant should be determined on the basis of clear criteria.

After recovery of the energy potential, just under one third of the original waste volume remains in mineralized form such as slag, ash and filter dust. These incineration residues can be recycled provided that they satisfy defined criteria for an environmentally compatible reuse. This will typically require further treatment such as sorting, classifying, washing. Moreover, valuable metals can be recovered in the process.

If the incineration residues are reused as backfill in above-ground applications they are subject to the German soil protection legislation, while their reuse as a secondary building material in the construction industry will be regulated by a forthcoming federal ordinance on the reuse of mineral waste streams (Secondary Building Materials Ordinance) – both imposing stringent requirements for pollutant concentrations and releases. Highly polluted ash and filter dust may be used as structural fill in salt mines. While the filter dust meets the physical specifications for use as a structural fill for mining cavities and is thus routed to long-term use, the heavy metals-contaminated filter cake separated from the flue gas scrubber effluent can be disposed of to an underground landfill (salt cavern). Despite the high residue reuse levels attained so far – more than 85 percent of the incinerator slag (see section 3.2) – it is imperative to further improve the slag quality. This is all the more important in view of the stringent requirements of the forthcoming Secondary Building Materials Ordinance (Ersatzbaustoffverordnung).

While no major investment in new MSWIs is to be expected in the future - limited to replacements or upgrades to existing facilities – the coming years will see the construction of a large number of RDF-fired power plants at industrial locations with a high energy demand. These plants are characterized by high energy efficiency. Fuels used include high-calorific municipal waste fractions produced, for instance, by mechanical-biological processes or segregated from commercial waste. Keeping a sense of proportion in terms of planning and construction of RDF-fired power plants is vital in order to avoid overcapacities.

In conclusion, it can be said that complete municipal solid waste recovery is already largely accomplished through energy reclamation in advanced waste incineration facilities with energy recovery – though for the greater part not in the strict sense of the legal definition, but de facto through the efficient use of the energy embedded in the waste and the reuse of the combustion residues. Thermal waste treatment is a major cornerstone of the Target 2020 strategy and is bound to become even more important in view of the planned capacity extensions. Further potential for a high-quality complete recovery of residual waste in MSWIs can be tapped by increasing energy efficiency and optimizing treatment of the combustion residues. While some MSWI operators have been increasingly investing in slag treatment technology, disposal of the combustion residues still leaves room for improvement at many facilities. Part of the slag and filter dust generated is still being landfilled. Here, there is further material recovery potential that could be tapped by adequate slag treatment using a downstream slag washing unit, for instance, and enhanced non-ferrous metals extraction. In view of rising raw material prices, metals recovery from the boiler and filter ash at central smelters may also become an attractive option in the future.

For this reason, the Federal Environment Agency (UBA) continues to support complete waste recovery via the classification of MSWIs as recovery operations and encourages energy efficiency upgrades - through incentive instruments like the CHP Act for instance - and the improvement of the slag quality through the further development of the state of the art.

Besides, we are developing the Target 2020 strategy further to an effective closed-cycle material management where secondary raw materials will be increasingly recovered for reuse in an environmentally sound manner and resources conserved in line with the EU's Thematic Strategy on the Prevention and Recycling of Waste right through to the development of a European "recycling economy".

Despite the advances made to date in environmentally sound waste management in Germany and other industrialized countries, we would like to point out that this holds only true for a very small portion of the waste generated worldwide. There is enormous potential for improving the global state of the environment through sustainable waste management, notably in the areas of climate protection and the conservation of natural resources; this, in turn, will create export opportunities for countries that can draw on advanced waste treatment technologies, opportunities which should be increasingly exploited – also in terms of an "ecological industrial policy".

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Footnotes

1 "MSWI" stands for (municipal) solid waste incineration or waste incineration facilities treating predominantly mixed residual municipal waste.

2 17. Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes - Verordnung über

Verbrennungsanlagen für Abfälle und ähnliche brennbare Stoffe (Seventeenth Ordinance on the Implementation of the Federal Immission Control Act (Ordinance on Incineration Facilities for Waste and Similar Combustible Substances)

3 instead of elaborate wet scrubbing technology: optimized dry or quasi-dry flue gas cleanup

4 excluding RDF-fired (combined heat and) power plants

3 "Dioxins and furans" stands for polychlorinated dibenzodioxins and dibenzofurans (PCDDs/PCDFs).

6 At the end of the seventies, the chemical literature reported indications of dioxin and furan emissions. In response to these findings, the Federal Environment Agency became active in this field. Using a sampling technology developed in Hamburg, measurements conducted at the Stellinger Moor waste incinerator in 1986 confirmed the hypothesis that polychlorinated dibenzodioxins and dibenzofurans (PCDDs/PCDFs) are destroyed in the combustion chamber of the incineration plant but that a denovo-synthesis of these substances may occur in the flue gas path at low temperatures and defined conditions. This result formed the basis for the primary and secondary PCDD/PCDF abatement measures successfully implemented in today's waste incineration facilities. As an aside, it should be mentioned that the investigations under the Germany–wide dioxin measurement program went beyond waste incineration activities and laid the foundations for a comprehensive catalogue of measures to minimize dioxin and furan releases to the environment.

7 According to the Waste Storage Ordinance of 2001

8 Ordinance on the Incineration and Co-incineration of Waste

9 Explanatory note from BMU publication (2005): Incineration – A Potential Danger? Bidding Farewell to Dioxin Spouting
(http://www.bmu.de/files/pdfs/allgemein/application/pdf/muellverbrennung_dioxin.pdf):

Arsenic is twice as toxic as cadmium, five times as toxic as chromium and 500 times as toxic as benzene. To obtain a single measure for the toxicity of the carcinogenic heavy metals and organic compounds the individual toxicities are converted to arsenic equivalents. Two kilograms of cadmium have the toxicity of one kilogram of arsenic or correspond to an arsenic equivalent of one kilogram. The toxicity of dioxins is likewise converted to arsenic and is included in these data. The equivalent model has been derived from climate researchers who work with C02 equivalents.

10 IFEU: Contribution of the Waste Management Industry to Sustainable Development in Germany: UFOPLAN Project FKZ 203 92 309, Heidelberg 2004

11 IFEU: "Example of a complete high-quality recovery scheme in a MSWI with a special focus on climate relevance", UFOPLAN Project FKZ 205 33 311, Heidelberg 2007

12 Best Available Techniques - Reference Document

13 Selective catalytic reduction

14 Selective non-catalytic reduction

15 Öko-Institut (2005), ifeu (2007)

16 Alwast 2007

17 MBT here also includes mechanical and mechanical-physical treatment plants

18 ASA 2007:

19 LAGA 2008

20 UBA background paper "Dioxins", 2005;
http://www.umweltbundesamt.de/chemikalien/dioxine.htm

[21] Deposition of pollutants on surfaces of any kind

[22] Verordnung über Immissionswerte für Schadstoffe in der Luft - 22. Bundes-Immissionsschutzverordnung (Ordinance on Ambient Air Pollutant Levels – 22nd Federal Air Pollution Control Ordinance)

[23] Validity

[24] comprises carcinogenic effects

[25] comprises mutagenic effects

[26] Net volume (excluding waste from waste treatment plants); Destatis 2008

[27] IFEU: "Example of a complete high-quality recovery scheme in a MSWI with a special focus on climate relevance", UFOPLAN Project FKZ 205 33 311, Heidelberg 2007

[28] Total efficiency of electricity plus heat generation, including own consumption

[29] Interessengemeinschaft der Thermischen Abfallbehandlungsanlagen in Deutschland e.V.

[30] EU Directive 2004/8/EC of 11/02/2004

[31] This refers to the capital expenditure eligible for funding, i.e. all costs actually incurred for third-party services within the scope of the new construction or extension of heating grids. Not included are internal costs for planning and design, imputed costs, plot, insurance and financing costs as well as the cost of construction of heat transfer stations and their connection to the consumer.

[32] as against the Renewable Energy Sources Act (EEG) which also classifies the biogenic fraction of municipal solid waste as a renewable energy source but does not fund MSWI electricity fed to the grid because of the exclusivity principle.

[33] There are 5 landfill classes (0 to IV) for different types of waste. Class II landfill sites are predominantly used for the disposal of municipal solid waste and similar-type commercial waste.

[34]

Rl = (Ep - (Ef + Ei))/ (0.97 x (Ew + Ef))

Ep – means annual energy produced as heat or electricity
It is calculated with energy in the form of electricity being multiplied by a factor of 2.6 and heat produced for commercial use multiplied by a factor of 1.1 (GJ/year).

Ef - means annual energy input to the system from fuels contributing to the production of steam (GJ/year).

Ew – means annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year)

Ei - means annual energy imported excluding Ew and Ei (GJ/year)
0.97 – factor accounting for energy losses due to bottom and fly ash and radiation