**Forschungszentrum Karlsruhe**
in der Helmholtz-Gemeinschaft
**Wissenschaftliche Berichte**
FZKA 7346

**Bioenergy NoE**

# Needs and Challenges in Implementing Key Directives

## *Waste-to-Energy Progress*

**J. Vehlow, B. Bergfeldt, C. Wilén, H.J.M. Visser**
**Institut für Technische Chemie**

**Dezember 2007**

Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft
Wissenschaftliche Berichte
FZKA 7346

# NEEDS AND CHALLENGES IN IMPLEMENTING KEY DIRECTIVES
-
# *WASTE-TO-ENERGY PROGRESS*

**J. Vehlow, B. Bergfeldt, C. Wilén*, H.J.M. Visser****

Institut für Technische Chemie

* VTT Technical Research Centre of Finland, Espoo, Finland
** ECN Energy Research Centre of the Netherlands, Petten, The Netherlands

**Forschungszentrum Karlsruhe GmbH, Karlsruhe**
**2007**

**Prepared by members of the**

**EU Network of Excellence Bioenergy**

**J. Vehlow, B. Bergfeldt, Forschungszentrum Karlsruhe GmbH, Germany**

**C. Wilén, VTT Technical Research Centre of Finland, Espoo, Finland**

**H.J.M. Visser, ECN Energy Research Centre of the Netherlands, Petten, The Netherlands**

Sponsored by the EC DG Research.
Bioenergy NoE is a partnership of eight leading bioenergy institutes that are integrating their expertise and activities to foster excellence in European bioenergy RD&D.
For more information about Bioenergy NoE please visit the website:
www.bioenergynoe.org



Forschungszentrum Karlsruhe GmbH
Postfach 3640, 76021 Karlsruhe

Mitglied der Hermann von Helmholtz-Gemeinschaft
Deutscher Forschungszentren (HGF)

ISSN 0947-8620

urn:nbn:de:0005-073466

## Übertragung von EU-Richtlinien in nationales Recht – Energetische Verwertung von Abfällen


Zusammenfassung

In der Europäischen Union ist der Abfallsektor praktisch vollständig durch EU-Richtlinien geregelt und damit werden, wenn auch noch nicht zur Zeit, so doch in absehbarer Zukunft, zur Abfallentsorgung in der EU homogene Lösungen zu finden sein. Die wichtigste Richtlinie ist die Richtlinie 99/31/EG des Rates zu Abfalldeponien von 1999. Sie setzt die Standards für die Ablagerung von Abfällen. Das vorgegebene Ziel ist eine Reduktion der direkten Ablagerung organischer oder reaktiver Abfälle. Von besonderer Bedeutung in diesem Kontext sind auch die schon 1975 erlassene Richtlinie 75/442/EEG des Rats über Abfälle und die Richtlinie 2000/76/EC des Europäischen Parlaments und des Rats zur Verbrennung von Abfällen aus dem Jahr 2000.

Dieser Bericht beschreibt die wesentlichen EU-Bestimmungen zur Abfallbehandlung und deren Adaption in nationales Recht in den Ländern Deutschland, Finnland und den Niederlanden, zwei hoch industrialisierten und dicht besiedelten Ländern und einem Land das mehr durch Land- und Forstwirtschaft sowie forstwirtschaftliche Industrie charakterisiert ist.

Die Deponierichtlinie hat in den letzten Jahren große Veränderungen in den abfallrechtlichen Maßnahmen in allen Ländern, allerdings in unterschiedlichem Ausmaß gehabt. Die Niederlande und Deutschland haben nicht nur starke Anstrengungen zur Verwirklichung der Ziele der Abfallrichtlinie unternommen, in diesen beiden Ländern gibt es nationale Initiativen in diese Richtung bereits in den neunziger Jahren des 20. Jahrhunderts und einige der damals beschlossenen Maßnahmen können als Ausgangspunkt der Deponierichtlinie angesehen werden. In beiden Ländern hatte Recycling schon damals einen hohen Stellenwert. Der wesentliche Unterschied war die Stellung der Energierückgewinnung in beiden Ländern; die in den Niederlanden bereits um 1990 ein essentieller Teil des nationalen Abfallrechts wurde. Heute ist eine große Kapazität an modernen Verbrennungsanlagen in den Niederlanden errichtet, die zum Teil sogar importierten Abfall, z.B. aus Deutschland, behandelten. Diese Bedeutung der Abfallverbrennung wurde durch eine hohe Deponiesteuer gefördert, die die Ablagerungskosten nahezu verdoppelt.

Der starke Widerstand gegen Abfallverbrennung, betrieben durch NGOs, lokale Gruppierungen, aber auch durch Politik und Medien führte zu einer Stagnation im Bau von Abfallverbrennungsanlagen in derselben Zeit. Obwohl die TA Siedlungsabfall von 1993 bereits ein Ablagerungsverbot für unbehandelten Siedlungsabfall ab 2005 vorsah, und obwohl dieses Ziel uneingeschränkt akzeptiert wurde, herrschte trotzdem die allgemeine Meinung vor, dass jede Behandlung der Verbrennung vorzuziehen sei. In dieser Zeit tauchten alternative Verfahren zur thermischen Abfallbehandlung, Pyrolyse, Vergasung und kombinierte Prozesse auf dem Markt auf und erregten großes Interesse. Nachdem zwei großtechnische Realisierungen dieser Prozesse scheiterten – 1999 das Schwel-Brenn-Verfahren der Firma Siemens und 2004 das Thermoselect-Verfahren in Karlsruhe – wurden alle Projekte auf der Basis dieser Verfahren eingestellt.

Aus vorwiegend politischen Gründen wurde die mechanisch-biologische Abfallbehandlung gefördert und eine Reihe entsprechender Anlagen wurde errichtet. Diese Anlagen kamen unter Kritik im Hinblick auf ihre Umweltverträglichkeit. Die Reststoffe entsprachen nicht den Vorgaben der deutschen Deponieverordnung und auch das Produkt, der Abfall basierte Sekundärbrennstoff, hatte und hat mit Qualitätsproblemen zu kämpfen. Halogen und Schwermetallgehalte erlauben in den meisten nicht die Verbrennung in Industrieöfen sondern erfordern eine Gasreinigung zur Einhaltung der 17. BImSchV, der deutschen Emissionsverordnung für die Abfallverbrennung. Dies aber macht den Einsatz von Sekundärbrennstoff teuer.

Diese Situation änderte sich in den letzten Jahren als klar wurde, dass nach der Deponieverordnung eine Ablagerung reaktiver organischer Abfälle ab 1.6.2005 nicht mehr möglich

ist. In kurzer Zeit wurde eine Kapazitätserhöhung von Abfallverbrennungsanlagen um 6 Mio Tonnen oder knapp 50 % realisiert und es ist zu erwarten, dass ab 2007 ausreichende Behandlungskapazität für die Restabfälle aus dem Siedlungsbereich zur Verfügung steht. Die Situation könnte noch kritisch sein für die Abfälle aus dem kommerziellen und leichtindustriellen Bereich.

Besonders in diesem Bereich wird auf die Herstellung von Sekundärbrennstoff (SBS) gesetzt und es ist eine Reihe von Kraftwerken in Planung die neben SBS auch Biomasse verarbeiten. Es ist abzuwarten, ob diese Strategie auf dem Markt erfolgreich sein wird, denn SBS und Biomassen haben Inhaltstoffe wie Halogene und Alkaliverbindungen, die nicht nur besondere Beachtung bezüglich der Emissionen sondern auch im Hinblick auf Ablagerungen und Korrosion in Brennraum und Kessel erfordern.

In Finnland ist die Energiegewinnung ein wesentliches Ziel der nationalen Abfallstrategie. In dem dünnbesiedelten Land ist eine Abfallverbrennung meistens aus ökonomischen Gründen obsolet. Daher fördert die finnische Regierung bereits seit Jahren die Mitverbrennung in Kraftwerken und anderen Feuerungen. Die Waste Incineration Directive setzte dieser Strategie ein Ende, da die Ausrüstung von Kraftwerken mit entsprechenden Gasreinigungsanlagen zu teuer ist. Daher kann eine Mitverbrennung oder die Verbrennung von Synthesegas aus einer Abfallvergasung nur bei Einsatz besonders separierter und behandelter Abfallströme akzeptiert werden. Die Behörden haben erste Erlasse zur Umsetzung der Landfill Directive Herausgegeben, eine detaillierte Strategie steht aber noch aus.

Zur Situation in den neuen Mitgliedsländern fehlen spezifische Informationen, sie dürfte aber ähnlich der in Finnland sein. Die neuen Mitglieder haben Übergangslösungen und müssen erst später als die der EU-15 die Vorgaben der Landfill Directive erfüllen. In einigen dieser Staaten sind sogar geordnete Deponien kaum zu finden.

Österreich hat die 65 % Reduktion organischen Abfalls, die für 2016 vorgesehen ist, vor allem durch Kompostierung (>35 %) erfüllt. Hier erhebt sich die Frage, wie weit eine derartige Strategie zu einer nachsorgefreien Abfallwirtschaft führt.

Das Vereinigte Königreich hat von den alten EU-Mitgliedern die größten Schwierigkeiten, die Landfill Directive umzusetzen. Auch hier wird derzeit die mechanisch-biologische Behandlung priorisiert.

Die Mittelmeerländer Italien, Portugal und Spanien erweitern zurzeit ihre Verbrennungskapazitäten. Hier fehlen Energieabnehmer, besonders für den Wärmeanteil. Erfolgversprechend könnte Fernkälte sein, die aber hohe Investitionen in ein Verteilernetz erfordert.

In etlichen Ländern wird eine Deponieabgabe als wirkungsvolles Mittel zur Durchsetzung der Ziele der Landfill Directive gesehen. In Deutschland gelang dies auch ohne ein solches fiskalisches Mittel.

Eine offene Frage im Hinblick auf die öko-effiziente energetische Nutzung von Abfällen ist das Potential der Blogasherstellung. Diese Technologie könnte sich als erfolgreicher Weg für die Behandlung nasser biogener Abfälle, eventuell gemeinsam mit landwirtschaftlichen Reststoffen und Klärschlamm herausstellen. Offenes Problem neben der technologischen Entwicklung ist der Verbleib der Reststoffe dieser Prozesse. Die bevorzugte Kompostierung könnte zu Problemen bei der Schadstoffbeherrschung werden.

Die gesammelten Informationen in den drei Ländern erlauben keine Empfehlungen für Strategien in anderen Länden. Universallösungen für die gesamte EU werden nicht sinnvoll sein, so sehr auch die Behörden solche herbeiwünschen mögen. Es ist aber zu erwarten, dass in den meisten Ländern der EU die energetische Verwertung von Abfällen an Bedeutung gewinnen wird. Probleme bereiten

- die hohen Kosten der Abfallverbrennung,
- mangelnde politische und teilweise gesellschaftliche Akzeptanz,
- in den nordischen Ländern eventuell geringe Strompreise,
- in den südlichen Ländern die fehlende Senke für Wärme, was den Markt für Kraft-

Wärme-Kopplungen einschränkt, und schließlich
- eine überzeugende Lösung für den Verbleib der Reststoffe, insbesondere derer aus der Gasreinigung.

Eine Reihe von Strategien und Technologien ist erprobt und auf dem Markt, ihr Einsatz hängt sehr stark von den lokalen Gegebenheiten ab. Zukünftige Aktivitäten zu den folgenden Themen sind anzuraten:
- welche Strategien sind am besten geeignet für Gegenden mit geringer Bevölkerungsdichte und für ländliche Bereiche,
- kann Sekundärbrennstoff, der aus getrennt gesammelten Abfällen hergestellt wird, die für eine Verwertung in Kraftwerken und Industriefeuerungen notwendige Qualität garantiert erreichen,
- welches Potential haben die Biogasverfahren im Hinblick auf die Erfüllung der Vorgaben der Landfill Directive,
- welches ist die best-geeignete Entsorgung von festen Prozessreststoffen, besonders solchen aus der Gasreinigung und aus biologischen Verfahren.

Mit Blick auf die ersten drei Themen kann erwartet werden, dass Länder mit einem gut etablierten Fernwärmemarkt ihren Schwerpunkt auf die Herstellung möglichst sauberer Brennstoffe aus separat gesammelten Abfällen legen werden und diese in geeigneten Anlagen mit Kraft-Wärme-Kopplung nutzen werden. Die zurückbleibenden, stark schadstoffhaltigen Fraktionen müssen in wenigen zentralen Anlagen inertisiert werden. Von besonderem Interesse wird es sein, die Verbrennung hochkaloriger, aber auch stark biogener Abfälle in konventionellen Feuerungsanlagen zu beherrschen.

Die Biogasherstellung benötigt vor ihrem flächendeckenden Einsatz für Abfälle aus dem Siedlungsbereich technische Weiterentwicklung, vor allem im Hinblick auf ihre Umweltauswirkungen. Hier könnte ein Vergleich erfolgreicher Lösungen in hochindustrialisierten und alten EU-Staaten – z.B. Österreich und Deutschland – und in einem Land mit vorwiegend agrarischer Struktur – z.B. Polen – hilfreich sein.

Der vierte Punkt ist von fundamentaler Bedeutung nicht nur für abfallbasierte Verfahren sondern für Biomasseprozesse generell. Bei den Abfällen steht die Kontrolle von Schadstoffen im Vordergrund, wobei die wasserlöslichen Salze in ihrer Bedeutung ständig übersehen werden. Bei Biomasseverfahren fehlt eine Einschätzung, in welchem Maße Nährstoffe zurückgewonnen werden können und sollten.

## Executive Summary

In the European Union the waste management sector is almost totally regulated by EU Directives. A core directive is the 1999 issued Landfill Directive 99/31/EC which sets standards for the final disposal of waste and aims for reducing the direct deposition of organic or reactive waste on landfills. Important in this context are also the Framework Directive on Waste Disposal 75/442/EEC and the Waste Incineration Directive 2000/76/EC. A report was put together which describes the basic EU regulation on waste management and the respective adaptation of the EU directives, preferentially the Landfill Directive to national law and its influence on the waste management strategies in the three countries Finland, Germany and The Netherlands. This selection comprises two densely populated and highly industrialised countries and one country with low population density which is more characterised by agriculture, forestry, and forest related industry.

The waste management situation described for these countries and its changes during the last few years indicates a strong influence of the Landfill Directive on the respective national regulations. However, the actual status of adaptation shows no uniform picture. The Netherlands and Germany have not only taken strong actions to comply with the targets of the Landfill Directive, their national initiatives in the early nineties of the last century can be looked upon as the basis of this directive.

Both countries gave recycling a high priority and therefore it is no surprise to see them as spear head for this strategy in the EU - and even world wide – today. A main difference between the two countries is seen in the importance they gave to waste-to-energy. The Dutch regulations had already in the early nineties consequently included energy recovery as an essential part into their National Waste Management Act. Following this decision and also due to the fact that the existing waste incinerators had to be upgraded a high capacity of state-of-the-art incineration was built all over the country. These plants did to some extent even treat imported waste, mainly from Germany. The establishment of today's waste management practice was definitely supported by the high landfill tax which doubles almost the disposal costs.

Since waste incineration was strongly opposed in Germany by NGOs, local interest groups, but also to a great extent by media and politicians, there was almost no enlargement of the installed capacity during the nineties of the last century. Although the fundamentals of the German waste management strategy, to prevent disposal of reactive waste, was widely accepted, there was also wide-spread understanding that all measures other than incineration should be applied. This was the period when alternative thermal treatment processes like pyrolysis, gasification or combined processes became of high interest. After the failure of two full-scale realisations of such processes – in 1999 the Siemens Thermal Recycling Process in Fürth and in 2004 the Thermoselect Process in Karlsruhe – all projects for such processes were withdrawn.

The major political and also public preference, however, was mechanical-biological treatment with the effect that a great number of such plants were built. However, the environmental quality of such plants came under criticism with time and the residues from such plants were also not in line with the German TASi and especially the German Landfill Ordinance. Another problem arose from the quality of the product of mechanical biological treatment, the fuel fraction. Due to its potentially high halogen and heavy metal inventory it could not just be burnt in utility boilers of industry furnaces but fell under the regime of the air emission regulation, the 17. BImSchV, which made this strategy expensive or even obsolete.

This situation changed only few years ago when local authorities became aware that the full inaction of the Landfill Ordinance and with that the landfill ban for organic waste was unavoidable. In short time a substantial increase in incineration capacity by approx. 50 % or almost 6,000,000 Mg was realised. Hence it can be expected that in 2007 there is enough capacity in operation to treat the total amount of residual waste from the municipal sector. A not really solved problem is the disposal of commercial and light industrial waste. There is a

strong tendency to promote the production of SRF which should preferentially be burnt in dedicated combustion plants, equipped with air pollution control systems. In view of still existing animosity against waste incineration such SRF plants which can also be fuelled with biomass sell better to the public than waste incinerators – although they are not much different from those. Another problem associated with the combustion of SRF with high biogenic content is the risk of fouling and deposition in the combustion chamber and the boiler caused by the high alkali inventory.

The waste management situation in Finland is quite different. Energy recovery from waste was an important pillar of the Finnish strategy. In this sparsely populated country, however, there are not many locations were pure energy recovery from waste makes sense from an economic point of view. That is why the Finnish government aimed mainly for co-treatment of waste in power plants or other boilers, a practice in many places already established years ago. The Waste Incineration Directive stopped this disposal route in most cases since the installation of an air pollution control system to comply with the air emission standards made it too expensive. Hence co-treatment, either by direct addition of waste fuel or by utilisation of synthesis gas from waste gasification will only be possible for well separated and clean waste fractions and with that the disposal of the more or less polluted residual waste fractions is yet an unsolved problem. The authorities have released basic regulations to comply with the Landfill Directive which contain energy recovery, but a detailed strategy is still missing.

Although the authors have no specific information, the situation in the eastern new EU member states is ought to be similar to that in Finland. These got a longer time for adaptation than the 15 old EU members since in many place there existed after the fall of the 'Iron Curtain' even no sanitary landfills.

Basic information available to the authors on other EU countries shows a rather fragmented picture. Austria e.g. has already today fulfilled the goals of 65 % reduction set in the directive for 2016. This has mainly been done by composting (>35 %). Recycling, energy recovery and landfilling account roughly for 20 % each. The question to be answered is whether that much compost has the quality to be utilised and whether such strategy is in line with the intention of the Landfill Directive: to establish an aftercare free waste disposal.

The UK is currently far behind any schedule to meet the targets of the Landfill Directive. For political reasons mechanical-biological treatment is highly promoted and it will be of great interest whether the UK finds an acceptable outlet for the products from such processes.

Southern member states like Italy, Spain, and Portugal are extending their waste-to-energy capacities, in these countries the utilisation of that energy causes problems. In summertime there is no market for heat other than direct steam use in industrial processes and a market for central cooling is not easy to be established.

It can be assumed that a landfill tax would be a driver for energy recovery but the situation in Germany shows an expansion of energy recovery by legal actions only.

An open question concerning eco-efficient energy recovery is the potential role of biogas production in future waste management systems, especially for rural areas. This technology could theoretically become an efficient tool for wet organic waste, especially if the wet municipal solid waste fraction could be co-treated with agricultural residues and eventually with sewage sludge. A pending problem is seen in the final destination of the residues for which the today often practised composting might not be the ultimate solution.

The acquired information does not allow drawing conclusions in terms of recipes for other countries. It is obvious that there will be no universal solution for all EU countries, even if politicians and bureaucrats would like to install one. Of course in most countries a more intense energy recovery can be expected. Obstacles are

- the high costs of waste-to-energy systems,
- the lack in political and public acceptance,
- in northern countries eventually the low revenues for power,

- in southern countries the lack in a market for heat, thus preventing cheap CHP solutions, and finally
- a convincing solution of the final disposal of process residues, especially those from gas cleaning..

As a cautious general conclusion it can be stated that a future increase in energy recovery from waste is to be expected in almost all EU countries which have not yet reached the targets of the Landfill Directive. There are many technologies on the market and every specific solution depends strongly on local conditions. However, some topics can be identified for further activities:

- which strategies are best suited for low population density and mainly rural areas,
- can SRF produced from source separated waste reach a quality which allows its combustion or co-combustion in conventional furnaces,
- what is the potential of biogas production in terms of meeting the targets of the landfill directive,
- what is the most eco-efficient management of residues, especially those from gas cleaning and from biological processes.

The first three topics are supposed to go to a great extent together. For countries like Finland with low population density but a well established power and heat market 'clean' SRF is a promising option to dispose most of the waste of in a way which complies with the EU directives. There is a need to get more information of the effects of SRF with high calorific value and/or with high biogenic inventory on the combustion process in conventional fluidised beds, grate systems and eventually also in pulverised coal boilers.

Biogas production which has a good potential for energy recovery from agricultural waste needs more detailed investigation in terms of the actually applied technologies, their compliance with the Landfill Directive and their importance in the local energy supply system. Such investigation could be accompanied and supported by a case study comparing successful solutions in an old and highly industrialised EU member state – e.g. Austria or Germany – and in a rural area in e.g. Poland.

The forth topic is a fundamental one not only for waste-to-energy systems but also for biomass combustion. In the first case the main issue is the control and final destination of heavy metals and – often overlooked – of highly water soluble salts. These are the problematic ingredients in gas cleaning residues. For biomass combustion residues there is a lack in knowledge to what extent the recovery of nutrients makes sense, especially if contaminated biomass is used. A further already above mentioned issue for biogas systems is the management of digestion residues which may have a potential as fertilisers after composting but may cause problems if wet organic waste, agricultural residues, and sewage sludge are co-treated. For establishing sound practice in this area a primary study should be performed to get a detailed overview of applied strategies. This should be followed by an experimental part for the control of residues from different processes and after different treatment measures.

## Table of Content

## 1 Introduction

In the EU the waste management sector is almost totally regulated by EU Directives which have already been or will in near future be adopted by all member states. This practice started very early in the seventies of the last century already and resulted in a harmonisation of national regulations in terms of management strategies, technological measures, and environmental standards.

The fundamental Framework Directive on Waste Disposal 75/442/EEC [European Council 1975] was released in 1975. It gives general advises on waste management and disposal. Its objectives are the prohibition of uncontrolled discarding, discharge and disposal of waste and the promotion of prevention, recycling and conversion of wastes with a view to their reuse. The respective Articles in this respect are:

*Article 3*

*1. Member States shall take appropriate steps to encourage the prevention, recycling and processing of waste, the extraction of raw materials and possibly of energy there from and any other process for the re-use of waste.*

*They shall inform the Commission in good time of any draft rules to such effect and, in particular, of any draft rule concerning: (a) the use of products which might be a source of technical difficulties as regards disposal or lead to excessive disposal costs; (b) the encouragement of: - the reduction in the quantities of certain waste,*

*- the treatment of waste for its recycling and re-use,*
*- the recovery of raw materials and/or the production of energy from certain waste;*
*(c) the use of certain natural resources, including energy resources, in applications where they may be replaced by recovered materials.*

*Article 4*
*Member States shall take the necessary measures to ensure that waste is disposed of without endangering human health and without harming the environment, and in particular: - without risk to water, air, soil and plants and animals,*
*- without causing a nuisance through noise or odours,*
*- without adversely affecting the countryside or places of special interest.*

These are rather soft statements and it needs a number of other Directives to specify the principles to be followed to establish a practicable and long-term environmentally acceptable strategy for '*the prevention, recycling and processing of waste, the extraction of raw materials and possibly of energy there from and any other process for the re-use of waste*'.

A core directive is the 1999 issued EU Directive 99/31/EC on the landfill of waste [European Council 1999] which sets standards for the final disposal of waste and aims for reducing the direct deposition of organic or reactive waste on landfills.

This report intends to give an overview about the effects of this directive on the development of management strategies of municipal solid waste in the three countries Finland, Germany, and The Netherlands. After a short overview of the EU regulations and especially the targets of the EU Landfill Directive the legal status and the consequences of its adaptation in the three countries will be described. The focus will be on

- consequences for waste management,
- current practice,
- problems in terms of treatment facilities,
- the cost situation and
- future perspectives.

Consequences for the energy market, the elaboration of problems caused by the adaptation as well as solutions to overcome those problems will also be dealt with.

# 2 The EU Regulation on Final Disposal

## 2.1 Landfill Directive

The EU Landfill Directive 99/31/EC and its amendment with the acceptance criteria of 2003 [European Council 1999] is the key regulation for the disposal of all kinds of waste and residues - hazardous, non-hazardous, and inert - in the EU. This directive is intended to prevent or reduce the adverse effects of the landfill of waste on the environment, in particular on surface water, groundwater, soil, air and human health and sets up a system of operating permits for landfill sites.

The most important part is Article 5 which requires a reduction of biodegradable waste going to landfills. The targets are the reduction of biogenic waste compared to the situation in 1995 by

- 25 % in 2006,
- 50 % in 2009, and
- 75 % in 2016.

The newly accessed countries have transitional periods for full adoption of these EU regulations.

Measures to achieve those targets should include in particular recycling, composting, biogas production or materials and energy recovery. Consequently this Directive does not only promote recycling and composting but even more waste incineration which is for the time being the only proven and efficient technology to destroy organic matter.

Criteria to be followed for the acceptance of waste on a landfill are laid down in Annex II and include

- basic characterisation,
- compliance testing, and
- on-site verification.

The Landfill Directive specifies only general criteria and principles to be obeyed for the acceptance of a waste or residue on a landfill but it does not contain specific parameters and their limit values. Each country is obliged to define procedures and set standards which have to be met by a material to be listed for a specific class of landfill.

An efficient instrument used in some EU countries to divert biogenic waste from landfills is a landfill tax which is imposed on untreated waste going to disposal sites like issued in Finland and in The Netherlands. Other countries like Germany rely on legislative regulations which guarantee the compliance with the respective targets of the Landfill Directive.

## 2.2 Council Decision 2003/33/EC

Whereas the Landfill Directive is a kind of framework directive which outlines the principles of final disposal, in the Council Decision 2003/33/EC [European Council 2003] general criteria for the acceptance of waste on each landfill class are laid down. This decision defines also the methods to be used for sampling and testing of waste.

**Table 1** Limit leaching values for the acceptance of waste at an inert waste landfill, for granular non-hazardous waste accepted in the same cell as stable non-reactive hazardous waste, and for granular waste accepted at landfills for hazardous waste, calculated at L/S = 2 and 10 l/kg dry matter for total release and directly expressed in mg/l for $c_0$ (in the first eluate of percolation test at L/S = 0.1 l/kg)

| ***component*** | ***inert waste landfill*** | | | ***granular non-hazardous waste*** | | | ***hazardous waste landfill*** | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***L/S=2*** | ***L/S=10*** | ***$c_0$*** | ***L/S=2*** | ***L/S=10*** | ***$c_0$*** | ***L/S=2*** | ***L/S=10*** | ***$c_0$*** |
| ***As*** | 0.1 | 0.5 | 0.06 | 0.4 | 2 | 0.3 | 6 | 25 | 3 |
| ***Ba*** | 7 | 20 | 4 | 30 | 100 | 20 | 100 | 300 | 60 |
| ***Cd*** | 0.03 | 0.04 | 0.02 | 0.6 | 1 | 0.3 | 3 | 5 | 1.7 |
| ***$Cr_{total}$*** | 0.2 | 0.5 | 0.1 | 4 | 10 | 2.5 | 25 | 70 | 15 |
| ***Cu*** | 0.9 | 2 | 0.6 | 25 | 50 | 30 | 50 | 100 | 60 |
| ***Hg*** | 0.003 | 0.01 | 0.002 | 0.05 | 0.2 | 0.03 | 0.5 | 2 | 0.3 |
| ***Mo*** | 0.3 | 0.5 | 0.2 | 5 | 10 | 3.5 | 20 | 30 | 10 |
| ***Ni*** | 0.2 | 0.4 | 0.12 | 5 | 10 | 3 | 20 | 40 | 12 |
| ***Pb*** | 0.2 | 0.5 | 0.15 | 5 | 10 | 3 | 25 | 50 | 15 |
| ***Sb*** | 0.02 | 0.06 | 0.1 | 0.2 | 0.7 | 0.15 | 2 | 5 | 1 |
| ***Se*** | 0.06 | 0.1 | 0.04 | 0.3 | 0.5 | 0.2 | 4 | 7 | 3 |
| ***Zn*** | 2 | 4 | 1.2 | 25 | 50 | 15 | 90 | 200 | 60 |
| ***Chloride*** | 550 | 800 | 460 | 10000 | 15000 | 8500 | 17000 | 25000 | 15000 |
| ***Fluoride*** | 4 | 10 | 2.5 | 60 | 150 | 40 | 200 | 500 | 120 |
| ***Sulphate*** | 560[(1)] | 1,000[(1)] | 1500 | 10000 | 20000 | 7000 | 25000 | 50000 | 17000 |
| ***Phenol index*** | 0.5 | 1 | 0.3 | - | - | - | | | |
| ***DOC[(2)]*** | 240 | 500 | 160 | 380 | 800 | 250 | 480 | 1000 | 320 |
| ***TDS[(3)]*** | 2500 | 4000 | - | 40000 | 60000 | - | 70000 | 100000 | - |

*[(1)] If the waste does not meet this limit value for sulphate, it may still be considered as complying with the acceptance criteria if the leaching does not exceed either of the following values: 1500 mg/l as $c_0$ at L/S = 0.1 l/kg and 6000 mg/kg at L/S = 10 l/kg. It will be necessary to use a percolation test to determine the limit value at L/S = 0.1 l/kg under initial equilibrium conditions, whereas the value at L/S = 10 l/kg may be determined either by a batch leaching test or by a percolation test under conditions approaching local equilibrium.*

*[(2)] If the waste does not meet this value for DOC at its own pH value, it may alternatively be tested at L/S = 10 l/kg and a pH between 7.5 and 8.0. The waste may be considered as complying with the acceptance criteria for DOC, if the result of this determination does not exceed 500 mg/kg for inert waste respectively 800 mg/kg for granular non hazardous waste.*

*[(3)] The value for total dissolved solids (TDS) can be used as an alternative to the values for sulphate and chloride.*

**Table 2** Limit values for the total content of organic parameters for the acceptance at an inert waste landfill in mg/kg

| **Parameter** | ***Value*** |
|---|---|
| **TOC (total organic carbon)** | 30,000[(1)] |
| **BTEX (benzene, toluene, ethylbenzene and xylenes)** | 6 |
| **PCBs (polychlorinated biphenyls, 7 congeners)** | 1 |
| **Mineral oil (C10 to C40)** | 500 |
| **PAHs (Polycyclic aromatic hydrocarbons (total of 17)** | Member states to set limit value |

*[(1)] In the case of soils a higher limit value may be admitted by the competent authority, provided the DOC value of 500 mg/kg is achieved at L/S 0 10 l/kg either at the soil's own pH or at a pH value between 7.5 and 8.0..*

The acceptance criteria base first of all on leaching tests, but also other characteristic properties where necessary and available. These other criteria are mainly associated with the organic inventory of the waste. On top of that mechanical parameter limit should be set by the national authorities.

There are criteria for inert waste, for non-hazardous waste and for hazardous waste. For non hazardous waste the member states may create subcategories of landfills. A special one could be for municipal solid waste which is separately collected and can be admitted without testing.

The acceptance criteria at a landfill for inert waste and those for granular non hazardous waste on cells which also accept stable non reactive hazardous waste are compiled in Table 1 and Table 2.

For granular hazardous waste to be accepted at landfills for non-hazardous waste apply the same leaching criteria as for granular non-hazardous waste which is landfilled in the same cell as stable non reactive hazardous waste (see Table 1). For this waste, however, additional limiting criteria are

- a TOC value of 5 % (a higher value may be admitted by the competent authority, provided that the DOC value on 800 mg/kg is achieved at L/S = 10 l/kg),
- a minimum pH value of 6 and
- the ANC (acid neutralisation capacity) must be evaluated.

For hazardous landfills there are the following additional criteria to be met:

- a TOC value of 6 % (a higher value may be admitted by the competent authority, provided that the DOC value on 1000 mg/kg is achieved at L/S = 10 l/kg) or
- alternatively a LOI (loss on ignition)value of 10 % and
- the ANC must be evaluated.

These criteria are guidelines for the respective regulation in the member countries and some countries have already used these limits for new standards (e.g. United Kingdom).

## 2.3 Waste Incineration Directive

Based on the principle statements about health and environment protection laid down already in the Waste Framework Directive of 1975 and combining as well as strengthening former standards found in various directives (e.g. 89/369/EEC and 89/429/EEC on the prevention and reduction of air pollution from municipal waste incineration plants, 94/67/EC on the incineration of hazardous waste) the Directive 2000/76/EC of the European Parliament and of the Council on the incineration of waste, the so-called Waste Incineration Directive was published by 28. December 2000 [European Parliament and Council 2000].

The Waste Incineration Directive contains in its annexes emission limits for waste incineration and also specific provisions for the co-combustion of waste in cement kilns and power plants. On top of that concentration limits for liquid effluents from wet flue gas cleaning are contained.

The statements concerning residues from waste incineration or co-combustion are rather general: these should be minimised and as far as possible utilised.

Table 3 compiles the daily average and the half-hourly emission data for the continuously to be monitored off-gas species for the Waste Incineration Directive as well as the respective daily average data in the German and Dutch emission regulations. It is obvious from the data shown in the table that the EU emission limits are almost identical in the two states

**Table 3** Emission data in the Waste Incineration Directive and the respective daily average regulations in Germany and The Netherlands in mg/m$^3$ (273 K, 101.3 kPa, 11 vol.-% $O_2$, dry)

| *parameter* | *EU 2000/76/EC (daily)* | *EU 2000/76/EC (half-hourly)* | *Germany 17. BImSchV* | *Netherlands* |
|---|---|---|---|---|
| ***dust*** | 10 | 30 | 10 | 5 |
| ***CO*** | 50 | 100 | 50 | 50 |
| ***TOC*** | 10 | 20 | 10 | 10 |
| ***HCl*** | 10 | 60 | 10 | 10 |
| ***HF*** | 1 | 4 | 1 | 1 |
| ***$SO_2$*** | 50 | 200 | 50 | 40 |

| | | | | |
|---|---|---|---|---|
| ***$NO_x$ (as $NO_2$)*** | 200 | 400 | 200 | 70 |

Heavy metals and PCDD/F have to be measured periodically in sampling campaigns lasting 0.5 to 8 h each. The respective limits to be met are – again with those in Germany and The Netherlands – compiled in Table 4

**Table 4** Average emission data to be measured over a sampling period between 0.5 and 8 h in the Waste Incineration Directive and the respective regulations in Germany and The Netherlands for the not continuously monitored species in $mg/m^3$ (273 K, 101.3 kPa, 11 vol.-% $O_2$, dry; PCDD/F in $ng(I\text{-}TE)/m^3$)

| ***parameter*** | ***EU 2000/76/EC*** | ***Germany 17. BImSchV*** | ***Netherlands*** |
|---|---|---|---|
| ***Hg*** | 0,05 | 0,03 | 0,05 |
| ***Cd+Tl*** | 0,05 | 0,05 | 0,05 |
| ***Sb+As+Pb+Cr+Co+Cu+Mn+Ni+V*** | 0.5 | 0.5 | 0.5 |
| ***PCDD/F*** | 0,1 | 0,1 | 0,1 |

The Waste Incineration Directive had to be adopted by national law at the latest by 28. December 2002. In Germany and in The Netherlands the respective legislative regulations had already been in place prior to the release of this Directive and it can be concluded that in these countries all operating waste incineration or co-combustion plants comply with them.

# 3 Finland

## 3.1 Legal Situation

### 3.1.1 Fundamentals of Waste Management

The minimisation and prevention of formation of waste material is the first goal of the current waste policy in Finland, just like in the other EU countries. The waste should be recycled as material when possible, and the second option is energy recovery. Landfilling should always be the last option.

Both the European Union and Finland apply the principle of producer responsibility to minimise the waste generation and to enhance the recovery of certain types of waste. This principle was first incorporated into the Finnish law through the Government decisions on discarded tyres (1246/1996), packaging and packaging waste (962/1997), the government decree about packages and package wastes (1025/2000), and waste paper (883/1998).

### 3.1.2 Environmental Protection Act

The revised environmental protection and water legislation came into force in Finland on 1 March 2000. The Environmental Protection Act (86/2000) implements the European Union directive on Integrated Pollution Prevention and Control (IPPC), which obliges EU member states to integrate the control of emissions caused by industry. The stipulations on environmental protection are combined in the Environmental Protection Act. It is a general act on the prevention of pollution, which is applied to all activities that cause or may cause environmental damage.

The principles of the Environmental Protection Act are:

- the prevention or reduction of harmful impacts (principle of preventing and minimizing harmful impact),
- the exercise of proper care and caution to prevent pollution (principle of caution and care),
- the use of the best available technique (BAT principle),
- the use of best practices to prevent pollution (principle of environmentally best use),
- parties engaged in activities that pose a risk of pollution have a duty to prevent or minimize harmful impacts (polluter-pays principle).

### 3.1.3 Waste Act and Waste Decree

The basis of the Finnish waste legislation is in the Waste Act (1072/1993) and Waste Decree (1390/1993), which came into force at the beginning of 1994. Their aim is:

- To support sustainable development by promoting the rational use of natural resources.
- To prevent and combat the hazards and harm to human health and the environment arising from wastes.

The Waste Act emphasizes preventive measures for minimizing the waste generated and diminishing the harmful properties of waste. The Act also requires the recovery of waste if it is technically and economically feasible, primarily in the form of material and secondarily as energy. (Ministry of the Environment 2001b)

### 3.1.4 Government Decisions on landfills

The Finnish legislation on landfills has been harmonised to EU legislation by the Government Decisions on landfills (861/1997, as amended 1049/1999).

- By the year 2002, all landfills should have a methane collection and recovery system or flaring in operation.
- By 2002, material which is not pre-treated (as it is needed for preventing the danger and harmfulness of the material) is not allowed to be deposited on landfills.
- By the year 2005, household waste and related industrial and commercial waste material, which has the same properties and composition and from which the most of the biode-

gradable waste is not separately collected for utilisation, is not allowed to be deposited on landfills either.
- By the 1st November 2007, all landfills, also the old ones, must meet the new criteria for the base of the landfill, which means that most of the existing landfills will be closed down by 2008.

The reduction targets for reactive waste brought to landfill which are set by the EU Landfill Directive and have been outlined above mean that in 2009 a maximum of 850 000 t/a of waste is allowed for direct landfilling, and in 2016 this number would be only 600 000 t/a. The existing Finnish legislation covers today the demands by 2006, but the Directive limitations for the year 2016 are tighter, which leads to adjusting the Finnish legislation in the next few years. Council Directive and the Finnish legislation on landfills have a significant effect on waste management in Finland, because of the prevalence of landfilling and the large number of landfills in operation today.

### 3.1.5 The National Waste Plan

The National Waste Plan until 2005 has been adopted 2002. It will hold good till 31.12.2005 or as long as a new plan has come out. [Ministry of the Environment 2002]. Quantitative goals are related to preventing generation of waste and increasing their recovery rate. The minimum reduction objectives and recovery rates set vary according to waste types:
- At least 70% of municipal-, construction- and industrial wastes should be recovered in 2005.
- Correspondingly, the average exploitation rate of hazardous waste should be at least 30 % in 2005.
- The amount of municipal-, construction- and industrial wastes in 2005 should be at least 15 % smaller than the waste amount in 1994 and the estimated waste amount (estimated according to gross domestic production’s growth in real terms).
- When it comes to hazardous waste, the decrease objective is 15 % as well, but the year of comparison is 1992.

Today, the recovery rate is approximately 40 %, but without energy use the 70 % target cannot be met. The energy use has been a big question because of the impurities of the household-derived SRF and the waste incineration directive. New solutions (like a boiler designed for 100 % SRF use, co-combustion by gasification and advanced fuel gas cleaning, new CHP plants for SRF) must be found for these household waste fractions in order to meet the target of 70 % for the waste recovery degree.

A new National Waste Plan is currently under preparation, and a proposal should be ready by 31.12.2006.

### 3.1.6 Waste Tax Act

According to the Waste Tax Act (495/1996) the tax was 23 €/Mg till the end of 2004. In the beginning of 2005, the tax rose to 30 €/Mg. It must be paid on waste deposited at landfills operated by a municipality or a body appointed by the municipality. The tax shall be also paid at landfills, which operate primarily for the purpose of receiving waste from another party. Some waste types (e.g. de-inking waste produced during the refining of waste paper and desulphurisation waste from power plants) are excised from the waste tax. [Ministry of the Environment 2001b]

### 3.1.7 Adaptation of the EU Waste Incineration Directive

The EU Waste Incineration Directive (2000/76/EC) was implemented into the Finnish legislation by the Council Decree on Waste Incineration (362/2003), following more or less exactly the stipulations in the EU directive. The directive shall apply to existing plants from December 2005. The directive/decree:
- covers incineration and co-incineration plants,
- sets tighter emission limit targets for co-incineration plants typical to Finland and sets

measurement obligations for these emissions.

### 3.1.8 Government Decision on Construction Waste

The purpose of the Government decision on construction waste (295/1997) is to reduce the quantity and harmfulness of construction waste and to increase its recovery. Sorting of the construction waste into the following four main waste categories are required: metals, bricks and concrete, soil and wood. An average of at least 50% of all construction waste, except for soil, rock and dredging waste must be recovered in the year 2000. The Decision came into force on June 1, 1997. (Ministry of Environment 2001b)

### 3.1.9 National Biowaste Strategy

The Ministry of Environment prepared 2003 a National Biowaste Strategy to enhance the diversion of biowaste from landfills (by 1 Tg). According to the strategy:

- The biodegradable part of the MSW will decrease by 15% until 2010 compared to 2000.
- During the same period the amount of biodegradable waste put to landfills should decrease by one third.
- The energy use of biodegradable waste increases to 24%.

According to the tax law in Finland MSW contains 60% biodegradable waste. The electricity produced from this renewable resource is supported by 2.5 €/MWh.

## 3.2 Effects of National Regulations

### 3.2.1 The Situation in Finland prior to 2005

The waste management in Finland has been heavily relying on landfills still in the 1990's. However, landfilling will be limited in future due to legislative decisions and new solutions for material and energy recovery of waste are considered.

The total amount of municipal solid waste (MSW) in Finland is estimated to be approximately 2.6 million Mg/a, of which about 750 000 Mg/a are recycled and recovered as material. About 270-300 000 Mg/a is recovered as energy, and 1.6 million Mg/a is still deposited on landfills. The current recovery rate for MSW is some 39%. In order to meet the recovery targets set in the Finnish National Waste Plan for 2005, additional 1 million t/a waste should be recovered as energy.

An increasing amount of waste is burnt in Finland in co-combustion with wood, peat and coal. Co-fired waste, Solid Recovered Fuel, is usually a processed fuel from source separated household waste or packaging waste from stores and industry. The quality of SRF is based on good source separation of wastes and recovered fuel production technology. There are about 20 co-firing plants in Finland nowadays. The amount of waste co-fired ranges typically between 5 and 30 % of fuel energy input. About 300 000 t/a of dry SRF is co-fired in industrial and municipal boilers. In Finland, there is currently only one MSW incineration plant located in the city of Turku (50 000 t/a) in operation.

Waste-to-energy technology in Finland is focused on co-firing waste-derived fuels in combined heat and power (CHP) plants, mainly on fluid-bed combustion and gasification technologies. Landfill disposal is still the dominating alternative for MSW in Finland. However, material recycling and composting of biowaste are the most rapidly growing alternatives.

For the new investments, the references are typical mixed-waste incineration plants in Europe, most of them generating only electricity and some units in Scandinavia also district heat. In Finland, most of the solid fuel boilers generate combined heat and power (CHP) for municipalities or industry, and there are more than 150 biomass-fired boilers where also high-grade SRF could be co-fired. The power price in the Scandinavian grid is low, typically 3–4 cent/kWh, and economically condensed-mode separate power production from waste fuels is not attractive. Most of heat loads in cities have already been built, and it is difficult to sell additional SRF-based energy to the market other than for co-firing in CHP boilers. This issue will be critical for gate-fee estimates besides additional costs due to EU's Waste Incineration Directive for waste-to-energy operators. New technologies and concepts are needed to intensify the material recycling and energy recovery. The European trend of using additional renewable energy including biomass and waste will catalyse this development and business opportunities.

### 3.2.2 The Situation in Finland after 2005

The implementation of the WASTE INCINERATION DIRECTIVE to all waste incineration and co-combustion plants from the beginning of 2005 reduced the number of plants using combustible waste in energy production. At present only 4-5 plants have permits to co-combust waste together with other fuels. A large number of new plants (about 20) are in the phase of environmental permitting, all being delayed by complaints filed by NGOs. The general estimate is that less than 10 waste incineration plants will be built in Finland in the near future. A realistic estimate would be 7-8 plants with a total fuel input of 400 MW. About half of the plants may be grate fired large plants (60 -100 MW).

The following issues should be considered to influence the waste management solutions in Finland:

- high efficient combined heat and power production extensively implemented.
- low electricity price,
- strong seasonal fluctuation in heat and power demand,
- rather small waste volumes and long transport distances compared to Mid-Europe,
- a well developed source separation system implemented in major part of the country,
- material recycling favoured before energy use.

A possible solution model could be:

- good quality SRF could be locally produced and used in co-combustion (or gasification) in existing fluidised bed CHP-plants. The problem of surplus heat to a saturated district heating net could be avoided and high efficient power production utilised.
- SRF of lower quality could be burnt in specially designed fluid-bed boilers with a reasonably good efficiency.
- low quality and inhomogeneous waste fractions (in case of limited source separation) could be combusted in medium size grate boilers located so that the energy can be utilised. This would be the option if SRF of good quality cannot be produced with reasonable energy input from mixed waste.

# 4 Germany

## 4.1 Legal Situation

### 4.1.1 Fundamentals of Waste Management

Already in the early nineties of the last century activities started in Germany to establish an integrated waste management strategy. The principles based of course on those of the EU Waste Framework Directive on Waste Disposal 75/442/EEC. It was and is common understanding that the waste management should base on a hierarchy following the line

- prevention, followed by
- reuse,
- material recycling,
- raw material recovery,
- energy recovery, and finally
- disposal.

The most important acts, ordinances, guidelines and memoranda will be described in short terms following their time of implementation.

In this context only regulations affecting the management of municipal solid waste will be considered.

### 4.1.2 Waste Disposal Act and Waste Avoidance and Management Act

The first Waste Disposal Act [Bundesminister des Inneren 1972] was enacted in 1972 already, three years before the EU Waste Framework Directive. It was issued to regulate the landfill market by closing most of the 50 000 dump sites and replace them by 300 controlled landfills under the regime of regional and local authorities. This was accomplished within few years; however, the logistics and the shortage in capacity caused local crises and public opposition. To cope with the permanently rising waste generation the Waste Avoidance and Management Act [Bundesminister des Inneren 1986a] was adopted in 1986. It set the principles that avoidance and recycling should be given preference over waste disposal.

### 4.1.3 Air Emission Regulations

Along with the re-organisation of sanitary landfills the number and capacity of waste incineration plants was extended, too. Caused by the growing perception that the existing plants have unacceptable air emissions – especially since after the Seveso accident in 1976 [Buser 1982] the dioxins had been detected in the fly ashes from waste incinerators [Olie 1977] – and driven by the declining public acceptance of such plants efforts started in the early eighties of the last century to strengthen the air emission standards for waste incineration. The first regulation was the Technical Guideline Clean Air (TA Luft) in 1974 which did for waste incineration only limit the dust emission to 100 mg/m$^3$. This guideline was significantly strengthened in 1986 when the new TA Luft 1986 was released [Bundesminister des Inneren 1986b]. The air emission standards for waste incineration where five years later again strengthened by the 17. Federal Immission Control Ordinance (17. BImSchV) [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 1990]. This ordinance is one of the sources for the later EU Waste Incineration Directive 2000/76/EC [European Parliament and Council 2000] and is after a number of minor changes by amendments still in power today. The actual emission standards are included in Table 3.

This ordinance set for the first time a limit for the emission of dioxins (0.1 ng(TE)/m$^3$) and restricted the emission of a number of toxic and volatile heavy metals. To comply with these new provisions waste incineration plants had to implement complex air pollution control systems.

It has to be mentioned that these stringent safety standards helped to reduce the public opposition against thermal waste treatment to a great extent.

### 4.1.4 Packaging Ordinance

The fact that approx. 50 % of the volume of waste from households was comprised of packaging material was the reason to regulate the disposal of this waste stream in the Packaging Ordinance [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 1991] by shifting the responsibility for the adequate management of this waste stream to the manufacturers and retailers. As a consequence of this ordinance the Dual System Germany (DSD) was established which collects packaging material free of charge for the citizen and organises the recycling of special fractions like glass, paper, or plastics. The system is financed by the 'Green Dot' licence fee which the manufacturer - but in fact the user - pays.

### 4.1.5 Technical Ordinance on Waste from Human Settlements (TASi)

A weak point of the Waste Act was the lack in distinction between waste and product respectively commercial good. For mixed residential waste in 1993 the government issued the Technical Ordinance on Waste from Human Settlements (TASi) [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 1993]. Its main objectives were

- the restriction of direct disposal of biodegradable waste on landfills,
- the outline of design, operation and allocation criteria of future landfills,
- the priority for material recovery incl. composting and anaerobic digestion and finally
- a thermal treatment for pollutant destruction and inertisation with energy recovery and residue utilisation - as far as possible - prior to its final disposal.

**Table 5** Acceptance criteria for German landfills as laid down in the TASi (landfill class 1 and 2) and the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (landfill class 3)

| *parameter* | *unit* | *landfill class 1* | *landfill class 2* | *landfill class 3* |
|---|---|---|---|---|
| ***vane shear strength*** | $kN/m^2$ | ≥25 | ≥25 | ≥25 |
| ***axial deformation*** | % | ≤20 | ≤20 | ≤20 |
| ***uniaxial compressive strength*** | $kN/m^2$ | ≥50 | ≥50 | ≥50 |
| ***LOI*** | wt% | ≤3 | ≤7 | - |
| ***TOC*** | wt% | ≤1 | ≤3 | ≤18 |
| ***extractable lithophilic substances*** | wt% | ≤0.4 | ≤0.8 | ≤0.8 |
| ***pH*** | | 5.5 - 13 | 5.5 - 13 | 5.5 - 13 |
| ***el. conductivity*** | µS/cm | ≤10000 | ≤ 50000 | ≤ 50000 |
| ***TOC*** | mg/l | ≤20 | ≤100 | ≤250 |
| ***phenols*** | mg/l | ≤0.2 | ≤50 | ≤50 |
| ***As*** | mg/l | ≤0.2 | ≤0.5 | ≤0.5 |
| ***Pb*** | mg/l | ≤0.2 | ≤1 | ≤1 |
| ***Cd*** | mg/l | ≤0.05 | ≤0.1 | ≤0.1 |
| ***Cr-VI*** | mg/l | ≤0.05 | ≤0.1 | ≤0.1 |
| ***Cu*** | mg/l | ≤1 | ≤5 | ≤5 |
| ***Ni*** | mg/l | ≤0.2 | ≤1 | ≤1 |
| ***Hg*** | mg/l | ≤0.005 | ≤0.02 | ≤0.02 |
| ***Zn*** | mg/l | ≤2 | ≤5 | ≤5 |
| ***F*** | mg/l | ≤5 | ≤25 | ≤25 |
| ***ammonium-N*** | mg/l | ≤4 | ≤200 | ≤200 |
| ***cyanide*** | mg/l | ≤0.1 | ≤0.5 | ≤0.5 |
| ***AOX*** | mg/l | ≤0.3 | ≤1.5 | ≤1.5 |
| ***soluble fraction*** | wt% | ≤3 | ≤6 | ≤6 |
| ***as breathing activity ($AT_4$)*** | mg/g | | | ≤5[1] |
| ***or as gas formation rate in fermentation test ($GB_{21}$)*** | l/kg | | | ≤20[2] |
| ***upper thermal value ($H_0$)*** | kJ/kg | | | ≤6000 |

*[(1)] mg $O_2$ with respect to dry weight, [(2)] standard litre of gas with respect to dry weight)*

Two types of landfills were foreseen for the disposal of mixed municipal solid waste the acceptance criteria of which are compiled in Table 5. The most important parameter is the residual content of organic matter, analysed as TOC (total organic carbon) which is 1 wt% in case of landfill class 1 or at the highest 3 wt% for landfill class 2.

The core target of the ordinance was the prevention of reactive waste from being landfilled and with that the formation of landfill gas and organic leachates. The above outlined waste management hierarchy had not to be followed in a strict way if technical or economic aspects were in favour of other strategies.

Since after all recycling or biological treatment efforts still a significant amount of residual waste was left over which needed to be treated in order to comply with the acceptance criteria and since no other than thermal treatment could guaranty the almost total destruction of organic matter the TASi could have been a strong instrument to promote waste incineration with energy recovery. However, during the late eighties and early nineties a strong opposition against waste incineration had formed in Germany and made it difficult to site new plants which would urgently have been needed to fulfil the requirements of the TASi.

Another weak point for the full implementation of the TASi – which was to be accomplished at the lasted at June 1, 2995 – was its status: the ordinance was addressing the administrative bodies and act as a guideline for the establishment of an integrated waste management system, but it had no legally binding power. That means that the federal government could not enforce its immediate application and with that the direct ban of landfilling of reactive materials. As a consequence almost all federal states and all local bodies made excessive use of permits which allowed the permanence of the status quo partly even far longer than the transition time.

The principles and requirements laid down in the TASi already have many years later been used as basis of the EU Landfill Directive. In that way this ordinance – although not really effective in Germany - gave at least an important input for the waste management strategies in the EU.

#### 4.1.6 Closed Substance Cycle Act (KrW-/AbfG)

In the early nineties the German government had in mind to get better control of the still increasing waste generation by introducing a waste disposal fee which should apply for all waste which was not recycled. This attempt failed due to heavy resistance, especially from various industry sectors which had to deal with high amounts of production residues. Another reason was the unclear constitutional situation since a high fraction of the tax would not serve common interests in the waste disposal area but was foreseen for other purposes

At the same time Germany was sued by the European Court of Justice for not having fully adopted the Framework Directive on Waste Disposal. The crucial point was the inconsistent labelling of material as waste. Whereas the German legislative regulation addressed only materials for disposal as waste in the EU Directive also materials diverted for recycling fell under the waste denomination. A further promotion to enact new regulations originated from the World Summit in Rio de Janeiro which brought the term 'sustainability' on stage.

Hence in 1994 the Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal (KrW-/AbfG) [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 1994] was issued. This was a legal act which adopted the waste classification of the EU Waste Framework Directive and was in line with the fundamentals of the former TASi. The KrW-/AbfG set a series of rules including

- the establishment of a waste management hierarchy based on avoidance, utilisation, treatment, and disposal,
- the request for low-waste product design and closed-cycle management of substances within plants,
- the introduction of the polluter pays principle (producer and holder of waste is responsible for its disposal according to the principles laid down),

- the definition of environmental compatibility as the basic principle to decide upon priority between recycling and energy recovery.

A controversial discussion was at that time going on about waste incineration: to what extent is it classified as disposal and to what extent can it be energy recovery. The KrW-/AbfG set the following acceptance criteria for energy recovery:

- the lower heating value of the material has to exceed 11 MJ/kg,
- the combustion efficiency of the combustion plant must exceed 75 %,
- the energy released by the process has to be used as heat or power, and
- the residues meet the landfill acceptance criteria of the TASi without further treatment.

The KrW-/AbfG stated also clearly that energy recovery will not be accepted for municipal waste, regardless of the compliance with the above cited acceptance parameters.

### 4.1.7 Regulation of Biological Treatment Processes for Waste

As a consequence of the opposition against a too high importance of waste incineration and to open an alternative treatment route in 2001 the 30. Federal Immission Control Ordinance [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2001a] was issued which regulates the operation and environmental aspects of mechanical-biological waste treatment plants. Such plants have to meet air emission standards which are similar to those for waste incineration plants. This means the plants have to control their emissions and have to install air pollution control systems.

Since mechanical and/or biological processes are not able to meet the landfill class 1 or class 2 criteria, especially the low TOC numbers, the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (AbfAblV) [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2001b] opened an outlet for the residues of such facilities by defining acceptance criteria for another landfill category, the landfill class 3. The standards are included in Table 5.  Instead of 1 or 3 wt% the TOC has been set to 18 wt% ordinance for mechanical-biological treatment  This standards is accomplished by the limitation of the upper heating value of the material to 6 MJ/kg and a restriction of the amount of extractable organic matter to 0.8 wt%.

### 4.1.8 Ordinance on Landfills and Long-Term Storage (DepV)

The EU Landfill Directive had to be transferred into national law within two years after it had been published. In Germany this happened with the Ordinance on Landfills and Long-Term Storage Facilities and Amending the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and Biological Waste-Treatment Facilities (DepV) [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2001b] in July 2001. This ordinance adapted not only the Landfill Directive but it converted finally the principles of the TASi into a legally binding regulation. The direct disposal of reactive waste on landfills was now definitely prohibited after 1. June 2005. After this date all standards for design, operation and aftercare of all landfill classes for municipal waste, commercial waste and waste requiring special surveillance (hazardous waste) came in force as they had been laid down already in the TASi. All initially granted exemptions expired. This regulation was meanwhile backed up by a decision of the

### 4.1.9 Act on Commercial, Construction and Demolition Wastes

In 2002 the Germany released new rules for the disposal of commercial as well as construction and demolition waste with the Ordinance on the Management of Municipal Wastes of Commercial Origin and Certain Construction and Demolition Wastes [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2002]. The disposal of these waste streams had to be taken care of by the producers of the materials and the amount as well as the quality of the residues in question is for some reason widely unknown.  The new ordinance defines pre-treatment and recovery requirements and it seems obvious that there is a distinct lack in treatment capacity for these wastes.

### 4.2 Effects of National Regulations

#### 4.2.1 The Situation in Germany prior to 2005

In Germany the TASi established already in 1993 a guideline for the environmentally acceptable disposal of waste which anticipated the later targets of the Landfill Directive. The crucial point of this ordinance which hampered a fast conversion of the up to that time common direct disposal of untreated waste on a landfill was the long transition time for the full adaptation of this ordinance. The consequence of the TASi, the incineration of waste prior to its final disposal, was not popular and hence the public bodies responsible for waste management did not invest in such treatment facilities. Landfills got exemptions from the direct application of the TASi which reached far beyond 2005. These exemptions were granted by the regional or local authorities and the federal government had no instrument to prevent them.

In 1993 there was a municipal solid waste generation of 43 Tg. About 13 % of this material were collected separately or diverted for recycling (the amount of residues from this treatment is not known). Mechanical-biological treatment (MBT) played no major role and some 3 Tg were composted in 300 composting facilities. 49 waste incineration plants with a throughput of about 9.4 Tg were in operation. About 68 % or 29 Tg of MSW were still landfilled.

In the following years MBT became popular as an alternative to the unwanted incineration. 76 plants were taken into operation up to 2005 with a total capacity of 6.25 Tg. However, the quality of this so-called secondary fuel was to low to allow combustion or unlimited co-combustion in utility boilers or industrial furnaces. Limited amounts were accepted by cement kilns and by the gasification plant ‘Schwarze Pumpe’.

The rejection of the material for co-combustion in power plant is due to high risk of corrosion and fouling caused by halogen and alkali inventory the limits of which cannot be guaranteed.

#### 4.2.2 The Situation in Germany after 2005

The generation of municipal solid waste in 2005 is estimated to roughly 50 Tg. Out of these almost 24.5 Tg are expected to remain after all recycling activities as residual waste for disposal. Another 5 Tg are expected to come from the commercial and light industrial sector [Radde 2006, Jaron 2006].

72 waste incineration plants were in operation with a capacity of 16.5 Tg. For 2006/2007 a capacity enlargement to almost 18 Tg is expected. The gate fee of new or upgraded waste incineration plants ranges from slightly below 100 € up to approx. 200 €/Mg of waste.

The theoretical throughput of the 76 MBT plants of 6.25 Tg of waste is not exhausted since the combustion of the high-calorific fraction coming from these plants is still not guaranteed although high prices are paid to the combustion plant operators. It is expected that in 2005 less than 4 Tg of waste could be treated by this process. There is a controversial discussion whether MBT should be continued since it produces a fuel without market. Furthermore, also the residues from this process do not comply with the DepV and require thermal treatment prior to final disposal. An option is the utilisation of MBT as de-centralised pre-treatment process for waste incineration. However, such systems are economically not attractive since the costs of MBT are in the order of 70 up to 100 €/Mg of waste.

Solid Recovered Fuel (SRF) or Secondary Fuel produced from special waste fractions, mainly from the commercial and light industrial sector, could also cause disposal problems. For this material approx. 2.4 Tg are expected to be burnt in industrial furnaces but here, too, the capacity is not in place (although there are a number of mono-combustion plants in the design or construction phase which have to be looked upon as waste incinerators since most of them are or will be falling under the regime of the WID).

Anaerobic digestion plays for the time being a minor role in the municipal solid waste management strategies. Few smaller digestion plants treat source separated organic waste fractions. The problem is the quality of the feed material which should be free from plastics and inert materials. The biogas is typically used in gas engines, partially together with landfill gas. The potential for power generated from biogas from organic municipal solid waste is estimated to reach 1.2 TWh/a [Weiland 2006].

The process is more common in sewage treatment plants were the sewage sludge id used for biogas generation. The biggest and fast growing application is found in the agricultural sector where in 2006 approx. 3400 biogas plants with an estimated electrical capacity of 8500 MW are in operation which ferment preferentially manure, often in combination with agricultural residues like straw from maize, in some cases also energy crops [Weiland 2006]. This strategy is strongly promoted by policy and the power delivered to the grid is subsidised.

The residues from anaerobic digestion is in most cases composted and used as fertiliser or for landscaping. This practice seems critical for digesters which use waste originated matter and in some cases also combustion of these residues has been considered.

The conclusion is that at least for 2005 there was not enough treatment capacity in place to dispose of all waste according to the DepV and with that in accordance with the EU Landfill Directive. The situation should change in 2007. The planned waste incineration capacity should be in place to cope with the residual municipal solid waste. For the high-calorific product there may still be problem on regional level.

Since no old landfill is allowed to be operated after 01.06.2005 the solution is an intermediate storage of waste materials. Meanwhile all federal states have at least installed one such storage area, some have already up to 10 on their list and the storage period reaches 5 years. It can be doubted that this waste will ever go back to a treatment facility.

# 5 Netherlands

## 5.1 Legal Situation

### 5.1.1 Fundamentals of Waste Management

For over 40 years, the waste regulation has legally been a part of the environmental legislation in the Netherlands. In 1979, Lansink, a member of the Dutch parliament suggested the priority range for waste treatment. This has become known as the “Ladder of Lansink”. It became part of legislation in 1994 and was updated in 2001 by the addition of one more step. The hierarchy to date is:

- prevention of formation of waste material
- the preparation of products from waste derived materials without negative consequences for the environment (re-use in new products)
- re-use of waste derived products (recycling)
- re-use of waste derived (raw) materials
- the use of waste as a fuel for energy generation
- disposal

### 5.1.2 The National Waste Management Act and National Waste Management Plan

Starting from the EU Waste Framework Directive in 1975 several laws have been implemented in the Netherlands. In 1976 a law on Chemical Waste came into force and in 1977 a general law on waste. A period of major change and legal achievements is the period 2000-2003, when the results of the policy prior to 2000 was evaluated, the landfill tax was steeply raised in 2001, the total provincially organised waste management (by law) was replaced by a national governance and finally this resulted in the revised National Waste Management Act in march 2002. The National Waste Management Act is imbedded, as a separate chapter, within the National Environmental Governance Law (“Wet Milieubeheer”). Based on the Waste Management Act, which is a framework law to be further worked out in details, it was decided to develop a national waste management plan, which is revised every 4 years (in the future every 6 years). The first worked out Waste Management Plan came into force in March 2003 incorporating all national policies to 2012. A number of changes have come into effect in April 2005 and evaluation for the second Plan are in full swing at the moment.

### 5.1.3 Organic Waste

Within the “Wet Milieubeheer” (National law on environmental governance) in which the legal framework for waste is imbedded as explained above, organic waste must be separately collected. Every household has a “green bin” to collect organic waste separately from the other waste. Since 2004 a very intense debate has started, discussing whether or not the organic fraction being rendered into compost is a more environmental friendly option than to burn it and recover the energy. A compromise has been recently reached in which it is decided to keep the separate collection of organic waste within the law, however, to allow local Councils to deviate from this obligation to collect this at least every two weeks. Councils can decide to collect only a fraction of the organic waste, such as garden waste and councils can decide to collect the organic waste together with other streams, such as e.g. diapers.

### 5.1.4 Digestion

Digestion of manure has only recently become more popular in the Netherlands, compared to Germany and Denmark, due to recent more stringent legislation. Currently about 34 digestion installations are in operation, generating 22 MWe power (of which 15 MWe from co-digestion). The current average generated power is 200 kWe and the trend is that the amount will increase to 300-500 kWe in the medium and up to 2000 kWe in the long term. The produced heat is often not used.

To obtain maximum yield usually a co-substrate is added, like e.g. corn. Main current bottlenecks are the recent withdrawal of subsidies for renewable energy from digestion, although it is expected that the subsidies will be replaced in another form soon. Without subsidies digestion is not economically feasible. Another bottleneck is the application of the digestate. Under the current legislation all produced digestate is considered as manure, also if a non-animal co-substrate has been used, such increasing the amount of manure. The use of digestate within agriculture is bound to strict rules. The cost of disposal of digestate is currently 3-15 €/Mg. For the time being there is a strong lobby for recognition of digestate as replacement of (artificial) fertilizer and not having the status as manure. Furthermore there is also an interest in the upgrading of the biogas to natural gas quality. The maximum degree of natural gas substitution is estimated at few percent.

### 5.1.5 Disposal

Since 1997 a law is in force that forbids the disposal of any waste that can be re-used or burned for energy recovery. When the European Landfill Directive was introduced in 1999, it had very little effect on the Dutch everyday practise. An instrument that is used in the Netherlands to promote any useful application is the landfill tax. Since this tax did not exist in other European countries such as France and Germany, the export of waste was very attractive. In 2002, it was decided not to increase the tax any further and to aim for a similar tax in all European countries. At present the disposal tax is 85 €/Mg.

The incinerator capacity was kept for a long time at 5.5 Tg/y which was too little. The reason was to stimulate recycling and re-use of waste-derived materials. The negative side-effect was that more waste was land-filled. In the year 2000 this amounted to 3,000,000 Mg. The ban on enlarging the incineration capacity was finally lifted July 1$^{st}$ 2003.

### 5.1.6 Air Emission Regulations

Before the EU Incineration Directive (2000/76/EC) was implemented into the Dutch legislation (2004), emission limits were already set by the law ”Emissions to air by the incineration of waste’. This law restricted the emissions of dioxins, $NO_x$, total dust and mercury. After the introduction of the Waste Incineration Directive, the old limits for Mercury, dust and $NO_x$, more stringent than the EU-limits, were maintained. Although nearly all incinerators date from before 2004, the Dutch waste incinerators still have advanced and up to date gas cleaning facilities, due to the early pre-European law.

### 5.1.7 The Targets in the National Waste Management Plan

Apart from the general aims of prevention of waste and stimulating re-use some quantitative goals are stated in the National Waste Management Plan.

- The extent of useful applications from waste has to rise from 77% in 2000 to 83% in 2012.
- The remainder of the burnable waste that was still land-filled in 2002 must be zero in 2007
- The amount of waste disposed of by land-filling or incineration must be reduced to 9,500,000 Mg/y in 2012.

## 5.2 Effects of National Regulations

### 5.2.1 The Situation in the Netherlands prior to 2005

In 2004 roughly 7 million Dutch households produced 9,000,000 Mg of MSW. In addition, 20,000,000 Mg of industrial waste was produced and 19,500,000 Mg of waste was from construction materials and building activities. In total 60,000,000 Mg of waste was produced.

In total 12 grate fired incinerator locations are present with a total capacity of 5,640,000 Mg/y permitted. Of the total capacity, 90% was used in 2003. Since 1997, no new capacity was built, except for a paper-residue burning installation that did not become very efficient in this period.

### 5.2.2 The Situation in the Netherlands after 2005

The capacity of the waste incinerators has increased with 180,000 Mg in one location in 2006 and another 500,000 Mg capacity at another location will become available in 2007.

Many plans in various stages are made for even further expansion of the capacity. With the land-fill ban in Germany an important export possibility has ceased to exist. In the second half of 2005, the amount of waste being land-filled increased significantly. It is gradually diminishing again to pre-June 2005 volumes, but the longer-term trend is difficult to predict.

Because tariffs for incineration are at present much higher in Germany than in the Netherlands (range 78-146 €/Mg in 2004), open borders per January 1, 2007 would likely attract waste streams from Germany at higher prices. As a result, it seems likely that more Dutch waste would be landfilled due to shortage of incineration capacity. This scenario is tempered somewhat by the fact that most clients have very long-term contracts with the incineration organisations (often 10-15 years).

AVR, the largest incineration company in the Netherlands, was sold end of 2005 to a consortium of private equity firms (the largest being KKR). In general, 2005 and 2006 so far, have seen many mergers and business overtaking. It is a waste Incineration Directive held opinion that the sector is in for a consolidation phase and with the opening of the borders per 01-01-2007, this is expected to become a European or even global process at an even faster rate.

## 6 Conclusions and Outlook

The waste management situation described for three countries in this report and its changes during the last few years indicates a strong influence of the Landfill Directive on the respective national regulations. However, the actual status of adaptation shows no uniform picture. The Netherlands and Germany have not only taken strong actions to comply with the targets of the Landfill Directive, their national initiatives in the early nineties of the last century can be looked upon as the basis of this directive.

Both countries gave recycling a high priority and therefore it is no surprise to see them as spear head for this strategy in the EU - and even world wide – today. A main difference between the two countries is seen in the importance they gave to waste-to-energy. The Dutch regulations had already in the early nineties consequently included energy recovery as an essential part into their National Waste Management Act. Following this decision and also due to the fact that the existing waste incinerators had to be upgraded a high capacity of state-of-the-art incineration was built all over the country. These plants did to some extent even treat imported waste, mainly from Germany. The establishment of today's waste management practice was definitely supported by the high landfill tax which doubles almost the disposal costs.

Since waste incineration was strongly opposed in Germany by NGOs, local interest groups, but also to a great extent by media and politicians, there was almost no enlargement of the installed capacity during the nineties of the last century. Although the fundamentals of the German waste management strategy, to prevent disposal of reactive waste, was widely accepted, there was also wide-spread understanding that all measures other than incineration should be applied. This was the period when alternative thermal treatment processes like pyrolysis, gasification or combined processes became of high interest. After the failure of two full-scale realisations of such processes – in 1999 the Siemens Thermal Recycling Process in Fürth and in 2004 the Thermoselect Process in Karlsruhe – all projects for such processes were withdrawn.

The major political and also public preference, however, was mechanical-biological treatment with the effect that a great number of such plants were built. However, the environmental quality of such plants came under criticism with time and the residues from such plants were also not in line with the German TASi and especially the German Landfill Ordinance. Another problem arose from the quality of the product of mechanical biological treatment, the fuel fraction. Due to its potentially high halogen and heavy metal inventory it could not just be burnt in utility boilers of industry furnaces but fell under the regime of the air emission regulation, the 17. BImSchV, which made this strategy expensive or even obsolete.

This situation changed only few years ago when local authorities became aware that the full inaction of the Landfill Ordinance and with that the landfill ban for organic waste was unavoidable. In short time a substantial increase in incineration capacity by approx. 50 % or almost 6,000,000 Mg was realised. Hence it can be expected that in 2007 there is enough capacity in operation to treat the total amount of residual waste from the municipal sector. A not really solved problem is the disposal of commercial and light industrial waste. There is a strong tendency to promote the production of SRF which should preferentially be burnt in dedicated combustion plants, equipped with air pollution control systems. In view of still existing animosity against waste incineration such SRF plants which can also be fuelled with biomass sell better to the public than waste incinerators – although they are not much different from those. Another problem associated with the combustion of SRF with high biogenic content is the risk of fouling and deposition in the combustion chamber and the boiler caused by the high alkali inventory.

The waste management situation in Finland is quite different. Energy recovery from waste was an important pillar of the Finnish strategy. In this sparsely populated country, however, there are not many locations were pure energy recovery from waste makes sense from an economic point of view. That is why the Finnish government aimed mainly for co-treatment of waste in power plants or other boilers, a practice in many places already established years ago. The Waste Incineration Directive stopped this disposal route in most cases since the installation of an air pollution control system to comply with the air emission standards made it too expensive. Hence co-treatment, either by direct addition of waste fuel or by utilisation of synthesis gas from waste gasification will only be possible for well separated and clean waste fractions and with that the disposal of the more or less polluted residual waste fractions is yet an unsolved problem. The authorities have released basic regulations to comply with the Landfill Directive which contain energy recovery, but a detailed strategy is still missing.

Although the authors have no specific information, the situation in the eastern new EU member states is ought to be similar to that in Finland. These got a longer time for adaptation than the 15 old EU members since in many place there existed after the fall of the 'Iron Curtain' even no sanitary landfills.

Basic information available to the authors on other EU countries shows a rather fragmented picture. Austria e.g. has already today fulfilled the goals of 65 % reduction set in the directive for 2016. This has mainly been done by composting (>35 %). Recycling, energy recovery and landfilling account roughly for 20 % each. The question to be answered is whether that much compost has the quality to be utilised and whether such strategy is in line with the intention of the Landfill Directive: to establish an aftercare free waste disposal..

The UK is currently far behind any schedule to meet the targets of the Landfill Directive. For political reasons mechanical-biological treatment is highly promoted and it will be of great interest whether the UK finds an acceptable outlet for the products from such processes.

Southern member states like Italy, Spain, and Portugal are extending their waste-to-energy capacities, in these countries the utilisation of that energy causes problems. In summertime there is no market for heat other than direct steam use in industrial processes and a market for central cooling is not easy to be established.

It can be assumed that a landfill tax would be a driver for energy recovery but the situation in Germany shows an expansion of energy recovery by legal actions only.

An open question concerning eco-efficient energy recovery is the potential role of biogas production in future waste management systems, especially for rural areas. This technology could theoretically become an efficient tool for wet organic waste, especially if the wet municipal solid waste fraction could be co-treated with agricultural residues and eventually with sewage sludge. A pending problem is seen in the final destination of the residues for which the today often practised composting might not be the ultimate solution.

The acquired information does not allow drawing conclusions in terms of recipes for other countries. It is obvious that there will be no universal solution for all EU countries, even if politicians and bureaucrats would like to install one. Of course in most countries a more intense energy recovery can be expected. Obstacles are

- the high costs of waste-to-energy systems,
- the lack in political and public acceptance,
- in northern countries eventually the low revenues for power,
- in southern countries the lack in a market for heat, thus preventing cheap CHP solutions, and finally
- a convincing solution of the final disposal of process residues, especially those from gas cleaning..

As a cautious general conclusion it can be stated that a future increase in energy recovery from waste is to be expected in almost all EU countries which have not yet reached the targets of the Landfill Directive. There are many technologies on the market and every specific solution depends strongly on local conditions. However, some topics can be identified for further activities:

- which strategies are best suited for low population density and mainly rural areas,
- can SRF produced from source separated waste reach a quality which allows its combus-

- what is the potential of biogas production in terms of meeting the targets of the landfill directive,
- what is the most eco-efficient management of residues, especially those from gas cleaning and from biological processes.

The first three topics are supposed to go to a great extent together. For countries like Finland with low population density but a well established power and heat market ‘clean’ SRF is a promising option to dispose most of the waste of in a way which complies with the EU directives. There is a need to get more information of the effects of SRF with high calorific value and/or with high biogenic inventory on the combustion process in conventional fluidised beds, grate systems and eventually also in pulverised coal boilers.

Biogas production which has a good potential for energy recovery from agricultural waste needs more detailed investigation in terms of the actually applied technologies, their compliance with the Landfill Directive and their importance in the local energy supply system. Such investigation could be accompanied and supported by a case study comparing successful solutions in an old and highly industrialised EU member state – e.g. Austria or Germany – and in a rural area in e.g. Poland.

The forth topic is a fundamental one not only for waste-to-energy systems but also for biomass combustion. In the first case the main issue is the control and final destination of heavy metals and – often overlooked – of highly water soluble salts. These are the problematic ingredients in gas cleaning residues. For biomass combustion residues there is a lack in knowledge to what extent the recovery of nutrients makes sense, especially if contaminated biomass is used. A further already above mentioned issue for biogas systems is the management of digestion residues which may have a potential as fertilisers after composting but may cause problems if wet organic waste, agricultural residues, and sewage sludge are co-treated. For establishing sound practice in this area a primary study should be performed to get a detailed overview of applied strategies. This should be followed by an experimental part for the control of residues from different processes and after different treatment measures.

## 7 References


Bundesminister des Inneren (1972) Abfallablagerungsgesetz (11. Juni 1972), *Bundesgesetzblatt, Teil I,* 873

Bundesminister des Inneren (1986a) Gesetz über die Vermeidung und Entsorgung von Abfällen (27. August 1986), *Bundesgesetzblatt, Teil I,* 1410

Bundesminister des Inneren (1986b), Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Technische Anleitung zur Reinhaltung der Luft - TA Luft - vom 27. Februar 1986), *Gemeinsames Ministerialblatt, 202*, 95

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (1990), 17. Verordnung zur Durchführung des Bundesimmissionsschutzgesetzes (Verordnung über Verbrennung und die Mitverbrennung von Abfällen - 17. BImSchV) vom 23. November 1990, *Bundesgesetzblatt*, *Teil 1,* 2545
Amendments:
23. Februar 1999, *Bundesgesetzblatt*, *Teil 1,*186
3. Mai 2000, *Bundesgesetzblatt*, *Teil 1,* 632
27. Juli 2001, *Bundesgesetzblatt*, *Teil 1,* 1950
14. August 2003, *Bundesgesetzblatt*, *Teil 1,* 1633
14. August 2003, *Bundesgesetzblatt*, *Teil 1,* 1614, 1633

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (1991), Verordnung über die Vermeidung von Verpackungsabfällen (Verpackungsverordnung - VerpackVO) vom 12. Juni 1991, *Bundesgesetzblatt I,* 1234

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (1993), Dritte Allgemeine Verwaltungsvorschrift zum Abfallgesetz (TA Siedlungsabfall), Technische Anleitung zur Verwertung, Behandlung und sonstigen Entsorgung von Siedlungsabfällen vom 14. Mai 1993, *Bundesanzeiger Jahrgang 45*, Nr. 99a

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (1994) Gesetz zur Förderung der Kreislaufwirtschaft und Sicherung der umweltverträglichen Beseitigung von Abfällen vom 27. September 1994 (Kreislaufwirtschafts- und Abfallgesetz – KrW-/AbfG). *Bundesgesetzblatt I 1994*, 2705

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2001a), 30. Verordnung zur Durchführung des Bundesimmissionsschutzgesetzes (Artikel 2 der Verordnung über die umweltverträgliche Ablagerung von Siedlungsabfällen und über biologische Abfallbehandlungsanlagen) vom 20. Februar 2001, *Bundesgesetzblatt I 2001,* 317

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2001b) Verordnung über die umweltverträgliche Ablagerung von Siedlungsabfällen (AbfAblV – Abfallablagerungsverordnung) vom 20. Februar 2001, *Bundesgesetzblatt I 2001,* 305, geändert durch Artikel 2 V vom 24. Juli 2002, *Bundesgesetzblatt I 2002,* 2807

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2002) Verordnung über die Entsorgung von gewerblichen Siedlungsabfällen und von bestimmten Bau- und Abbruchabfällen vom 19. Juni 2002 (Gewerbeabfallverordnung GewAbfV). *Bundesgesetzblatt I 2002,* 1938

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2002) Verordnung über Deponien und Langzeitlager vom 24. Juli 2002 (Deponieverordnung DepV). *Bundesgesetzblatt I 2002,* 2807

Buser H.R. (1982) The Seveso accident - an environmental application of mass spectrometry. *Trends in Analytical Chemistry, 1,* 318

European Council (1975**)** Framework Directive on waste disposal. Council Directive 75/442/EEC of 15 July 1975. *Official Journal L 194 , 25/07/1975 P. 0039 – 0041*
*Amendments:* Council Directive 91/156/EEC of 18 March 1991;
Council Directive 91/692/EEC of 23 December 1991;
Commission Decision 96/350/EC of 24 May 1996;
Council Directive 96/59/EC of 16 September 1996

European Council (1999) Council Directive 1999/31/EC of 26. April 1999 on landfill of waste. Official Journal of the European Communities, 16.7.199, L182

Amendment: Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC (2003/33/EC)

European Parliament and Council (2000) Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste. Official Journal of the European Communities, 28.12.2000, L332/91

Jaron A. (2006) Novelle des europäischen und deutschen Abfallrechts aus strategischer Sicht. 6. Fresenius Fachtagung Waste-to-Energy, 30./31. 5. 2006, Köln

Olie, K., Vermeulen, P.L. & Hutzinger, O. (1977), Chlorodibenzo-p-Dioxins and Chlorodibenzofurans are Trace Components of Fly Ash and Flue Gas of Some Municipal Incinerators in the Netherlands, *Chemosphere, 6,* 455

Radde C.-A. (2006) Entwicklung der Abfallwirtschaft in Deutschland. *11. Fachtagung Thermische Abfallbehandlung, 14./15. März 2006, München. Tagungshandbuch,* 57

Weiland P. (2006) Anaerobic digestion of agricultural waste and selected biomass. *Venice 2006, Biomass and Waste to Energy Symposium Venice, Italy; 29 November – 1 December 2006 Proceeding on CD*