

**EUROPEAN COMMISSION – DIRECTORATE  
GENERAL ENVIRONMENT**

**REFUSE DERIVED FUEL, CURRENT PRACTICE AND  
PERSPECTIVES (B4-3040/2000/306517/MAR/E3)**

**FINAL REPORT**

**WRc Ref: CO5087-4  
JULY 2003**



# **REFUSE DERIVED FUEL, CURRENT PRACTICE AND PERSPECTIVES (B4-3040/2000/306517/MAR/E3)**

## **FINAL REPORT**

Report No.: CO 5087-4

July 2003

Authors:

WRc: A. Gendebien, A. Leavens, K. Blackmore, A. Godley, K. Lewin, K.J. Whiting and R. Davis  
IFEU: J. Giegrich, H. Fehrenbach and U. Gromke  
ECOTEC: N. del Bufalo  
Eunomia: D. Hogg

Contract Manager: Alison Leavens

Contract No.: 12429

RESTRICTION: This report has the following limited distribution:

External: Authors

Internal: Commission

Any enquiries relating to this report should be referred to the authors at the following address:

WRc Swindon, Frankland Road, Blagrove, Swindon, Wiltshire, SN5 8YF.  
Telephone: (01793) 865000

The contents of this document are subject to copyright and all rights are reserved. No part of this document may be reproduced, stored in a retrieval system or transmitted, in any form or by any means electronic, mechanical, photocopying, recording or otherwise, without the prior written consent of the copyright owner.

This document has been produced by WRc plc.

# CONTENTS

SUMMARY	1
1. INTRODUCTION	9
1.1 Background	9
1.2 Scope	10
1.3 Objectives	10
1.4 Report structure	10
2. LEGAL AND POLICY ASSESSMENT	13
2.1 European regulatory framework	13
2.2 International guidelines	19
2.3 National legal and policy framework	20
3. CURRENT PRACTICE OF PRODUCTION AND USE OF WASTE-DERIVED FUELS	31
3.1 Introduction	31
3.2 RDF from processed municipal solid waste	31
3.3 RDF from industrial wastes	38
4. ENVIRONMENTAL IMPACT ASSESSMENT	55
4.1 Introduction	55
4.2 Methodology	55
4.3 Technological Assumptions	65
4.4 Scenario Assumptions	67
4.5 RDF assumptions	69
4.6 Substitution effects	70
4.7 Results	71
4.8 Conclusions	96
5. ECONOMIC ASSESSMENT	99
5.1 Municipal Waste Management Perspective	99
5.2 Co-Incineration Plant Perspective	104
5.3 Cost Implications of Environmental Considerations	105
5.4 Market dynamics	106
5.5 Cost information	108
5.6 Conclusion	109
6. ALTERNATIVES MANAGEMENT ASSESSMENT	111
6.1 Alternative waste management options	111
6.2 Alternative RDF utilisation processes	112
7. CONCLUSIONS AND RECOMMENDATIONS	119

REFERENCES	121
------------	-----

## APPENDICES

APPENDIX A	EC REGULATORY FRAMEWORK	127
APPENDIX B	COUNTRY OVERVIEW	135
APPENDIX C	CO-INCINERATION FACILITIES	213
APPENDIX D	ALTERNATIVE RDF UTILISATION	217

## LIST OF TABLES

Table 2.1	EURITS criteria for co-incineration of waste in cement kilns	19
Table 2.2	Quality standards for solid recovered fuels	23
Table 2.3	Specification for recovered fuels used in cement plants in Sweden	24
Table 2.4	Typical Emission Limit Value and reference conditions for co-incineration of secondary fuels in cement plants in Europe (adapted from EA 2001)	28
Table 3.1	Conversion rate for RDF production according to treatment process and country	32
Table 3.2	RDF production from MSW in EU Member States, 2001	34
Table 3.3	Estimates of RDF from MSW in Europe in 2000 (CEN 2001)	35
Table 3.4	Utilisation of RDF from MSW in Europe	36
Table 3.5	Typical composition of tyre-derived fuels	39
Table 3.6	Types of secondary fuels co-incinerated in Europe <sup>a)</sup>	43
Table 3.7	Number of industrial plants co-incinerating RDF from industrial wastes in Europe <sup>a)</sup>	44
Table 3.8	Quantities of RDF from industrial waste co-incinerated in cement industry in Europe (x10 <sup>3</sup> tpa) <sup>a)</sup>	46
Table 3.9	Quantities of waste used as alternative fuels in cement industry in the fifteen EU Member States (RDC and Kema 1999)	47
Table 3.10	Overview of co-firing at coal fired power plants (RDC and Kema 1999)	48
Table 3.11	Co-incineration in the paper and pulp industry in Austria and Germany (x10 <sup>3</sup> tpa)	49
Table 3.12	Typical RDF composition	50
Table 3.13	Quality of RDF from household and industrial sources	51
Table 3.14	Comparative analysis of waste recovered fuel quality across Europe	52
Table 4.1	Impact categories and indicators and classified data categories	62
Table 4.2	Reference values for normalisation and grouping of the impact categories and indicators	63
Table 4.3	Guide values for the EIA-type valuation	64
Table 4.4	Toxic load of selected waste derived fuels compared with hard and brown coal	69
Table 4.5	Results of inventory and impact assessment of four technical options for combusting 1 Mg RDF Trockenstabilat®	73

Table 4.6	Normalisation of the differences between the recovery options referred to 10 Mio t RDF; the most advantageous option is shown by an ①; 1 square indicates 100.000 PEV (rounded) Ecological priority: ■ = A (very high), : ■ = B (high), : ■ = C (medium).	79
Table 4.7	Discharge of air pollutant by combusting 1 t of RDF, assumed capacity for RDF-combustion of typical plants, assumed dispersion factor for typical plants and resulting maximum air emissions in the ambience of a typical plant	81
Table 4.8	Calculated toxic load in cement clinker; co-incineration ratio: 50%	84
Table 4.9	Availability of chromium in cement under various conditions (Abfallbericht 2001)	86
Table 4.10	Calculated toxic load in fly ash of a hard coal fired power plant; co-incineration ratio: 5%	88
Table 4.11	Gypsum from flue gas cleaning of a hard coal fired power plant	90
Table 4.12	Slag of a hard coal fired power plant	91
Table 4.13	Calculated toxic load in fly ash of a brown coal fired power plant	92
Table 4.14	Calculated toxic load in gypsum of a brown coal fired power plant	94
Table 5.1	Comparative Costs of Incineration in Different Member States (Hogg <i>et al</i> , 2002)	101
Table 5.2	Cost of waste derived fuels production and utilisation in some Member States	109
Table 6.1	Main technologies and supplier for gasification and pyrolysis processes in Europe	115
Table 6.2	Gasification plants processing RDF in Europe	116
Table 6.3	Capital cost for alternative processes in Europe	117
Table A.1	Air emission limit values as specified in Hazardous Waste Incineration Directive	130
Table A.2	Air emission limit values for incineration and co-incineration of waste under Directive 2000/76/EC	132
Table A.3	Emission limit values (C proc.) for co-incineration of waste in combustion plants under Directive 2000/76/EC	133
Table B.1	Emission limit value for cement plant co-incinerating waste in Austria (Incineration Decree 1999, as reported by EA 2001a)	137
Table B.2	Mechanical Biological Treatment plants in Austria, 2000 (Grech 2001a)	139
Table B.3	Co-incineration of secondary fuels in Austria	140
Table B.4	Co-combustion capacity in the pulp and paper industry in Austria (UBA 2001)	141
Table B.5	In-house secondary fuels co-incinerated in Austrian pulp and paper industry, 1998 (Grech 2000)	141
Table B.6	Co-combustion capacity in the cement industry in Austria (UBA 2001)	142
Table B.7	Fuel consumption in the cement industry in Austria	143
Table B.8	Typical emission limit value for cement plant co-incinerating waste in the Walloon Region (Impel 1998, as reported by EA 2001)	145

Table B.9	Potential production of RDF and secondary fuels in the Flemish Region, 1999 (VITO 2000)	146
Table B.10	Quantities and outlets for plastic waste in the Flemish Region (1999)	148
Table B.11	Emission limits for co-incineration in cement kilns in Denmark (Entec 1999 as reported by EA 2001)	152
Table B.12	Finish quality standards for RDF	155
Table B.13	Typical emission limit for co-incineration in cement kilns in Finland (E C 2000 reported by EA 2001)	155
Table B.14	RDF production capacity in Finland	156
Table B.15	Quality of RDF from various sources	156
Table B.16	Emission limits for co-incineration in cement kilns in France (Impel 1998 as reported by EA 2001)	160
Table B.17	Production of secondary fuels in France, 1998 (Ademe 2000)	161
Table B.18	Co-incineration of secondary fuels in cement plants in France, 1998 (Ademe 2000)	163
Table B.19	Emission limits for co-incineration in cement kilns in Germany (as reported by EA 2001)	164
Table B.20	Mechanical-biological treatment plants with high calorific output in Germany	165
Table B.21	Potential production of secondary fuels in Germany (Köster 2001)	166
Table B.22	Co-incineration of secondary fuels in Germany <sup>1</sup>	167
Table B.23	Co-incineration of secondary fuels in cement kilns in Germany, 1999 (VDZ 2000)	167
Table B.24	Co-incineration of secondary fuels in power plants in Northrhine-Westfalia (Prognos 2001)	168
Table B.25	Co-incineration of secondary fuels in paper industry in Germany (RWI 1999)	169
Table B.26	Co-incineration of secondary fuels in blast furnaces in Germany (Prognos 2001 and Grech 2001)	169
Table B.27	Emission limits for co-incineration in cement kilns in Italy (E C 2000 as reported by EA 2001)	175
Table B.29	Production capacity of CDR in Mechanical-Biological Treatment plants in Italy, 1999 (ANPA 2001)	176
Table B.30	Co-combustion of CDR in Italy	177
Table B.32	Emission limits for co-incineration in cement kilns in Luxembourg (Impel 1998 as reported by EA 2001)	180
Table B.33	Emission limits for co-incineration in cement kilns in the Netherlands (Impel 1998 as reported by EA 2001)	181
Table B.34	Production of RDF in the Netherlands, 2001 (van Tubergen, TAUW, pers. Comm. 2001)	182
Table B.35	Planned RDF plants in the Netherlands (van Tubergen, TAUW, pers. Comm. 2001)	183
Table B.36	Co-incineration of secondary fuels in the Netherlands	184
Table B.37	Co-incineration in power plants in the Netherlands (Croezen, CE-Delft, pers. Comm. 2001 and van Ree <i>et al</i> 2000, 2001)	185

Table B.38	Co-incineration of secondary fuels in cement kilns in the Netherlands (ENCI 2001)	186
Table B.39	Gasification and pyrolysis of secondary fuels in other plants in the Netherlands (De Vries <i>et al</i> 2000)	186
Table B.40	Emission limits for co-incineration in cement kilns in Portugal (Impel 1998 as reported by EA 2001)	188
Table B.41	Emission limits for co-incineration in cement kilns in Spain (Impel 1998 as reported by EA 2001a)	192
Table B.42	RDF characteristics in Spain	194
Table B.43	Co-incineration of secondary fuels in cement kilns in Spain (1997)	196
Table B.44	Trends in secondary fuel co-incineration in cement industry in Spain (OFICEMEN 2000)	197
Table B.45	Typical emission limits for co-incineration in cement kilns in Sweden (Impel 1998 as reported by EA 2001)	198
Table B.46	Specification for secondary fuels co-incinerated in cement plants in Sweden	200
Table B.47	Typical emission limits for co-incineration in cement kilns in the UK (as reported by EA 1999b and 2001a)	202
Table B.48	Typical RDF properties (adapted from 2 1.05, 1995)	204
Table B.50	Typical composition of fuel derived from tyres (Castle Cement 1996 reported by EA 2001a)	207
Table B.51	Co-incineration of secondary fuels in the cement industry in the UK, 2001	210
Table C.1	Main characteristics of cement production process (RDC & Kema 1999)	214
Table C.2	Main characteristics of coal fired power plant (RDC & Kema 1999)	215
Table D.1	Main aspects of thermal conversion processes	218

## LIST OF FIGURES

Figure 2.1	Climate Change Impacts of Switching from Incineration to Recycling (Smith <i>et al</i> 2001)	26
Figure 3.1	Schematic Representation of MBT Process (Separation Variety)	33
Figure 4.1	Scheme of the system for RDF production and use (E/M: input of energy and/or material resources)	58
Figure 4.2	Scheme of the system for substituted primary fuels (E/M: input of energy and/or material resources)	59
Figure 4.3	Scheme of a material flow analysis for RDF-inherent cadmium distribution in a cement kiln and in a coal power plant (figures are used as examples and do not represent exactly the real situation)	59
Figure 4.4	Proposed methodological approach supplementing elements of the MFA, EIA and risk analysis to a LCA-framework	60
Figure 4.5	Schematic description of furnace and flue gas cleaning system for MSW incinerator	67
Figure 4.6	Scheme of modelling the systems of RDF use	68

Figure 4.7	Toxic load of selected secondary fuels	70
Figure 4.8	Results for “global warming”(top) and “summer smog” (bottom) for the combustion of 1 Mg Trockenstabilat® by four different options	75
Figure 4.9	Results for “acidification” (above) and “nutrification” (below) for the combustion of 1 Mg Trockenstabilat® by four different options	76
Figure 4.10	Results for “human toxicity”, represented by the indicators “cancerogenic risk potential” (above) and “mercury emissions” (below) for the combustion of 1 Mg Trockenstabilat® by four different options	77
Figure 4.11	Results for “consumption of fossil resources”, for the combustion of 1 Mg Trockenstabilat® by four different options	78
Figure 4.12	Results for EIA-type valuation of combustion of RDF by four different technical options	82
Figure 4.13	Impacts of co-incineration on the cement clinker; co-incineration ratio: 50%	85
Figure 4.14	Changes in the toxic load cement clinker by co-incineration of MBT-output; co-incineration ratio: 50%	86
Figure 4.15	Impacts of co-incineration on the toxic load of fly ash of a hard coal fired power plant; co-incineration ratio: 5%	88
Figure 4.16	Changes in the toxic load of fly ash from a hard coal fired power plant by co-incineration of MBT-output; co-incineration ratio: 5%	89
Figure 4.17	Impacts of co-incineration on the toxic load of gypsum of a hard coal fired power plant; co-incineration ratio: 5%	90
Figure 4.18	Impacts of co-incineration on the toxic load of slag of a hard coal fired power plant; co-incineration ratio: 5%	91
Figure 4.19	Impacts of co-incineration on the toxic load of fly ash of a brown coal fired power plant; co-incineration ratio: 5%	93
Figure 4.20	Changes in the toxic load of fly ash from a brown coal fired power plant by co-incineration of MBT-output; co-incineration ratio: 5%	93
Figure 4.21	Impacts of co-incineration on the toxic load of gypsum of a brown coal fired power plant; co-incineration ratio: 5%	95
Figure 4.22	Changes in the toxic load of gypsum from a brown coal fired power plant by co-incineration of MBT-output; co-incineration ratio: 5%	95

# SUMMARY

## I OBJECTIVES

The objectives of the project were to undertake a survey on the current practices of production and use of refuse derived fuel (RDF) in the fifteen Member States of the European Union, as well as to undertake an overview of the legal and policy framework of RDF production and use; an assessment of the environmental impacts and of the economic aspects and a review of alternative outlets if the waste streams were not used to produce RDF.

It was agreed at the project inception meeting, that for this project, the term 'refuse derived fuel' would encompass any waste that is **traded** and co-burnt in installations for power generation or in a manufacturing process where heat is required (e.g. cement production).

## II REASONS

High calorific fractions from processed municipal solid waste (MSW) and industrial wastes are being used both in dedicated energy-to-waste plants and as fuel substitutes in industrial processes. There is no detailed information on the current scale of these practices across Europe.

It is argued that RDF co-incineration in industrial processes has several advantages such as saving non-renewable resources by substituting fossil fuels in high-demand energy processes. However there are concerns over the discrepancies between the controls applied on dedicated incineration and co-incineration plants and argument that it encourages their removal from the material recovery/re-use cycle, thereby going against the waste hierarchy which rates waste prevention/minimisation and recycling as being preferable to energy recovery and disposal. On the other hand, some argue that using RDF in industrial processes compared with bulk incineration has a flexibility advantage as to optimise economic performance, incinerators must be fed with a constant through put of waste which could in certain cases hinder the development of prevention or recycling initiatives.

There is a lack of environmental assessment information about these practices and the economics driving the production and utilisation of RDF are also unclear. This study is intending to provide this information.

## III MAIN FINDINGS

### Definition

Refuse derived fuels cover a wide range of waste materials which have been processed to fulfil guideline, regulatory or industry specifications mainly to achieve a high calorific value. Waste derived fuels include residues from MSW recycling, industrial/trade waste, sewage sludge, industrial hazardous waste, biomass waste, etc.

The term 'Refuse Derived Fuel (RDF)' in English speaking countries usually refers to the segregated high calorific fraction of processed MSW. Other terms are used for MSW derived fuels such as Recovered Fuel (REF), Packaging Derived Fuel (PDF), Paper and Plastic Fraction (PPF) and Processed Engineered Fuel (PEF).

The terms 'Secondary Fuel', 'Substitute Fuel' and 'Substitute Liquid Fuel (SLF)' are more commonly used in reference to industrial waste fractions such as tyres or solvents processed to achieve consistent quality compatible with particular process requirements.

### **Policy and legal framework**

Under EC law, the manufacture of RDF from waste does not change the status of the material. This implies that the movement and utilisation of RDF is subject to waste licensing. However, R1 – one of the 'Recovery Activities' as defined in Annex IIB of Directive 75/442/EEC as amended, implies that where waste is used 'principally as a fuel or other means to generate energy', Member States can under certain conditions exempt from licensing such processes.

An important EC Directive which has an impact on RDF market is the Landfill Directive 1999/31/EC which requires diversion from landfill of biodegradable fraction of MSW and used tyres. Member States will have to introduce either source-separation or implement waste sorting plants to separate biodegradable fraction from MSW or alternatively divert the waste to other treatment methods such as incineration. The residual fractions from such sorting plants can typically be converted into RDF, as it is a drier solid fraction usually with a higher calorific value. This is why RDF production is viewed in some countries as a strategic component of their integrated waste management policy in order to comply with the Landfill Directive recycling targets. Even in countries where source separation is not yet well-developed or where mass burn incineration is predominant, RDF production finds some support as it offers more flexibility in waste management to accommodate continuing progress in minimisation, re-use and source separation for recycling. Similar arguments are advocated by local authorities lacking hazardous incineration capacity and which rely on co-incineration of industrial hazardous waste as part of their waste management strategy.

The other important piece of EC legislation that will impact on co-incineration of waste is the new Waste Incineration Directive 2000/76/EC which aims to bring closer the requirements for incineration and co-incineration. The Directive appears to move matters in the right direction, but it has left divergence between these two processes in the requirements for emission control equipment. For example, air emission limit values for dust, NO<sub>x</sub> and SO<sub>2</sub> emissions are less stringent for cement kilns than for incinerators.

Another interesting point is that the New Incineration Directive imposes the same limit values for incineration and for co-incineration of 'untreated municipal waste'. The term 'untreated' is not defined in the Directive and will need to be clarified. This could have a positive impact on the increase in pre-treatments of residual waste, especially those designed to enhance the homogeneity and calorific value of the fuel fraction and thus encourage RDF production.

The Renewable Energy Directive 2001/77/EC is likely to have an impact on RDF markets for biomass waste (paper, organic) and a possible knock on effect on incineration as the Directive aims to promote the use of renewable energy such as biomass waste.

Key additional policy variables in this context are those related to climate change. Climate change policy may increase the benefits associated with fossil fuel displacement from waste derived fuels on the basis that greenhouse gas emissions are displaced. This is why RDF is viewed in some countries as part of their strategy to help them fulfil the requirements and commitments of Kyoto protocol. However, recent studies suggest that moving material away from incineration and into recycling is likely to be the more favourable treatment for materials when these treatments are assessed in terms of their global warming impacts. However, the

greenhouse gas inventories of countries do not include the 'embodied greenhouse gas emissions' of imports, so that countries which import primary materials will see no reduction in their greenhouse gas inventories if they recycle.

Two recent ECJ rulings could have an impact on the RDF markets. The ECJ (Case C-228/00) ruled that use of waste as a fuel in a cement kiln is recovery when excess heat is generated and that heat is used in the process. In contrast, the ECJ decided in February 2003 (Case C-458/00) that burning waste in a municipal incinerator, whether or not it reclaimed energy, should be classified as waste disposal rather than recovery. The report, however, did not cover in details these aspects which took place at the final stage of the study and which assessment of effects would be a complex exercise.

It appears that waste and energy policies interact to make this a complex and a dynamic area. As such, it is difficult to make clear predictions as to what is likely to happen in future. What does seem clear, however, is that the current developments are accelerating the overlapping of energy and waste policies. Policies on waste management, greenhouse gases control and energy need thoughtful integration which takes account of the broader environmental implications. Also, flexibility is needed to accommodate continuing progress in minimisation, re-use and source separation for recycling/composting/anaerobic digestion.

### **Current practices**

One of the less expensive and well-established technologies to produce RDF from MSW is mechanical biological pre-treatment (MBT). An MBT plant separates out metals and inert materials, screens out organic fractions (for stabilisation using composting processes, either with or without a digestion phase), and separates out high-calorific fractions for RDF. RDF can also result from a 'dry stabilisation process' in which residual waste (after separating out metals and inert materials) is dried through a composting process leaving the residual mass with a higher calorific value.

RDF production from MSW is most active in Member States with high levels of MSW source separation and recycling (i.e. Austria, Germany, Netherlands are the best examples), as the recycling activity generates non-recyclable high calorific residues suitable as RDF. The total quantities of RDF produced from MSW in the European Union have been estimated to amount to about 3 million tonnes. The capacity for RDF production from MSW is on the increase in Austria, Belgium, Finland, Italy and Netherlands with new MBT plants being built.

There is some limited co-incineration of RDF from MSW in Europe. RDF from processed MSW is reported to be incinerated in fluidised bed incinerators in the UK for energy generation, in multi-fuel district heating plants and paper mill boilers in Finland and in a few cement kilns in Austria, Belgium, Denmark, Italy and Netherlands. It is not always possible to secure an outlet for RDF and some quantities have to be stored. The total quantity of RDF co-incinerated has been estimated to amount to about 70% of the quantities produced. The quantities of RDF burnt are expected to increase in the future mainly in Belgium, Italy and in the UK. There are also plans for using RDF from MSW in other non-combustion processes such as gasification and pyrolysis.

A wide range of industrial wastes are also processed to be co-incinerated in industrial processes as secondary fuels. These wastes include plastics and paper/card from commercial and industrial activities (i.e. packaging waste or rejects from manufacturing), waste tyres, biomass waste (i.e. straw, untreated waste wood, dried sewage sludge), waste textiles, residues from car dismantling operations (Automotive shredder residues - ASR) and

hazardous industrial wastes such as waste oils, industrial sludge, impregnated sawdust and spent solvents. These wastes need to have a high calorific value, to be consistent in quality and to be cheap or even support a gate fee. In the past few years, the market for substitute fuels has been very buoyant with the arrival of cheaper fuel substitutes such as meat and bone meal following the crises of BSE and dioxins.

Secondary fuels processed from industrial waste are commonly co-incinerated in cement kilns across Europe. About 105 kilns are reported to co-incinerate more than 2.5 million tpa of secondary fuels, mainly hazardous waste such as spent solvents, used oils and tyres. In the last two years, the cement industry in Austria, Belgium and France has also co-incinerated large quantities of meat and bone meal, estimated to amount to 350,000 tpa. Other industrial wastes (i.e. paper rejects, waste wood, dried sewage sludge, waste textiles and residues from car dismantling operations) are also co-incinerated in cement plants.

District heating plants and the power industry is another sector using industrial RDF in its coal-fired power plants. They mainly co-combust non-hazardous secondary fuels such as waste wood, straw and dried sewage sludge. The co-firing of biomass waste in coal-fired power stations is likely to increase following the implementation of the EC Directive on Renewable Energy as it can account towards renewable obligations.

The paper industry also co-incinerated large quantities of waste mainly originating from its production processes (i.e. bark, paper sludge, spent liquor).

It is reported that most waste used in the iron industry are by-products of the process or waste recycled in-house in the sintering plant as reducing agent rather than energy substitution.

### **Environmental assessment**

The assessment of the environmental impacts of the production and use of RDF has been undertaken using a multiple approach including:

- An LCA type system analysis that considers general benefits or disadvantages of the total recovery system of RDF;
- An EIA type estimation of local impacts of the production and use of RDF; and
- An assessment of impacts on the products from industries co-incinerating RDF.

The assessment compared the use of RDF in brown and hard coal power plants, cement plants and MSW incineration plants. The calculations were based on the assumptions that the materials (both RDF and fossil fuel) were of average quality and that the technology modelled for the installations was of average to advanced level (in respect to BAT) for production and utilisation of RDF. The specified standards in the model for MSW incinerator are ensuring compliance with the new Incineration Directive 2000/76 while this could not be guaranteed in this assessment for cement and power plants as emissions will be dependant on the specific waste type used as a secondary fuel and on the ratio of energy substitution for waste derived fuels. In the power plants, the co-incineration ratio was set at 5% of the thermal energy supply while the ratio in the cement plant amounted to 50%.

The LCA has focused on RDF processed from MSW, especially high calorific fractions from dry stabilisation and compared co-incineration in brown coal-fired power plants, hard coal-fired power plants, in cement works with its incineration in MSW incinerators (MSWI).

The main conclusions of the LCA on the production and use of RDF are that none of the options is globally advantageous. On the one hand, due to the effective substitution of primary fossil fuels by RDF use in coal power plants and cement works, the co-incineration options show a large number of ecological advantages when they are compared with the alternative combustion in a MSWI. On the other hand, this general statement has, however, to be qualified by the tendency of industrial plants to cause higher emission rates (especially of mercury) than a modern MSWI. The benefit of using RDF as fossil fuel substitute at industrial plants must be secured by adequate controls on emissions and the quality of input materials. Although the modelled scenarios in this assessment represent a high standard technology (BAT) there is potential for optimising equipments in both incineration and co-incineration plants which means that differences might scale down but the trends will not be reversed.

The simplified EIA of possible negative impacts on the surroundings of a plant burning RDF leads to similar conclusions. With the given assumptions of average to advanced technologies in the EU for power generation, cement works and MSWI, and typical conditions regarding chimney stack controls and climate, no severe environmental impacts will be observed at a local level. Nevertheless mercury at the cement works and cadmium at the brown coal-fired power plant are the weak points for the use of RDF even if they are still below a 2% threshold of air quality guidelines. Content of these heavy metals in RDF and flue gas cleaning systems at the plants have to be managed to limit these potential negative impacts.

The most difficult part of the environmental assessment of co-incinerating RDF is connected with the potential impacts on the products and by-products. Five different secondary fuels were tested and compared with not using RDF; ASR (automotive shredder residue), paper-reject pellets, demolition wood, RDF produced from Trockenstabilat and Nehlsen mechanical biological treatment (MBT) processes.

The results of the assessment showed a change in the toxic load of all products and by-products (e.g. clinker from cement plants, gypsum, fly ash and slag from coal power plants). There was an increase in the content of contaminants such as chloride and metals e.g. lead, cadmium copper and zinc. The toxic loading depended on the type of RDF used - automotive shredder residues (ASR) produce a higher toxic loading than demolition wood or RDF from MSW. These effects are even more evident when co-incineration of RDF is taking place in brown coal power station as brown coal is less loaded with heavy metals than hard coal.

These materials are typically used or re-used in the construction industry so an increase in toxic loading is of concern for the environment and health (i.e. availability of chromium in cement). The study has, however, not looked at binding conditions, bioavailability or leaching of these contaminants. Slag and ashes from MSWI are often recovered and used as a secondary aggregate for road construction, although this has not been included in this analysis.

It is important to remember that the results of this assessment can vary if different assumptions than the ones presented above are used. The key parameters for which the sensitivity of the model is high are summarised below:

- The technical standard of the combustion plant is one of the most sensitive parameter. Setting rather low standards concerning MSWI as well as co-incineration plants would lead to a modified picture. But for plants that generally meet the targets given by the New Incineration Directive (for MSWI as for co-incineration) the differences are rather narrow.

- Another key parameter is the quality of the substituted fossil fuel. A low difference in burden of pollutants between conventional fuel and RDF strengthens the advantage of co-incineration. To compare scenarios between “with and without RDF”, it is advised to define an average fossil fuel content of heavy metals and use it for benchmarking. It can be used for direct comparison of different types of RDF or even serve as basis for the development of a material specific standard. That standard could be defined as an average content of heavy metals in a product and have the regulations specify for example an enrichment factor not higher than 2.
- Also the energy efficiency of MSW incineration plant is a sensitive parameter. There are existing plants that deliver most of their processed energy for district heating. These plants have nearly the same high-energy effectiveness as power plants or cement kilns but have a more efficient flue gas cleaning equipment.

### **Economic assessment**

There are a number of factors which would seem to be favouring an increased use of RDF in co-incineration facilities. Whilst the economic drivers may be increasingly strong, they are somewhat complex and coupled with local conditions and policies such as the strategy chosen by Member States to implement the Landfill Directive and its obligation to divert large quantities of biodegradable material away from landfill within the next few years.

A range of cost factors influence the situation, including all of the major factors determining the costs of incineration, the costs and revenues associated with the output of RDF production plants, and the market for the calorific value produced in the process itself. Another factor which may enter the decision-making process is the geography of the country concerned. A dispersed population may make investment in smaller-scale facilities prohibitive, and this may tend to favour co-incineration where suitable industrial outlets already exist.

The decision for a municipality or waste management company to produce RDF through MBT or to rely on MSW incineration to comply with the Landfill Directive will depend on whether the costs of the MBT process are less than that of incineration or thermal treatment.

Hence, though it is difficult to generalise, where the cost of incineration is low, the desirability of MBT will rest upon the ability to make use of RDF in a low cost manner. For example, the costs of conventional energy are high and/or the use of RDF requires no additional investment.

Where the cost of incineration is high and where source separation is well developed, the MBT route is still more favourable. This partly reflects the fact that moderate sized composting equipment (circa 20,000 tonnes) tends to cost half the cost of incineration. Indeed, it may become a cheaper option even where RDF is combusted in dedicated incinerators since the mass reduction achieved and the higher calorific value of the remaining material may ‘pay for’ the separation and treatment process.

Local market conditions in addition to treatment process cost will influence the overall economics of RDF operation. For example, the gate fee for capital intense, ‘constant throughput’ facilities such as incinerators, is not related to costs. Where these have excess capacity, the gate fee can fall significantly below costs and it is entirely possible that the lowest cost treatment of RDF may be its use in an incinerator.

There are additional reasons for a municipality to choose MBT as a more flexible solution to mass-burn incineration. Not only can the biological treatment aspect of the process be made modular (to allow switching away from treatment of mixed waste to composting of source-separated waste) but also the use of RDF in co-incineration plants removes the need to invest in capital intense, dedicated incineration (or thermal treatment) facilities.

### **Alternative management options**

A number of studies about waste management alternatives show that from a system specific point of view, landfill is the least favourable option in terms of environmental impacts and efficient use of resources and that for each waste type, no net benefit can be obtained from the final disposal of that waste. As long as any kind of well managed recovery – ranging from recycling to energy recovery even reclamation of energy in a municipal incinerator – deliver environmental benefits, the lack of benefit from the landfill option clearly devalues the landfill alternative. In particular this type of assessment shows that high calorific value wastes are literally wasted when landfilled. Applying the landfill option for a possible RDF waste stream should only be considered for waste material for which the energy recovery might cause a high environmental impact.

A key concern is whether the manufacture of RDF is likely to jeopardise prospects for higher rates of recycling of materials. The MSW fraction used to produce RDF is generally the non-recyclable residue left after sorting/recovery/recycling pre-treatment. However this is not always true. For example, if the waste collector is paid for the delivery of waste which can be used as fuel, and if this exceeds the material value which could be derived from material recycling, the use of material as fuel is likely to persist.

RDF from MSW can be utilised in other processes than incineration and combustion. Gasification and pyrolysis processes are generally promoted as “greener” alternatives to incineration or energy-from-waste. Via gasification, the energy content of the waste is transformed into a syngas which can be re-used as chemical feedstock or to produce power. Pyrolysis produces from waste a bio-fuel and syngas which again can be used as chemical and/or for power production. However, the major negative factor about adopting gasification and pyrolysis for waste treatment is that they are less proven in operation than mass burn incineration and can be just as inflexible as mass burn incineration. In contrast to mass burn incineration, which is optimised around large-scale single site implementation, many gasification and pyrolysis processes lend themselves to economic implementation at smaller scale.

An economic comparison is an essential part of any review process. However, this is not a straightforward issue on which it is easy to provide conclusions. “Real” cost data do not exist for many processes because they are at an early stage of development and, even where they do exist, the economics are very sensitive to site, local and regional factors, making direct comparison from a reference site to another specific project potentially misleading.

## **IV CONCLUSIONS AND RECOMMENDATIONS**

- As long as any kind of well managed recovery – ranging from recycling to energy recovery even reclamation of energy in a MSW incinerator – deliver environmental benefits, the lack of benefit from the landfill option clearly devalues the landfill alternative for high calorific value wastes.

- Use of RDF in industrial processes offers more flexibility than incineration. It leaves more opportunity for future recycling programmes, it does not need to be fed with a constant amount of waste and it does not require investment in capital intensive dedicated incineration facilities.
- Use of RDF in coal power plants and cement works, due to the effective substitution of primary fossil fuels, shows a large number of ecological advantages when they are compared with the alternative combustion in a MSWI as long as the plants comply with the New Waste Incineration Directive 2000/76.
- However, mercury emissions might be problematic when RDF is co-incinerated in industrial processes and special measures should be developed (permits, amending 2000/76, and/or minimum quality standards for RDF).
- There is a need to study the increase of heavy metals in cement and other by-products from co-incineration facilities to investigate possible environmental consequences this may cause.
- Market mechanisms may favour inclusion in RDF of fractions that could be recycled in favourable environmental and economic conditions.
- This phenomenon could increase for some types of RDF (i.e. biomass waste) as a consequence of Directive 2001/77/EC on renewable sources of energy
- There are technologies other than combustion which can convert MSW into energy sources; gasification and pyrolysis. However, the major negative factor about adopting gasification and pyrolysis for waste treatment is that they are less proven in operation than mass burn incineration and can be just as inflexible.

# 1. INTRODUCTION

## 1.1 Background

The Directorate-General Environment has commissioned WRc, in collaboration with IFEU, Eunomia Research & Consulting and ECOTEC, to undertake a survey on the current practice of production and use of refuse derived fuel (RDF) in the fifteen Member States of the European Union. In addition, the legal and policy framework and its environmental and economic implications are covered.

Processed municipal solid waste (MSW) and industrial waste are being used both in dedicated energy-to-waste plants and as fuel substitutes in industrial processes. There is no detailed information on the current scale of these practices across Europe. This study addresses this gap in existing knowledge.

The legal and policy framework for installations that produce and use RDF is not yet well developed at either the national or EU levels. The term RDF has not been legally defined, and the operational requirements for the production and utilisation installations are not well specified.

There is also some debate regarding the environmental and economic benefits associated with production and use of RDF (i.e. BZL 2001, CE 2001). The environmental benefits of producing and using RDF have not been well researched.

Opponents argue that such combustion processes (i.e. incineration and co-incineration) remove the material from the recovery/re-use cycle, inhibiting the degree to which the waste hierarchy can be followed, both in the static (i.e. today) and the dynamic (i.e. in future) context as the waste hierarchy favours waste prevention/minimisation and recycling over energy recovery and disposal. Certainly, to the extent that dedicated facilities demand to be 'fed' waste materials, they neither encourage minimisation, nor re-use and recycling.

Public concern has focused on the differences in the levels of regulatory control between dedicated waste incineration and co-incineration of waste in industrial processes.

Operators of hazardous waste incinerators view the discrepancy in emission standards between incineration and co-incineration as offering a competitive advantage to industrial plants relying on co-incineration, due to the expense of the additional pollution abatement technologies that incinerators are required to operate compared with co-incinerating industrial plants. In addition, some incinerator operators argue that if high calorific value (CV) wastes continue to be re-directed and used as substitute fuels, some incinerator operators may be forced to burn fossil support fuel and increase the gate fees for lower CV wastes.

By contrast, industries co-incinerating industrial wastes argue that the use of waste derived fuels contributes to the conservation of non-renewable energy sources and improves energy recovery as the efficiency of energy recovery is low in incinerators which are not CHP plants, whilst in co-incineration facilities, there is a direct replacement of fuel. In addition, they also argue that the production of certain emissions and residues are avoided (e.g. destruction of organic contaminants due to high temperatures, incorporation of ash in clinker etc.).

## **1.2 Scope**

In practice, the term RDF is commonly applied in the UK to the processed solid, high calorific value (CV) fraction remaining after the recovery of recyclable elements from municipal solid waste (MSW). It was however agreed at the project inception meeting, that for this project, the scope of the term 'refuse derived fuel - RDF' would encompass any waste that is **traded** and burnt in installations for power generation or in a manufacturing process where heat is required (e.g. cement production).

Article 2 section 2b of the Directive on the Incineration of Waste 2000/76/EC excludes from its scope experimental plants used for research, development and testing, which treat less than 50 tonnes of waste per year. It was initially suggested that the study would consider only plants that handled over 50 tonnes of waste per hour – in order that the most significant processes for pollution were considered. However, to avoid constricting the scope of the project, it was agreed at the inception meeting that no limitations on the size of an installation producing or burning RDF should be made.

## **1.3 Objectives**

The specific objectives of the project are to report on:

1. The quantity and types of waste used to produce RDF;
2. The number of installations, capacity and type of technology used for RDF production;
3. The quality and quantity of RDF produced;
4. The type of installations using RDF as fuel and the quantities in which this occurs;
5. Assessment of environmental impacts of the production and use of RDF;
6. Assessment of the economical aspects of the production and use of RDF;
7. Assessment of alternative management options for the waste streams were they not used for RDF production and combustion (e.g. separate collection and recycling or mixed collection and landfill); and
8. Overview of the legal and policy framework of the above mentioned activities.

## **1.4 Report structure**

This is the Final Report presenting results for the contract B4-3040/2000/306517/MAR/E3 entitled 'Refuse Derived Fuel (RDF), current practice and perspectives'.

The structure of the Final Report is as follows:

- Section 1 – Introduction;
- Section 2 provides a summary of EC policy and legislation impacting RDF production and use and the specific regulatory conditions across Europe;

- Section 3 provides an overview of the current practices with regard to waste derived fuel production and use in different countries together with quality information on RDF and secondary fuels;
- Section 4 presents the economic assessment of RDF production and utilisation;
- Section 5 presents the environmental assessment of RDF production and utilisation;
- Section 6 presents the assessment of alternative management strategies;
- Appendix A provides detailed information for the most relevant EC Directives;
- Appendix B presents detailed country report for each of 15 Member States;
- Appendix C presents description of co-incineration processes;
- Appendix D presents description of alternative technologies for RDF utilisation.



## **2. LEGAL AND POLICY ASSESSMENT**

The following Section describes in separate parts, the relevant European policy and legislation and specific national regulatory framework on environment protection, waste management and energy production which influence the production and use of waste derived fuels in Europe.

Other relevant initiatives which are discussed below are the attempts to standardise waste derived fuels made by international organisations such as EURITS and CEN.

### **2.1 European regulatory framework**

The EC Directives controlling and affecting RDF production and utilisation are summarised below while a more detailed review is presented for the most important Directives in Appendix A.

The most important regulation is the recently adopted Waste Incineration Directive (2000/76/EC). It introduces emissions limits for co-incineration of waste for energy recovery, and seeks to bring these into line with those for waste incineration. Legislation regarding waste management notably, the Framework Directive on Waste (75/442/EEC as amended) and the Landfill Directive (1999/31/EC) also influence RDF production and utilisation as it requires Member States to move waste away from landfill and into options which are higher in the waste management hierarchy such as incineration and/or recycling. Which options are chosen depends not only on regulations and policies regarding waste, but also upon legislation and policy regarding the utilisation of climate change and renewable energy such as the recently adopted Directive (2001/77/EC) on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market. The other issue affecting the potential for utilising waste as energy is the changes occurring in the electricity market more generally. As markets for energy become more liberalised, markets for calorific value will become more competitive. Other European regulatory developments such as BSE controls, end of life vehicles have also had an indirect impact on the waste derived fuel markets.

#### **2.1.1 Waste Framework Directive**

The scope of the definition of waste for the purposes of the Waste Framework Directive 75/442/EEC (CEC 1975) as amended by Directive 91/156/EEC (CEC 1991) (see Appendix A) is broad and covers materials used to produce secondary fuels which are of interest to this study. Therefore, it seems fair to state that those materials are wastes, and do not cease to be such by virtue of their being processed and used to generate energy.

The manufacture of RDF from waste does not change the status of the material to that of a product. This is in line with the EU waste definition and the jurisprudence of the European Court of Justice (ECJ). Indeed, the EU definition of waste is such that it defines (more or less well) when something becomes a waste, but gives few if any indications as to when a material stops being a waste. The ECJ has, up to now, taken the view that a material remains a waste for a very long time in the chain of reprocessing and recovery.

Compliance with a potential CEN standard for RDF (see Section 2.2 below) would have no effect on the waste status of the material. If it were to be the case that one sought to alter the

existing situation such that RDF fulfilling a certain standards were no longer to be considered as a waste, this decision would have to be made through some legal mechanism (for example, an amendment of the Framework Directive, or the introduction of a Directive similar to the Second Draft Directive on Biowaste, but specifying the criteria which would have to be met in order for RDF to be considered as products, or fuels, as opposed to wastes). In the meantime, it may well be that both industry and some Member States take (implicitly) a different view (with the risk of infringement procedures).

The implications of this are that those waste materials which are to be used as fuel are subject to relevant licensing controls regarding their movement and utilisation. However, R1 – one of the 'Recovery Activities as defined in Annex IIB of Directive 75/442/EEC as amended (see Appendix A), implies that where waste is used 'principally as a fuel or other means to generate energy', Member States can under certain conditions exempt such processes from licensing.

The fact that the competent authority may exempt a waste burning facility with energy recovery does not mean that it is free from any controls as general rules must be adopted by the Member State implementing such exemptions.

Two recent European Court of Justice (ECJ) rulings could have an effect on the RDF markets. The ECJ ruled that use of waste as a fuel in a cement kiln is recovery when excess heat is generated and that heat is used in the process (Case C-228/00). In contrast, the ECJ decided in February 2003 (Case C-458/00) that burning waste in a municipal incinerator, whether or not it reclaimed energy, should be classified as waste disposal rather than recovery. It means that energy recovery from dedicated MSW incinerators should no longer be counted towards recovery targets under the EC Directives on Packaging, End of Life Vehicles or Waste Electrical and Electronical Equipment. This could divert more packaging and automotive shredder residues (ASR) towards co-incineration in industrial facilities as secondary fuel to help Member States fulfil their recovery obligations. It is not clear if this ruling will also mean that combustion of RDF in a RDF dedicated plant is disposal rather than recovery. The report, however, has not analysed in more details these aspects which took place at the final stage of the study and which assessment of effects would be a complex exercise.

### **2.1.2 Landfill Directive**

The Landfill Directive 1999/31/EC (CEC 1999) imposes a phased reduction of biodegradable waste going to landfill from 2006. In this context, the need to find alternative treatments for residual municipal waste is clear and this could indirectly influence the production of RDF. Member States will have to introduce either source-separation of biowaste or implement waste sorting plants to separate biodegradable fraction from MSW or pre-treat the residual waste. The residual fraction from such sorting plants can typically be processed and converted into RDF to be used in industrial combustion processes, as it is a drier solid fraction usually with a higher calorific value depending on the process. Alternatively, the residual material can be sent to mass-burn incinerators without pre-treatment.

The Landfill Directive (CEC 1999) also imposes a progressive ban on the disposal of tyres to landfill (Article 5 3 d). Landfilling of whole tyres is due to cease from 16 July 2003 and landfilling of shredded used tyres is to be stopped from 16 July 2006, but excluding tyres used as engineering material, bicycle tyres and tyres with an outside diameter exceeding 1400 mm. One route already exploited for used tyres is co-incineration as secondary fuels in industrial

processes. This outlet could become increasingly important to fulfil the bans implied by the Directive.

### 2.1.3 Incineration Directives

The legislation in respect of different facilities which incinerate waste materials is changing. Previously, two Directives concerning Municipal Waste Incineration, Directive for new MSW Incineration Plants 89/369/EEC (CEC 1989a) and existing plants 89/429/EEC (CEC 1989b) and one concerning Hazardous Waste Incineration 94/67/EC (CEC 1994), were of particular significance. These Directives are now being 'merged' and their combined coverage is being expanded, through implementation of the new Waste Incineration Directive (2000/76/EC) (CEC 2000 a). There are provisions in these directives for co-incineration of RDF from MSW and hazardous waste.

#### MSW Incineration Directives

The Council Directive 89/369/EEC (CEC 1989a) on the prevention of air pollution from new municipal waste incineration plants actually defined what is 'waste derived fuels' and states that "*exceptionally, Member States may derogate from some of the provisions of this Directive in the case of plants specially designed to burn waste-derived fuels (see definition above) where compliance with such provisions would entail excessive costs or if, given the technical characteristics of the plant in question, such provisions are inappropriate from a technical viewpoint provided that: - those plants burn no waste other than that defined above (apart from back-up fuels used for start-up operations), - the provisions of Directive 84/360/EEC are complied with*".

Hence, for example, the provision that co-incineration plants would, under the new Directive 2000/76/EC, be regulated as incinerators where they burn RDF from municipal waste does not affect existing plant until the end of 2005.

#### Hazardous Waste Incineration Directive

The existing Directive on Hazardous Waste Incineration 94/67/EC (CEC 1994) entered into force in Member States in December 1996. New plants must comply from 31 December 1996 and existing plants from 30 June 2000.

Incineration plants include any incineration plants of hazardous waste including pre-treatment as well as pyrolysis or other thermal treatment processes (i.e. plasma process) insofar as their products are subsequently incinerated. This includes industrial plants co-incinerating hazardous wastes as regular or additional fuels. However, when a plant is not intended primarily to incinerate hazardous waste (co-incineration) and the resulting heat release from burning hazardous waste is no higher than 40% of the total heat release, the mixing rule applies. That means that emission limit values in this case are proportional to the percentage of hazardous waste. The determination of emission limit values for co-incineration is given in formula below. This has as consequence that hazardous waste incinerators are subject to more stringent emission limit values and have to install pollution abatement technology not required by cement kilns or other industrial combustion processes co-incinerating hazardous waste derived fuels.

$C = (V_w \times C_w + V_{proc} \times C_{proc}) / (V_w + V_{proc})$  with

C = total emission limit value for CO and the relevant pollutants

V w = exhaust gas volume resulting from the incineration of hazardous waste

Cw = emission limit values set for hazardous waste incineration plants

V proc = exhaust gas volume resulting from the combustion of authorised fuels (excluding hazardous waste)

C proc = emission limit values for industrial process

### **New Waste Incineration Directive**

The scope of the New Waste Incineration Directive 2000/76/EC (CEC 2000 a) specifically refers to incineration and co-incineration of waste and a definition is given of co-incineration plant. The new Directive imposes stricter limit values and thus stringent operational conditions and technical requirements. The key measures from the point of view of this piece of work are that the distinction between hazardous and non-hazardous wastes in respect of emission limit values is to some extent removed, and that cement plants co-incinerating waste are no longer subject to the mixing rule.

The Directive had to be implemented by Member States no later than 28 December 2002. It will apply to new incineration plants two years after adoption (i.e. 28 December 2002) and to existing plants five years after adoption (i.e. 28 December 2005). This means that the provisions of the previous Incineration Directives apply until then.

As in the earlier Hazardous Waste Incineration Directive 94/67/EEC (see above), the air emission limit values for co-incineration plants are based on the mixing rule (see formula in Appendix A) if less than 40% of resulting heat originates from hazardous waste and if untreated mixed MSW is not co-incinerated. However, cement kilns can no longer apply the mixing rule but special provisions both for C waste and C process apply. The Directive also establishes 'special provisions' for combustion plants. These facilities have been granted later deadlines of 2007, 2008 or 2010 depending on the pollutant.

The specific air emission limit values for cement plants and combustion plants are shown in Tables A.2 and A.3 (Appendix A) as compared with those for 'dedicated' incineration plant. It is clear from these that although the limit values for some pollutants are the same, there are significant differences in respect of some pollutants. The following points seem worth noting:

- Limit values for dust emissions (particulate matter) are higher (i.e. less stringent) for both cement kilns and co-incineration combustion plant than for incinerators;
- Limit values for NO<sub>x</sub> emissions are much higher (i.e. less stringent) for cement kilns, and higher for smaller scale co-incineration combustion plants, than for incinerators;
- Limit values for SO<sub>2</sub> emissions are much higher (i.e. less stringent) for co-incineration combustion plant (especially liquid and solid fuels) than for incinerators.

This alone suggests that, notwithstanding the intentions of the new Incineration Directive, the scope remains for considerable divergence in the requirements for emissions control equipment between incineration and co-incineration plants.

Given that many of the wastes used as fuel are characterized as hazardous wastes, it is worth considering some of the other implications of the Directive for those wastes which might be used as fuel:

- First of all, under Article 7(4), if the waste co-incinerated is 'untreated municipal waste', the more relaxed regimes discussed above for co-incineration plants do not apply. The term 'untreated' is not defined in the Directive. It would seem unlikely that this is meant to imply that waste which is left over after source separation has been 'treated'. The definition could be an important one.
- Under Article 6 (2), whereas co-incineration plants have to be 'designed, equipped, built and operated in such a way that the gas resulting from the process is raised in a controlled and homogeneous fashion and even under the most unfavorable conditions, to a temperature of 850°C, as measured near the inner wall or at another representative point of the combustion chamber as authorized by the competent authority, for two seconds', if hazardous wastes with a content of more than 1% of halogenated organic substances, expressed as chlorine, are co-incinerated, the temperature has to be raised to 1 100°C for at least two seconds.
- Under Article 7(2), if in a co-incineration plant more than 40% of the resulting heat release comes from hazardous waste, the (more stringent) emission limit values for dust, SO<sub>2</sub> and Nox relevant for incinerators shall apply.
- The Directive also allows for a review of the provisions for co-incineration, in particular where major waste streams are directed towards co-incineration plants other than combustion plants and cement kilns.

#### **2.1.4 IPPC Directive**

The Integrated Pollution Prevention and Control (IPPC) Directive 96/61/EC (CEC 1996) impacts on RDF utilisation as it regulates combustion installations with a rated thermal input >50 MW, installations for the disposal or recovery of hazardous waste and installations for the incineration of municipal waste.

Under the IPPC Directive, non-binding BAT standards referred to as BREFS are being prepared to help Member States in their IPPC implementation. BREFS have been published for the cement industry and being prepared for waste incineration and waste treatment.

The limit values established for co-incineration in cement plants in the 2000/76/EC Incineration Directive are in line with what is likely to be achieved under BAT as defined in the BREF for cement industry (BREF 2001). Hence, the limit values on co-incineration established under the Incineration Directive may well become the industry standard (irrespective of whether waste is co-incinerated). This has the important consequence of implying that the incremental costs of compliance with the limit values established under the Incineration Directive might actually fall to zero for the industry because these may be required under IPPC anyway, irrespective of whether or not waste is combusted.

The BREF on waste incineration will not cover co-incineration, which will be dealt with in the sector BREF where the waste is actually burned (i.e. cement industry) while the BREF on waste treatment will include preparation of RDF.

### 2.1.5 Large Combustion Plant Directive

There is a new Directive on the Limitation of Emissions of Certain Pollutants into the Air from Large Combustion Plant 2001/80/EC (CEC 2001 b) replacing from 27 November 2002 Directive 88/609/EEC (CEC 1988). The new LCP Directive applies more stringent limits for air emissions. The Directive applies to combustion plants with a rated thermal input  $\geq 50$  MW, irrespective of the type of fuel used. The definition of "fuel" excludes wastes covered by any of the incineration Directives but covers combustion plants using biomass waste such as

- vegetable waste from agriculture, forestry and food processing industry;
- fibrous vegetable waste from virgin pulp production and from production of paper from pulp, if it is co-incinerated at the place of production and the heat generated is recovered;
- cork waste; and
- wood waste with the exception of wood waste which may contain halogenated organic compounds or heavy metals as a result of treatment with wood preservatives or coating.

Thus, a large combustion plant burning fuels derived from other waste materials than the above does not fall under the scope of this Directive but under the scope of Incineration Directive 2000/76/EC.

### 2.1.6 Renewable energy Directive

The Directive on Renewable Energy Sources for Electricity Production 2001/77/EC (CEC 2001a) has recently been adopted with the specific purpose of promoting an increase in the contribution of renewable energy sources to electricity production.

With regard to waste, the pre-amble of the Directive states that: *'the incineration of non-separated municipal waste should not be promoted under a future support system for renewable energy sources, if such promotion were to undermine the (waste) hierarchy.'* However, the Directive support biomass waste incineration as a form of renewable energy source.

Biomass which is one of the renewable energy sources under this Directive is defined as the biodegradable fraction of products, waste and residues from agriculture including vegetable and animal substances, forestry and related industries as well as the biodegradable fraction of industrial and municipal waste. It does not include the high calorific fraction RDF. However, it may be difficult in some cases not to have any biodegradable fraction present in RDF.

This is likely to have an impact on RDF markets for biodegradable waste (paper and organics) and a possible knock-on effect on incineration and co-combustion of such waste in power plants. It is, however difficult, to make clear predictions as to what is likely to happen in the future. What does seem clear, however, is that the current developments are accelerating the overlapping of energy and waste policies.

### 2.1.7 Animal waste regulations

Following the BSE and dioxin crises, the EC Commission has adopted a series of measures and one of these measures is to prohibit the reuse of animal waste (i.e. meat and bone meal) into animal feed (Decision 2000/766/EC (CD 2000b) and Regulation 999/2001(ECR 2001)). This has had as consequence that large amounts of meat and bone meals have appeared on the market as 'cheap' secondary fuels as there was insufficient specialised incineration capacity to deal with these materials. The cement industry in many countries has been approached to take these wastes and co-incinerate them.

### 2.1.8 End-of-life vehicles regulations

The Directive 2000/53/EC (CEC 2000 b) on the End of Life Vehicles which had to be implemented by 21 April 2002 into Member States legislation aims at preventing waste from vehicles by promoting reuse, recycling and other forms of recovery. It sets targets for reuse and recovery which could potentially influence the volume of automotive shredder residues (ASR) being co-incinerated. It also aims at reducing the environmental burden of these wastes by limiting for example the presence of hazardous substances in vehicles such as lead, mercury, cadmium and hexavalent chromium for new vehicles. This should in the long term improve the quality of automotive shredder residues (ASR) which can be co-incinerated as secondary fuels in industrial processes.

## 2.2 International guidelines

Different international bodies have been working in standardising quality of fuels recovered from wastes.

### 2.2.1 EURITS criteria

EURITS is the European Association of Waste Thermal Treatment Companies for Specialised Waste. EURITS has published criteria for waste co-incinerated in cement plants as substitute fuel (Table 2.1). The cement industry has pronounced that these criteria are too stringent, especially with regard to the minimum calorific value.

**Table 2.1 EURITS criteria for co-incineration of waste in cement kilns**

Parameter	Unit	Value
Calorific value	MJ/kg	15
Cl	%	0.5
S	%	0.4
Br/l	%	0.01
N	%	0.7
F	%	0.1
Be	Mg/kg	1
Hg/Ti	Mg/kg	2

Parameter	Unit	Value
As, Se (Te), Cd, Sb	Mg/kg	10
Mo	Mg/kg	20
V, Cr, Co, Ni, Cu, Pb, Mn, Sn	Mg/kg	200
Zn	Mg/kg	500
Ash content (excl Ca, Al, Fe, Si)	%	5

### 2.2.2 CEN Committee

The CEN Task Force 118 was set up in April 2000 to deal with 'solid recovered fuels'. The objective of this Task Force is to initiate the drafting of a CEN Report to describe solid recovered fuels and their use and to develop a work programme for drafting relevant standards.

### 2.3 National legal and policy framework

The survey of practices in each Member State (see Appendix B for detailed information) has identified differences in waste management and energy policies which have influenced the production and use of RDF in the Union. The main differences are highlighted below with respect to:

1. Waste management policy;
2. Definition of RDF;
3. Quality criteria;
4. Product or waste status;
5. Authorisation procedure;
6. Emission limits for co-incineration; and
7. Energy policy.

#### 2.3.1 Waste management policy

Waste derived fuel from MSW production and its utilisation is viewed in some countries as a strategic component of an integrated waste management policy, as the landfill outlet for MSW is increasingly restricted by EC and Member State legislation:

- In Denmark and the Netherlands, bans on the landfilling of municipal waste are already in place. In practice, however, some landfilling of MSW still occurs of bulky waste in Denmark, and in the Netherlands of waste for which no available capacity in incinerators is available;

- In Germany and Austria, bans on landfilling will be applied to waste in 2005 with volatile solids content and total organic carbon content respectively greater than 5%, but with legislation in place allowing landfilling of residual waste treated through mechanical biological treatment where certain criteria are met. Typically, standards for the degree of stability, such as the respirometric index are used;
- Italy is in the process of drafting similar legislation and indeed, such legislation is already enacted in Veneto Region;
- In Flanders (Belgium), there are bans on the landfilling of a range of materials, particularly those which are separated at source;
- In Sweden, separated combustible waste cannot be landfilled (from 2002) and organic waste will not be landfilled after 2005;
- France introduced a ban on landfilling limiting it to 'ultimate waste' in 2002. There have been official communications concerning the difficulty to reach this target;
- Finland will ban landfilling of MSW from 2005 unless the biodegradable fraction has been separated at source.

Countries who had made greatest progress in source separation by 1995 (e.g. Austria and Germany are the best examples) are less well placed to achieve the targeted reductions in biodegradable municipal waste to be sent to landfill through source separation alone and will have to improve disposal of the residual waste fraction.

RDF production appears most common in Member States which already achieve relatively high levels of recycling and composting (i.e. Austria, Germany, Netherlands and Finland) as high rates of source separation leave non-recyclable residues which are suitable for RDF production.

Even in countries where source separation is not so well-developed (best examples are Greece, Spain, Ireland, Italy, Portugal, UK), and where source separation with or without residual waste treatments might be sufficient to meet the Landfill Directive targets, flexibility in waste management options will be very important.

In this context, mechanical biological treatment plants (MBT) could be utilised with a more specific objective of stabilising the biodegradable fraction of residual waste as a means to comply with the Landfill Directive. In such conditions, the non-biodegradable component of residual waste could be recycled, re-used or co-incinerated and the stabilised biowaste would fall out of the scope of the Article 5 targets in the Landfill Directive by virtue of the reduction in fermentability so achieved and be landfilled. The growth in MBT will depend on the degree to which Member State interpretate the term 'treated' under the Landfill and Incineration Directives.

There are also good reasons for proposing MBT as a more flexible solution to mass-burn incineration. Not only can the biological treatment aspect of the process be made modular (to allow switching away from treatment of mixed waste to composting of source-separated waste) but also the use of RDF in co-incineration plants removes the need to invest in capital intense, dedicated incineration (or thermal treatment) facilities.

Co-combusting of RDF is also more widely practised in countries with limited mass burn incineration capacity (i.e. Finland), while it was reported that several initiatives of RDF production from MSW have failed in the past as industrial operators and/or MSW incinerators were not prepared to pay for such materials (i.e. Denmark, France).

In some countries (Ireland and Greece), there is currently no plan to promote RDF or industrial secondary fuels to fulfil their diversion obligations under the Landfill Directive.

### 2.3.2 Definition

There is no legal definition of the term 'Refuse Derived Fuel (RDF)' and it is interpreted differently across countries. It should be noted that the terminology used in different countries to describe the material which is being co-combusted may reflect the desire of the users to have the material treated in a specific way under existing legislation.

Refuse is a general term for municipal solid and commercial wastes and in English speaking countries, RDF usually refers to the segregated high calorific fraction of municipal solid waste (MSW), commercial or industrial process wastes. Other terms are also used for MSW derived fuels such as Recovered Fuel (REF), Packaging Derived Fuels (PDF), Paper and Plastic Fraction (PPF) and Process Engineered Fuel (PEF). REF, PDF, PPF and PEF usually refer to a source-separated, processed, dry combustible MSW fraction (e.g. plastics and/or paper) which are too contaminated to be recycled. It has a higher calorific value, lower moisture content and lower ash content (on combustion) than RDF derived from mixed waste fractions.

The terms 'Secondary Fuel, Substitute Fuel and Substitute Liquid Fuel (SLF)' are used for processed industrial wastes which may be homogeneous or mixed to specification. Examples of these fuels include waste tyres, waste oils, spent solvents, bone meal, animal fats, sewage sludge and industrial sludge (e.g. paint sludge and paper sludge). These terms can also refer to non-hazardous packaging or other residues from industrial/trade sources (e.g. plastic, paper and textiles), biomass (e.g. waste wood and sawdust), demolition waste or shredded combustible residues from scrap cars.

In Italy, the English term RDF was used until 1998 when the Italian translation '*Combustibili derivato di rifiuti – CDR*' replaced the term 'RDF'. In the Netherlands, RDF is used to differentiate between biomass and other high calorific waste streams. In the UK, the term RDF or fibre fuel is generally taken to refer to processed paper/card/plastic fractions of municipal solid waste (MSW) or industrial wastes and may be burnt in dedicated waste-to-energy RDF utilisation plant. Cemfuel is the term used in the UK to label SLF waste substitute fuel manufactured to specification for the cement industry. Profuel is another term used in the UK to refer to a processed fuel derived from paper, plastics and carpet off-cuts. In Austria and Germany the term '*Brennstoff aus Müll – BRAM*' can be assimilated to the English term 'RDF'. The term '*Ersatzbrennstoff*' - Substitute fuel is used in a broader sense. Other terms such as '*Substitutbrennstoff*', '*Sekundärbrennstoff*' – Secondary Fuel can also be found. In Finland the term 'REF' is more commonly used for the processed residual of separate household collection of specific quality. In Sweden, 'Specialbränsle A' and 'Lattbränsle' are terms used to label waste derived fuels produced at specifications for the cement industry. In Spain the term COMBSU refers to SLF, GDF refers to MSW derived fuels and TDF to tyre derived fuels.

Throughout this report, and in particular in the country overviews, the information has been presented separately for fuels processed from municipal solid waste or commercial and

industrial waste with similar characteristics to MSW and for fuels, usually referred to 'Secondary Fuels', derived from industrial wastes.

### 2.3.3 Quality standard for RDF production and utilisation

There are national initiatives to reduce the environmental burdens of, and promote the use of, secondary fuels in industrial processes by specifying minimum quality requirements for waste derived fuels. The introduction of a certification label has occurred in Germany, and quality standards for RDF have been introduced in Finland, Italy (Table 2.2) and Netherlands.

There are also quality standards for secondary fuels specified by the cement industry for process reasons which have been issued for example in Sweden (Table 2.3) and the UK. The Flemish Region of Belgium applies the standards issued by European Federation for Waste Treatment Plants - EURITS for production and use of waste fuel in clinker production.

**Table 2.2 Quality standards for solid recovered fuels**

Characteristic	Unit	Italy	Finland <sup>1)</sup>			
			DL	Quality Class		
				I	II	III
Water content	%	<25				
Calorific Value	KJ/kg	15,000				
Ash content	%	20				
Chlorine content	% (m/m) <sup>2)</sup>	0.9	0.01	<0.15	<0.50	<1.50
Sulphur Content	% (m/m) <sup>2)</sup>	0.6	0.01	<0.20	<0.30	<0.50
Nitrogen Content	% (m/m) <sup>2)</sup>	-	0.01	<1.00	<1.50	<2.50
Potassium and sodium content <sup>3)</sup>	% (m/m) <sup>2)</sup>	-	0.01	<0.20	<0.40	<0.50
Aluminium Content	% (m/m) <sup>2)</sup>	-	0.01	<sup>4)</sup>	<sup>5)</sup>	<sup>6)</sup>
Mercury Content	Mg kg <sup>-1</sup>	-	0.1	<0.1	<0.2	<0.5
Cadmium Content	Mg kg <sup>-1</sup>	-	0.1	<1.0	<4.0	<5.0
Lead	Mg kg <sup>-1</sup>	200				
Copper	Mg kg <sup>-1</sup>	300				
Manganese	Mg kg <sup>-1</sup>	400				
Chromium	Mg kg <sup>-1</sup>	100				
Zinc	Mg kg <sup>-1</sup>	500				
Nickel	Mg kg <sup>-1</sup>	40				
Arsenic	Mg kg <sup>-1</sup>	9				
Cadmium+mercury	Mg kg <sup>-1</sup>	7				

Notes:

- 1) The limit value concerns a fuel amount of  $\leq 1000 \text{ m}^3$  or a fuel amount produced or delivered during one month, and it shall be verified at least for a respective frequency.
  - 2) % (m/m) denotes the percentage by mass
  - 3) Total content (K+Na) of water-soluble and ion-exchangeable proportion for dry matter.
  - 4) Metallic aluminium is not allowed, but is accepted within the limits of reporting precision.
  - 5) Metallic aluminium is removed by source separation and by the fuel production process.
  - 6) Metallic aluminium content is agreed separately.
- DL detection limit

**Table 2.3 Specification for recovered fuels used in cement plants in Sweden**

Parameter	Criteria	
	“Specialbränsle A”	“Lattbränsle”
Calorific value	23.9 – 31.4 MJ/kg	25.1 – 31.4 MJ/kg
Flash point	< 21°C	< 21°C
Specific density at 15°C	0.9 – 1.1 kg/dm <sup>3</sup>	0.80 – 0.95 kg/dm <sup>3</sup>
Viscosity	Pumpable	1 – 5 cst at 50°C
Ash content	5 – 10 %	0.6 – 0.8 %
Water	< 30 %	< 10 %
Cl	< 1 %	< 1 %
S	N/A	< 0.5 %
Cr	< 300 ppm	< 30 ppm
V	N/A	< 50 ppm
Z	N/A	< 300 ppm
Zn	< 2000 ppm	N/A
Cd	< 10 ppm	< 5 ppm
Pb	< 350 ppm	< 100 ppm
Ni	N/A	< 10 ppm
Hg	N/A	< 5 ppm
PCB	N/A	< 5 ppm

### 2.3.4 Status of RDF

There are discussions in certain Member States on whether pre-treated hazardous wastes made to specifications for substitute fuels in cement kilns should still be considered as waste. In the UK, for example, there was a debate as to whether the waste prepared as ‘Cemfuel’ constitutes a waste or a fuel. The UK High Court upheld the classification of the UK Environment Agency that it remains a waste under the Waste Directive. Other Member States (e.g. Belgium and France) have also opted for retaining the waste status to maintain a tight control on the movements of secondary fuels and record keeping, as well as quality control and emissions controls. It was argued that this latter strategy maintains the price of such materials at a low or negative value for industries using them as substitute fuels. A company burning a waste material does not have to pay for such fuel but receives payment for its disposal.

There was a legal battle between Germany and Belgium with regard to export of waste for incineration in Belgian cement kilns. The Belgian cement industry argued that this constituted a recovery operation, not disposal, while the German government wanted to prevent this

export. In a second legal opinion, the European Court of Justice has backed Commission arguments against Germany that the operation should be regarded as recovery.

### **2.3.5 Authorisation procedure**

In all countries studied, plants co-incinerating non-hazardous and hazardous wastes must have an authorisation from the relevant licensing authorities. Co-incineration of waste derived fuels in industrial processes is subject to authorisation under the IPPC. The authorisation procedure for the use of wastes (other than biomass waste) as fuel substitutes in Member States are usually granted on case-by-case basis following by extensive operational trials (i.e. United Kingdom). Most countries allow co-combustion of biomass waste without any additional controls and requirements than the ones applicable to any 'normal' combustion unit. In France for example, there is a pre-authorised list of waste types which are authorised for use as fuel substitutes without further trials.

In some countries, the authorisation procedure includes an environmental assessment and public consultation (i.e. Spain, United Kingdom).

Some countries are actively promoting through their regulations the use of RDF from MSW and other wastes in both dedicated and industrial plants by introducing simplified authorisation procedures (i.e. Italy) or introducing specific regulations supporting this practice (i.e. Portugal).

The authorisation for co-incinerating hazardous waste in cement kilns is usually valid for a limited period (i.e. in Spain 5 years and can only be renewed twice).

### **2.3.6 Emissions Limit values**

Emission limits values (ELV) imposed on cement plants co-incinerating solid waste derived fuels vary between countries within the framework of the 1994 Hazardous Waste Incineration Directive. Typical emission values as delivered in authorisation in Member States are reported in Table 2.4. This information has been extracted from a recent study on solid waste used as secondary fuels in the cement industry (EA 2001) and has not been re-checked during our study. A direct comparison is not always possible as reference conditions and monitoring requirements vary as well.

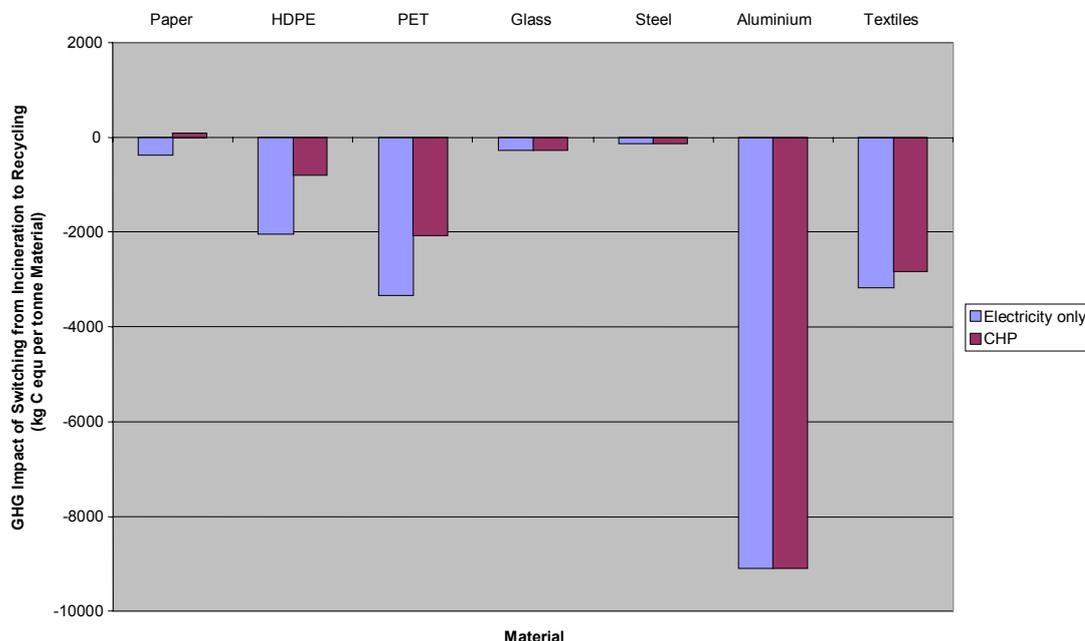
In countries such as Belgium, Spain and United Kingdom, for existing authorisation of co-incineration in cement plants, the mixing rule as specified in the 1994 HW Incineration Directive is applied, i.e. when energy substitution from hazardous waste is lower than 40%, the emission limits are proportional to the volume of exhaust gas resulting from the incineration of waste and are thus less stringent than the ELV imposed on Hazardous Waste Incinerators. Some countries do not allow the application of the mixing rule for cement plants (e.g. Austria, France, and Netherlands) or at lower energy substitution rate (e.g. 25% energy substitution rate in Germany). In addition, in Germany, above 25% of energy substitution, the limit values applying to co-incineration plants are more stringent than limits laid down in 1994 Incineration Directive. There are discussions in the Flemish part of Belgium to impose a 10% limit for substitution rule for any type of waste under which the mixing rule would only apply.

### 2.3.7 Energy market and climate change

Changes occurring in the electricity market are affecting the potential for utilising waste as energy more generally. As markets for energy become more liberalised, markets for calorific value will become more competitive.

Member States either already have, or are planning to implement, support schemes which do indeed subsidise the production of energy from mixed waste. To reach the Kyoto target, biowastes (i.e. waste wood) will play a key role in countries such as Finland. In some countries (i.e. Italy), it is also argued that electricity from fuels derived from MSW constitutes 'renewable electricity' production even though this is not covered by the Renewable Energy Directive 2001/77/EC. Italy argued that co-incinerating RDF in dedicated or industrial processes to generate energy can help to reduce greenhouse gas emissions and so help to achieve their commitments to the Kyoto protocol. This appears true if, and only if, the material being combusted is genuinely a residual material (i.e. material which cannot be recycled).

Recent studies suggest that moving material away from incineration and into recycling is likely to be the more favourable treatment for materials when these treatments are assessed in terms of their global warming impacts (*Smith, et al 2001*) as shown in Figure 2.1 below. It would seem desirable, from the waste management perspective, to remove the support for energy from waste so as to reinforce the waste management hierarchy (which itself reflects, at the global level, a more rational use of energy). However, the greenhouse gas inventories of countries do not include the 'embodied greenhouse gas emissions' of imports, so that countries which import primary materials will see no reduction in their greenhouse gas inventories if they recycle.



**Figure 2.1 Climate Change Impacts of Switching from Incineration to Recycling (Smith et al 2001)**

### **2.3.8 Conclusions**

The most important piece of EC legislation with regard to RDF utilisation in industrial processes is the new Waste Incineration Directive (2000/76/EC) which aims to bring closer the requirements for incineration and co-incineration. This is going in the right direction to address the concern of environmentalists that industrial plants co-incinerating waste derived fuels are not as strictly controlled as waste incinerators.

The implementation of the EC Landfill Directive (1999/31/EC) has an indirect impact on RDF production in EU. Strategies chosen by Member States to divert biodegradable fraction of MSW and used tyres from landfill as required under this Directive are likely to encourage RDF production.

In addition, several countries are implementing policies in respect of climate change and control of greenhouse gas emissions which will also have an impact upon the use of RDF in co-incineration facilities.

The overlapping concerns regarding waste management, greenhouse gas control and energy need thoughtful integration which takes account of the broader environmental implications. Also, flexibility is needed to accommodate continuing progress in minimisation, re-use and source separation for recycling/composting/anaerobic digestion.

As there is some variation in the interpretation of European Directives, it is difficult to make clear predictions as to what is likely to happen in future. What does seem clear, however, is that the policies being put in place are accelerating the overlapping of energy and waste policies. The legislative changes which are in the pipeline are helpful (i.e. new Waste Incineration Directive) and they appear to move matters in the right direction in seeking to harmonise standards as far as possible across co-incineration facilities and incinerators. But they do not go far enough.

**Table 2.4 Typical Emission Limit Value and reference conditions for co-incineration of secondary fuels in cement plants in Europe (adapted from EA 2001)**

Parameter	Unit	AT	BE	DK	FI	FR	DE	GR	IT	LU	NL	PO	ES	SE	UK
Particulate	Mg/Nm <sup>3</sup>	20-34	34-50	40	50a) – 50b)	35-50	15-25	30	50	50	30	77	30	50-150	40-50
		Daily/ha lf-hourly	Daily	Daily			Daily	100% half hourly		Half hourly	100% Half hourly	Daily	Half hourly	Monthly	Daily
TOC	Mg/Nm <sup>3</sup>	50 (10 by 2002)	49-75	20		20		20	5/ 20/ 150/ 300/ 600	30	40	50	20	20	20-50
		Daily/ha lf hourly	Daily	Annual		Half hourly		100% half hourly		Half hourly	Half hourly	Daily	Half hourly	3 hour av.	Daily
HCl	Mg/Nm <sup>3</sup>	10	20-30	65		60	10-25	60	30	30	10	10	60	2	10-50
		Daily/ha lf hourly	Daily	Daily		Half hourly	Daily	100% half hourly		Half hourly	Half hourly	Daily	Half hourly	90 min. av.	Daily
HF	Mg/Nm <sup>3</sup>	0.7	3-5	2		4	1-4	4	5	5	1	1	4	0.2	1
		Daily/ha lf hourly	Daily	Annual		Half hourly	Daily	100% half hourly		Half hourly	Half hourly	Daily	Half hourly	3 hour av.	Daily
SO <sub>2</sub>	Mg/Nm <sup>3</sup>	140/400 c)	600- 1000	300	150a)- 400b)	1280	<400	200	600	100	90 kg/hr	1300	200	200/ 1700	600- 1500
		Daily/ha lf hourly	Daily	Annual	Monthly	Half hourly	Daily	100% half hourly		Half hourly	10 day av.	Daily	Half hourly	20 month av.	?
NO <sub>2</sub>	Mg/Nm <sup>3</sup>	500a)/8 00b)	1000- 1800		1200a)- 1800b)	1200	<800		1800	1600	2600	1300	300 ppm	400- 1600	900- 1500

Parameter	Unit	AT	BE	DK	FI	FR	DE	GR	IT	LU	NL	PO	ES	SE	UK
		Daily/half hourly	Daily		Monthly	Daily	Daily	100% half hourly		100% Half hourly	100% Half hourly	Daily	Daily	Monthly	?
Cd+Tl	Mg/Nm <sup>3</sup>	0.05/0.05	0.1-0.2/0.1-0.2	0.2/-		0.05	0.05	0.05		0.2/0.2	0.05/0.05	0.1	0.05/0.05	0.0002/0.006	0.05/0.05
		30 min - 8 hour av.	Daily	Annual		30 min - 8 hour av.	Daily	30 min - 8 hour av.		Half hourly	Half hourly	Daily		3 hour av.	Daily
Hg	Mg/Nm <sup>3</sup>	0.05	0.1-0.2	0.2		0.05	0.05	0.05		0.2	0.05	0.1	0.05	0.001	0.1
		30 min - 8 hour av.	Daily	Annual		30 min - 8 hour av.	Daily	30 min - 8 hour av.		Half hourly	Half hourly	Daily		3 hour av.	Daily
Dioxin and furan	Ng/m <sup>3</sup> TEQ	0.1	0.1			0.1	0.05	0.1	10,000 (?)	0.1	0.1	0.1	0.1	0.1	0.1



### **3. CURRENT PRACTICE OF PRODUCTION AND USE OF WASTE-DERIVED FUELS**

#### **3.1 Introduction**

The expression Refused Derived Fuel, RDF has different meanings in different Member States (see Section 2.3.2 above) as a wide range of wastes are processed into substitute/secondary fuels across Europe. The current practice of production and use of waste derived fuels are summarised in Sections 3.2 for RDF produced from processed municipal solid waste and Section 3.3 for waste derived fuel from processed industrial waste respectively and the detailed findings of the survey are provided on a country by country basis in Appendix B.

#### **3.2 RDF from processed municipal solid waste**

##### **3.2.1 Production processes**

Refuse derived fuel (RDF) can be produced from municipal solid waste (MSW) through a number of different processes consisting in general of:

- Separation at source;
- Sorting or mechanical separation;
- Size reduction (shredding, chipping and milling);
- Separation and screening;
- Blending;
- Drying and pelletising;
- Packaging; and
- Storage.

Typically, the waste material is screened to remove the recyclable fraction (e.g. metals), the inert fractions (such as glass) and separate the fine wet putrescible fraction (e.g. food and garden waste) containing high moisture and high ash material before being pulverised.

The wet organic materials can then undergo further treatment such as composting or anaerobic digestion, and can be used as a soil conditioner for landfill restoration work or be landfilled. In some cases, the putrescible fraction is kept in place to enable the mass of material to be dried through biological treatment (the process of 'dry stabilisation').

The coarse fraction is either rejected or returned to the pulveriser. The medium fraction, consisting of paper, card, wood, plastic and textiles can either be burnt directly as coarse fuel

(cRDF) or dried and pelletised into dense RDF (d-RDF). The decision as to whether or not to pelletise is usually based upon the location of the RDF manufacturing facility relative to the combustion facility.

There are two technologies which have been developed and which produced from MSW a high calorific fraction which can be used as RDF;

- Mechanical Biological Treatment plant; and
- Dry Stabilisation Process.

In a mechanical biological pre-treatment plant (MBT) (Figure 3.1), metals and inerts are separated out and organic fractions are screened out for further stabilisation using composting processes, either with or without a digestion phase. It also produces a residual fraction which has a high-calorific value as it is composed mainly of dry residues of paper, plastics and textiles.

RDF can also be produced through a 'dry stabilisation' process, in which residual waste (minus inerts and metals) are effectively dried (and stabilised) through a composting process, leaving the residual mass with higher calorific value and suitable for combustion. The high calorific output of this process developed in Germany has the trade name of 'Trockenstabilat'.

Packaging derived fuel (PDF) or process engineered fuel (PEF) is usually of higher quality than RDF as it is a source-separated processed dry combustible fraction which cannot be used for recycling as for example cardboard drink containers or PE/PET bottles contaminated by PVC.

### 3.2.2 Quantity of RDF

The quantity of RDF produced per tonne of MSW varies depending on the type of collection, treatment process and quality requirement. Information collected during this survey indicated that the rate of RDF production from MSW can vary between 23 and 50% by weight of waste processed depending on the treatment process used and country (Table 3.1). In comparison, other surveys have quoted a recovery range varying from 55 to 85% (EA 2001). It was also reported that the amount of PEF obtained from processing of MSW varies between 35 and 40% by weight of waste processed.

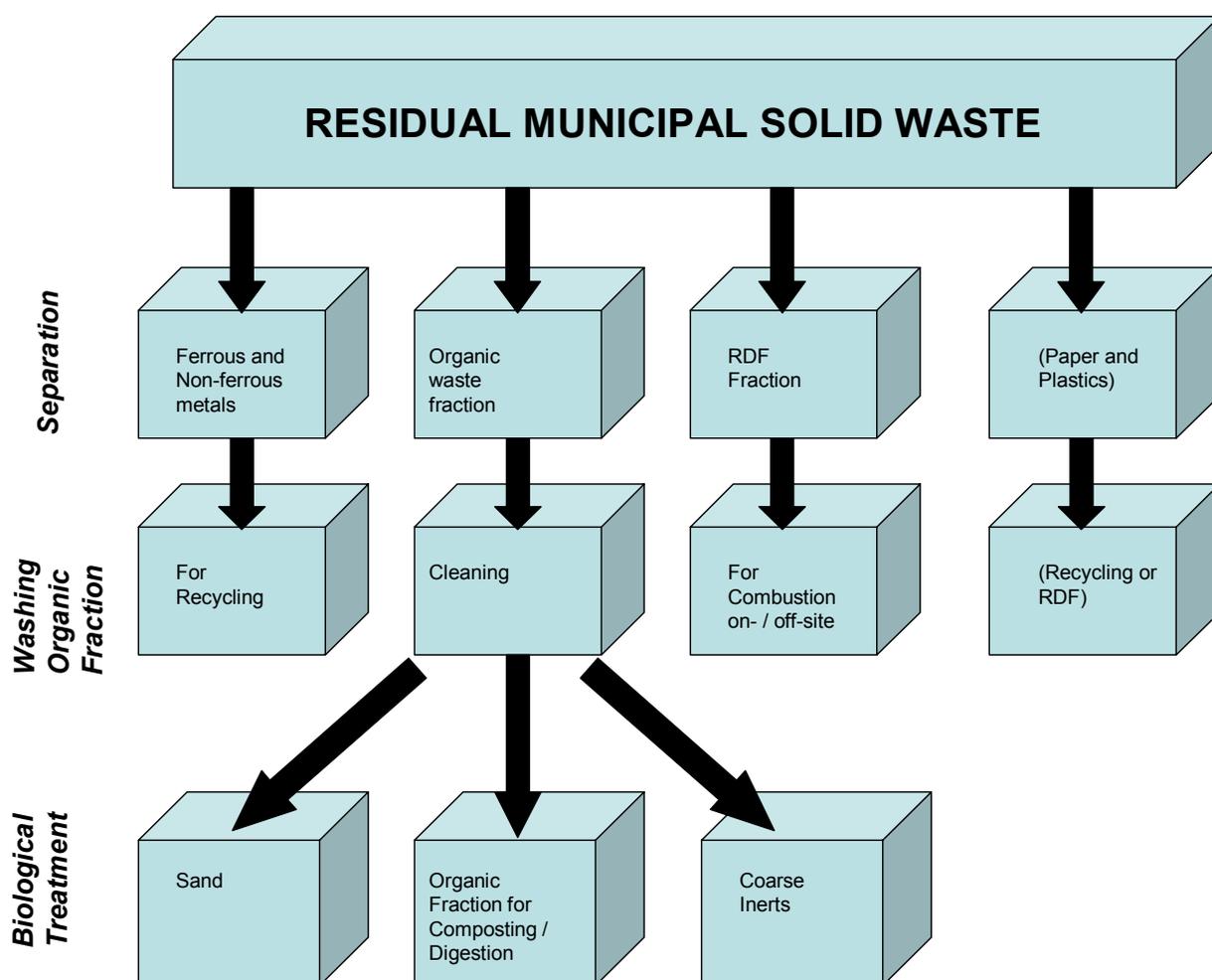
**Table 3.1 Conversion rate for RDF production according to treatment process and country**

Country	Treatment type	Rate (%)
Austria	MBT	23
Belgium	MBT	40-50
Finland	MT	Variable
Netherlands	MT	35
United Kingdom	MT	22-50

Notes:

MBT Mechanical biological treatment

MT Mechanical treatment



**Figure 3.1 Schematic Representation of MBT Process (Separation Variety)**

Table 3.2 summarises the information collected during this survey regarding production capacity and quantities of RDF produced from MSW across Europe. The figures reported below are rough estimates as quantitative information was missing for Finland, Germany, Italy and Spain. Quantities of RDF produced in Finland, Germany and Italy have been estimated based on quantities of MSW processed or reported MBT capacity and an assumed rate of conversion of 30%. It was not possible to estimate quantities of RDF produced in Spain. There were some uncertainties with regard to the level of treatment applied to MSW to produce RDF in Sweden.

The total quantities of RDF produced from MSW in the European Union have been estimated to amount to about 3 million tonnes. This is twice the estimate given in a draft document recently published by CEN Task Force 118 on solid recovered fuels (CEN 2001), in which the quantities of fuels from non-hazardous, mono- and mixed-wastes in Europe amounted to 1.4 million tonnes per annum (Table 3.3) expected to increase to about 13 million tpa by 2005.

Countries where RDF production is already well established are Austria, Finland, Germany, Italy, the Netherlands and Sweden. Countries where RDF production is currently being

developed are Belgium and the United Kingdom. RDF from MSW was produced in the past in Denmark and France but this has been discontinued for economical reasons.

In Finland, RDF is produced from source separated household waste, waste from commerce and industry and construction and demolition waste. In Sweden, there were reports of high calorific waste being source separated from households but it was unclear what technology was applied to these fractions. In the Netherlands, RDF is mainly produced from mechanically sorted paper and plastic from household waste (PPF). In Austria, Germany and Italy, RDF is largely produced in MBT plants from different waste sources (MSW, waste wood, commercial waste, industrial waste, sewage sludge, etc). In Germany and Italy, there are also plants which rely on the dry stabilisation process. In the UK, RDF is produced either from mechanically processing MSW or from dry source separated recycled fractions which cannot be reprocessed by manufacturing industries. The capacity for RDF production is on the increase in these countries as well as in the Flemish Region of Belgium.

**Table 3.2 RDF production from MSW in EU Member States, 2001**

Country	Type and Number of plant <sup>a)</sup>	Waste input <sup>a)</sup>		Fuel output <sup>a)</sup>
		Capacity (x10 <sup>3</sup> tpa)	Quantity processed (x10 <sup>3</sup> tpa)	Quantity produced (x10 <sup>3</sup> tpa)
Austria	10 MBT (+2)	340 (+60)	340 <sup>d)</sup>	70
Belgium <sup>e)</sup>	1+ (4 MBT)	NI + (600)	-	NI+(240-300)
Denmark	- <sup>c)</sup>	-	-	-
Finland	12 + (8)	200-300	140 - 300 <sup>f)</sup>	40 - 90 <sup>b)</sup>
France	- <sup>c)</sup>	-	-	-
Germany	14 MBT	1,100	NI	330 <sup>b)</sup>
Greece	-	-	-	-
Ireland	-	-	-	-
Italy	16 MBT + 6 + (3)	1,500 + NI	1,000 + NI	300 <sup>b)</sup>
Luxembourg	-	-	-	-
Netherlands	13 (+12)	2,000 (+1,300)	2,000	700
Portugal	-	-	-	-
Spain	NI	NI	NI	NI
Sweden <sup>c)</sup>	NI	NI	NI	1,350 <sup>g)</sup>
United Kingdom	3	250	250	90
<b>Total EU</b>	<b>&gt; 50</b>	<b>&gt; 5,500</b>	<b>&gt;3,700</b>	<b>≈ 3,000</b>

Notes:

a) Plants producing RDF planned or under construction are given into brackets

b) Assuming a RDF production rate of 30%

c) RDF production discontinued for economic reasons

d) Including MSW, sewage sludge, waste wood and commercial waste

e) Figures reported for the Flemish Region – there is no reported RDF from MSW in the Walloon Region

f) Including household, commercial and construction/demolition waste

g) Not clear which treatment had been applied to produce this high calorific household waste.

MBT Mechanical-biological treatment plant

**Table 3.3 Estimates of RDF from MSW in Europe in 2000 (CEN 2001)**

<b>Country</b>	<b>Quantity (x10<sup>3</sup> t/a)</b>
Austria	100
Belgium	<100
Denmark	0
Finland	170
France	0
Germany	500
Greece	0
Ireland	0
Italy	<200
Luxembourg	0
Netherlands	250
Portugal	0
Spain	0
Sweden	1)
United Kingdom	60
<b>Total EU</b>	<b>1,380</b>

Note:

- 1) no overall statistics for Sweden as this fuel is used in ordinary heat/power plants and in waste incinerators. It was reported that around 500 kt of waste were exported including 90% of wood, paper, plastic and rubber.

### **3.2.3 Utilisation of RDF from MSW**

The following options for the utilisation and conversion of RDF from MSW to energy have been used or could be used in the future:

- *on-site in an integrated thermal conversion device, which could include grate or fluidised bed combustion, gasification or pyrolysis;*
- *off-site at a remote facility employing grate or fluidised bed combustion, gasification or pyrolysis;*
- *co-combustion in coal fired boilers;*
- *co-incineration in cement kilns;*
- *co-gasification with coal or biomass.*

The total quantities of RDF from processed MSW used in Europe in dedicated waste to energy installations, in power generating plants, district heating plants and industrial

processes such as paper mills and cement kilns has been estimated to amount to more than 2 million tpa (Table 3.4). It was reported that it is not always possible to secure an outlet for RDF and in Germany for example, quantities have to be stored.

The quantities of RDF burnt are expected to increase in the future with planned increased capacity for RDF utilisation mainly in Belgium, Italy and in the UK. There are also plans for using RDF from MSW in other processes such as gasification and pyrolysis.

**Table 3.4 Utilisation of RDF from MSW in Europe**

Country	Number <sup>a)</sup>	Capacity <sup>a)</sup> (x 10 <sup>3</sup> tpa)	Quantity <sup>a)</sup> (x 10 <sup>3</sup> tpa)
<b>Dedicated plant</b>			
Italy	(2)		C
Sweden	NI		1,400
United Kingdom	1		30
<b>Power plant</b>			
Germany	NI		
Italy	(3)	(1,200)	T
United Kingdom	1		50
<b>Paper mill</b>			
Finland	NI		200
<b>District heating plant</b>			
Belgium	NI		NI
Denmark	NI		NI
Finland	50		50
Sweden	NI		NI
<b>Cement kiln</b>			
Austria	NI	NI	NI
Belgium	1		15
Italy	5		300
Denmark	1		2.6
Netherlands	1		7 <sup>b)</sup>
<b>Total</b>			<b>≈ 2,000</b>

Notes:

T in trial

C In construction

a) Figures into brackets are referring to quantities for which information was incomplete or uncertain

b) Paper and plastic pellets (PPDF)

### Dedicated incinerator

Fluidised bed incinerators are finding widespread application for RDF combustion, which offers some advantages in terms of ease of emission control over mass-burn incineration. They are also less sensitive to variations in calorific value (CV) of the incoming fuel. The waste pre-treatment processing (e.g. sorting and shredding) increases the level and consistency of calorific value. Burn-out, energy recovery and operations in general can

therefore be more efficient. In addition, as the particle size of the waste is small, combustion equipment can be smaller, less robust and therefore less expensive.

There is one dedicated RDF waste to energy combustion/incineration facility based on fluidised bed technology in the United Kingdom and two waste to energy plants are under construction in Italy (Table 3.7). Some of the waste-to-energy plants producing district heat in Sweden are fluidised bed incinerators.

### **District heating plant**

RDF is also incinerated and co-incinerated in district heating plants in Scandinavian countries mainly for heat production. The plants are normally smaller than plants operated for electricity generation and their emission control equipment is not as stringent as for waste incinerators.

Co-incineration of waste fuels (REF I) with biomass waste (i.e. peat, waste wood, etc) in small size (less than 20 MW) district heating plants is widespread in Finland relying on grate combustion technology. The amount of REF is usually 10 to 30% of the fuel mass flow of the boiler. The implementation of the new Waste Incineration Directive is expected to decrease the interest in co-combusting REF due to the gas cleaning and monitoring costs. It was also reported that household wastes were co-combusted in Denmark, Sweden and some district heating plants in Belgium.

### **Multi-fuel power plant**

In the UK, a CHP plant for energy production is co-combusting RDF pellets from MSW. In Italy, three power plants are currently testing or considering testing RDF as secondary fuels. Coal power plants in Germany are also reported to use RDF from MSW. In Finland, most of the CHP plants (50 to 500 MW) are using fluidised bed combustion technology and co-combust a wide variety of fuels such as biomass and waste such as bark, saw dust, sludge (deinking sludge, sewage sludge), paper waste, packaging waste and REF. They are located near a city or a pulp and paper mill. The paper industry also uses fluidised bed boiler burning bark, production waste and process sludge. It is reported that these fluidised-bed boilers in Finland use more than 200,000 t per annum (tpa) of REF and that the pulp and paper industry bark boilers also use about 300-400,000 tpa process sludge.

### **Cement kiln**

Most cement plants do not directly burn unsorted MSW due the heterogeneous nature of the waste and components which could pose quality and environmental concerns. MSW is used after sorting and balling into RDF in cement kilns in Austria, Belgium, Denmark, Italy and Netherlands. The bales are typically introduced at mid-kiln or calcination stage. It was reported that around 115,000 tpa of MSW were co-incinerated in cement kilns in Europe in 1997 (RDC and Kema 1999). We estimated that more than 300,000 tpa of RDF from MSW are co-incinerated in Europe in cement kilns.

In Belgium and Denmark the RDF co-incinerated in cement kilns is produced after some mechanical sorting of mixed household waste while in Austria, Germany and Italy the RDF is the residual of MBT plants or in the Netherlands, it is a mechanically sorted pelletised and compressed paper and plastic. The use of RDF from MSW in cement works in the UK was discontinued.

## Other

RDF from MSW is also reported to be used in gasification or pyrolysis systems in countries such as Finland, Germany, Italy, Netherlands, Sweden, UK. There are also plans to produce charcoal from MSW in France through a thermolysis. For detailed information, please see Section 6 and more specifically Tables 6.1 and 6.2.

### 3.3 RDF from industrial wastes

#### 3.3.1 Production of RDF

A wide range of industrial wastes are used as substitute or secondary fuels in Europe. These wastes include plastics and paper/card from commercial and industrial activities (i.e. packaging waste or rejects from manufacturing), waste tyres, biomass waste (i.e. straw, untreated waste wood, dried sewage sludge), waste textiles, residues from car dismantling operations (automotive shredder residues - ASR) and hazardous industrial wastes with high calorific value, for example, waste oils, industrial sludge, impregnated sawdust and spent solvents.

In the past year, the market for substitute fuels has been very buoyant with the arrival of cheaper fuel substitutes such as meat and bone meal. This follows the crises of BSE, dioxins and foot and mouth which have restricted the quantities of animal waste being re-used in animal feedstock. A new outlet for these products has been found in the cement industry across Europe.

Industrial wastes used as secondary fuels have to be processed to meet industry specifications e.g. homogenisation to provide a consistent calorific value and the limiting of compounds such as chlorine or phosphorous for clinker production. For example, industrial sludge, spent solvent or waste oil are mixed with sawdust before being injected in cement kilns, old tyres are shredded, sewage sludge is dried to 90% ds, etc.

RDF generated from certain commercial and industrial wastes (e.g. reject paper from composite paper manufacturing, packaging waste, wood waste) may require size reduction or simple screening, but usually do not require the advanced physical processing necessary to reduce contaminant levels in MSW and in some cases alter its physical form.

#### Tyres

Tyres have a typical high calorific value of 28.5 to 35 MJ/kg (RDC and Kema 1999, EA 2001). Typical composition and requirements for tyre derived fuels is given in Table 3.5 below. They contain relatively high levels of iron, sulphur ( $\approx 1.6\%$ ) and zinc ( $\approx 1.5\%$ ).

**Table 3.5 Typical composition of tyre-derived fuels**

Parameter	Spain	UK <sup>1)</sup>
CV (Gross) (MJ/kg)	30	>26
Ash content	15	
Sulphur (% w/w)	1	<1.8
Chlorine (% w/w)	-	<0.07
Mercury (mg/kg)		<2
Cadmium and thallium (mg/kg)		<79 <sup>a)</sup>
Antimony, arsenic, chromium, cobalt, copper, lead, manganese, nickel, tin and vanadium (mg/kg)		<640 <sup>a)</sup>

Ref:

1) Castle Cement 1996 reported by EA 2001

Note:

a) based upon 75% variability about the mean

### Used oils

Untreated waste oils are commonly used as secondary fuels. In addition, a proportion of collected waste oils receives limited treatment (separation of water and sediment) and is also re-used as fuel in cement kilns.

### Plastics

Examples of plastic waste processed into secondary fuels include non-recyclable plastics such as plastic bags from retail outlets or rejects from industrial processes. Some plastics are derived from source-separated MSW as discussed in Section 3.2.1 above.

Plastics usually have a high calorific value (29 to 40 MJ/kg, RDC and Kema 1999, EA 2001). It is usually shredded and mixed with other waste before injection. The principal limiting factor in plastics is chlorine content, mainly in PVC.

### Waste wood

Waste wood has a calorific value ranging between 15 and 17 MJ/kg at 10 to 15% residual water (RDC and Kema 1999). If the wood has been treated or painted concentrations of heavy metal (As, Cr, Cu), chlorine compounds and other toxic substances may be high.

### Paper and paper sludge

Waste paper is used as alternative fuel usually together with plastic and other waste. Paper has a typical calorific value of 12.5 to 22 MJ/kg (RDC and Kema 1999, EA 2001). Sludge or residues from the production of paper are also used secondary fuels mainly by paper industry itself. Paper sludge has a lower CV of about 8.5 MJ/kg (EA 2001).

### Sewage sludge

Dried sewage sludge (more than 90% ds) can be used as fuel in cement kilns in conjunction with other solid waste types. Dried sewage sludge has a calorific value of 16 to 17 MJ/kg (EA 2001). Reported to be lower (10 MJ/kg) in RDC and Kema (1999).

### Animal Waste

Animal wastes (bone meal and animal fats) has a typical CV of 16 to 17 MJ/kg (EA 2001). Rendered animal meal and fats are prepared at approved processing facilities. Animal carcasses from non-BSE infected animals undergo extraction of the spinal cord, nervous systems, tonsils and eyes, sterilisation (at 133°C under a pressure of 3 bars for at least 20 minutes) and then grinding. Meat not fit for human consumption, which is now banned from animal feed, is processed to extract fats and then also ground. These wastes are reported to have a high calorific value and are of stable composition. Pre-treatment can either be carried out off site by the supplier, or on-site by the industry themselves or a site-based subsidiary.

### Waste wood

Waste wood from mills, panel production (MDF) and furniture production is usually re-used in panel production or burned to generate process energy on site. This is usually not available for energy recovery in other sectors.

Waste wood from households or industrial sectors (i.e. construction/demolition, railway, others) on the contrary is potentially available for energy recovery.

### Other wastes

Other wastes fractions processed as secondary fuels are listed below:

- SLF mixed with sawdust (i.e. spent solvents)
- Automotive shredder residues (ASR)
- Carpet residues and off-cuts
- Textiles
- Nappy manufacturing waste
- Anode waste, etc.

### **3.3.2 Utilisation of Secondary Fuel**

The type of secondary fuels co-incinerated in industrial processes are summarised in Table 3.6 below:

- Tyres are one of the most commonly used solid secondary fuels in the cement industry (EA 2001) with regular utilisation in 10 countries across Europe. In Finland, Luxembourg and Portugal, tyres are the only secondary fuels utilised in cement kilns excluding trial

burns. In the Netherlands, however, the use of tyres as secondary fuels was discontinued following problems of supply consistency.

- Spent solvents are widely used as secondary fuels by the cement industry in most countries. Solvents are also used in coal-power plants and other industrial plants in the Netherlands. They can be mixed with sawdust before being injected into the kiln.
- Waste oils - There are approximately 2,448,000 tonnes of waste oil generated by the 15 EU Member States (Coopers & Lybrand 1997) - 70% of this is collected annually. The remaining 30% are unaccounted for and is probably burned, or illegally burned or disposed of to the environment. Approximately 565,000 tonnes (31%) receives no treatment and is used as an energy source in cement kilns and other industries (power and smelter). Approximately 584,000 tonnes (32%) receives limited treatment (separation of water and sediment) and is used as a fuel in cement kilns, the stone industry and power plants. Untreated used oils were reported to be used as secondary fuels in cement kilns in Austria, Belgium, France, Germany, Spain, Sweden and the UK. It is reported to be used in district heating plants in Denmark and power plants in the UK. In Portugal there are plans to convert half of the waste oils into a fuel to be used to produce electricity to be sold to the grid. Waste oils are also reported to be used as secondary fuels for the production of bitumen in France and United Kingdom.
- Waste plastics from residual recycling or commercial/industrial activities are used in cement kilns as alternative fuels in Austria, Belgium, Denmark, Germany, the Netherlands and Sweden. Plastics have been trialled in the UK as part of Profuel by Castle Cement (EA 2001). It is shredded and mixed with other wastes before injection and co-firing. Plastics are also reported to be used in Belgium in other types of combustion plants and in Germany as reducing agents in blast furnaces.
- Plastics from end of life vehicles (ASR-automotive shredder residues) are reported to be co-incinerated as secondary fuels in cement kilns in Belgium and in a power plant in Denmark.
- Waste paper/card from residual recycling or commercial/industrial activities is used in cement kilns in Austria, Belgium, Denmark, Germany, the Netherlands and Sweden. They have also been trialled in cement kilns in the UK as part of Profuel.
- Paper sludge is also used in cement kilns in Austria, Germany and the Netherlands. It is also co-combusted in one power plant in the Netherlands and in brick kilns in Austria and Germany as pore agents. Paper sludge and other residues from the production of paper are also co-combusted by the paper industry itself across Europe (i.e. Finland).
- Dried sewage sludge is co-incinerated in cement kilns as an alternative fuel in Belgium, Denmark, the Netherlands and the UK. There are plans to co-combust dried sewage sludge in a power plant in Belgium, in Germany and Netherlands and in a brick kiln in Spain.
- Bone meal and animal fats are used as alternative fuels in cement kilns in Austria, Belgium, France and Italy. Some animal fats are also co-combusted in other combustion plants in Belgium, in coal fired power plants in Austria and on a temporary basis in a power and district plant in Denmark. It is reported that in 2000, the French and Belgian cement industries co-incinerated about 200,000 tonnes of meal and 82,000 tonnes of rendered animal meal and fats. This practice is not authorised in the UK.

- Straw, chicken manure is or will be also co-incinerated as secondary fuel in power plant (i.e. UK and Netherlands).
- Waste wood is commonly co-combusted in multi-fuel boilers for district heating production in Finland, France and Sweden, in coal-fired power plants and other industrial plants in Netherlands, in brick kilns in Spain and also in cement kilns in Denmark, Germany and Spain.
- Sawdust is mixed with organics compounds to produce a more consistent secondary fuel for the cement industry in most European kilns. It is also used as a pore agent in the brick industry in Austria and Germany.
- Carpet off-cuts and textile wastes were reported to be used as secondary fuels in the cement industry in Belgium and Denmark.

**Table 3.6 Types of secondary fuels co-incinerated in Europe <sup>a)</sup>**

Secondary fuel	AT	BE	DK	FI	FR	DE	GR	IR	IT	LU	NL	PO	ES	SE	UK
Tyres	1	1		1	1	1				1		1	1	(1)	1
Solvent	1	1			1	1					1,2		1	1	1
Plastics	1	1	1			1,3					1			1	(1)
Car residues		1	2												
Paper/card	1	1	1,3			1					1				(1)(2)
Animal waste*	1,2	1,2	2		1				1		1,2				(2)
Used oils	1	1	(2)		1	1						(2)	1		1,2
Sawdust	3	1				3							1		
Wood	2		1	2	2	1					2		1,3	2	2
Paper sludge	1,3					3					1,2				
Sewage sludge		1,(2)	1			(2)					1,2		(3)		1
Straw	3														(2)
Textile/carpet		1	1			1									
Other	2,3		2,3		2	1,2,3					1,2				1

Notes:

- \* bone meal, animal fats or animal manure
- 1 cement industry;
- 2 public energy production;
- 3 other industrial sectors (i.e. blast furnace or brick industry, etc)
- a) Figures into brackets are planned or unconfirmed utilisation

Secondary fuels from industrial waste are co-incinerated mainly in 3 industrial sectors (Table 3.7):

- Cement industry;
- Paper industry; and
- Power industry (including district heating plants).

The most reliable and detailed information was collected for the cement industry while it was proven more difficult to have a clear picture in the other sectors. For the paper industry, it was difficult to quantify RDF co-incinerated as it was not possible to distinguish between waste generated on site such as bark, paper rejects or paper sludge and traded RDF. This is why the quantities of waste co-incinerated in the paper industry were not reported in this study but only some information when available was given in the country reports. In the power sector, the changes in the energy market made it difficult to collect reliable and up to date information.

Other sectors (i.e. brick industry and blast furnace) are also reported to co-incinerate waste derived fuels but these sectors argue that it was not primarily for energy substitution but for material substitution.

RDF from industrial wastes are also reported to be used in processes not relying on combustion such as biodigestion, gasification and pyrolysis, in Finland, Netherlands, the UK (see Section 6).

It is not the objective of this study to describe in detail the industrial sectors and processes which use secondary fuels. However, a short description of the main characteristics for combustion and substitute fuel for each main process is given in Appendix C.

**Table 3.7 Number of industrial plants co-incinerating RDF from industrial wastes in Europe <sup>a)</sup>**

Country	Cement kilns	Power plant (electricity and/or heat)	Brick kilns	Others	Total
Austria	10	7	2	165 <sup>b)</sup>	177
Belgium	9	e)	-	-	d)
Denmark	1	e)	-	e)	d)
Finland	1	e)	-	e) b)	d)
France	23	e)	-	-	d)
Germany	31	(11) <sup>c)</sup>	e)	(>37) <sup>b)</sup>	d)
Greece	-	-	-	-	-
Ireland	-	-	-	-	-
Italy	5	(3)	-	-	5
Luxembourg	1	-	-	-	1
Netherlands	1	7	-	-	8
Portugal	1	(1)	-	-	1

Country	Cement kilns	Power plant (electricity and/or heat)	Brick kilns	Others	Total
Spain	11	-	e)	-	d)
Sweden	3	e)	-	-	d)
United Kingdom	9 (+2)	1 + (2)	-	-	10
<b>Total</b>	<b>106</b>	d)	d)	d)	d)

Notes:

- a) Figures in brackets are for planned facilities under construction or incomplete
- b) Including paper mills
- c) Data only referring to Northrhine Westfalia
- d) Only partial information
- e) Secondary fuels are used but no detailed information available

### Cement industry

The cement industry has a very high energy demand as the process requires temperature of about 2000°C. Information on energy consumption including secondary fuels in the cement industry is relatively well known. Fossil fuels (e.g. coal, oil or natural gas) are the predominant fuels used in the cement industries. However, low-grade fuels such as shales, coal washings, petrol coke and waste derived fuels (traditionally waste oils, spent solvent, waste tyres) have been increasingly utilised in the recent years. More recently, the cement industry have also co-incinerated bone meals and animal fats.

In Europe, the cement industry is the largest consumer of secondary fuels from industrial waste with about 105 kilns across Europe co-incinerating about 2.6 million tpa of secondary fuels from industrial origin (Table 3.8). Previous studies had reported 1.8 million tonnes of secondary fuels co-incinerated in cement kilns in Europe in 1997, expected to increase by 15% by 2003 (RDC and Kema 1999) (Table 3.9). The industry strategy is to rely on alternative fuels to reduce its high energy bill as well as for sustainable development. It is reported that the industry is able to claim that RDF such as tyres and solvents are carbon neutral and thus benefit for carbon emission credits which might not apply beyond 2010.

Hazardous waste such as waste oils and spent solvents mixed with sawdust or injected in liquid form at the flame are one of the most common RDF co-incinerated in cement kilns across Europe, estimated to amount to 1 million tpa.

Tyres are also commonly used secondary fuels in cement plants. Cement kilns can use whole tyres or after shredding. They are typically introduced at mid-kiln or calcination stage. They can also be added into pre-heater systems or into the firing system (EA 2001). We estimated that about 550,000 tpa of tyres are co-incinerated in cement kilns in Europe.

The focus on these two types of RDF might have to switch to biomass-based fuels, waste paper and sewage sludge in the near future to be eligible for carbon emission credits.

**Table 3.8 Quantities of RDF from industrial waste co-incinerated in cement industry in Europe (x10<sup>3</sup> tpa)<sup>a)</sup>**

Secondary fuels	AT	BE	DK	FI	FR	DE	GR	IR	IT	LU	NL	PO	ES	SE	UK	Total
Tyres	30	25		8	200 <sup>f)</sup>	240				)	-	6.5	13		25	≈ 550
Waste oil	30	c,j)			520 <sup>c,f)</sup>	180							9	6	120	≈ 1000
Solvent	7.5					25					10					
Sewage sludge		15	7.5								30					≈ 50
Plastics/Paper	25	)	10			290										≈ 350
Bone meal/animal fat	10	220			100				( <sup>l)</sup> )							≈ 350
Wood			>0.5			80							2+ 5 <sup>h)</sup>			≈ 100
Other	40 <sup>b)</sup>	d,j)	22 <sup>e)</sup>			115					> 5 <sup>g)</sup>		10		<sup>l,j)</sup>	≈200
<b>Total</b>	<b>142.5</b>	<b>NI</b>	<b>40</b>	<b>8</b>	<b>820</b>	<b>930</b>	<b>0</b>	<b>0</b>	<b>(NI)</b>	<b>(NI)</b>	<b>&gt;45</b>	<b>6.5</b>	<b>39</b>	<b>6</b>	<b>(&gt;55)</b>	<b>≈2,600</b>
Substitution rate (%)	26	40	7		24	23			1.5	5-10			1.2	13		

Notes:

- a) Figures into brackets are for quantities which have been reported incomplete
- b) Paper fibre residues
- c) Mainly reconstituted fuel mixed with sawdust or other absorbent matter
- d) Including automotive shredder residues, carpet/textile pellets
- e) Including waste textiles and unspecified non-hazardous wastes
- f) estimates
- g) Including paper sludge and waste rubber
- h) Sawdust
- i) Profuel derived from a variety of sources including paper, plastics and carpet cut-offs
- j) Quantities were not available

Other wastes are co-incinerated in cement kilns in Europe, mainly commercial and industrial waste packaging, bone meal and sewage sludge. About 350,000 tpa of plastics and paper rejects from commercial and industrial origin are reported to be co-incinerated in cement kilns in Austria, Belgium, Denmark and Germany. Sewage sludge is reported to be co-incinerated in cement kilns in Belgium, Denmark and Netherlands. The reported quantities of sewage sludge co-incinerated in European cement kilns amounted to about 50,000 tpa. Bone meals are co-incinerated in Austria, Belgium, France and Italy, amounting to an estimated total of 350,000 tpa. Bone meals are injected into the heart of the flame where the temperature is 2000°C.

In cement industry, consistency in quality of the secondary fuel (i.e. calorific value) is a crucial factor for industrial process and product quality. There are strict internal control procedures for analysing secondary fuel composition to ensure compliance with industry specifications. This may involve random sampling or a check on all incoming wastes for a detailed list of parameters. The industry also has its own subsidiary producing secondary fuel. The countries with the largest quantities co-incinerated were France and Germany (>800,000 tpa) followed by Belgium and Austria (> 100,000 tpa). Greece and Ireland were the only European countries where there was no full-scale co-incineration of secondary fuels in cement plants. In the UK it is reported that cement kilns now co-incinerate more hazardous waste than high temperature incinerators (ENDS Report 324, 2002).

The European average energy substitution rate for secondary fuels in the cement industry is reported to range between 1 and 40%. It was reported that in 1995, that fuel usage in the cement industry in Europe was about 10% for waste derived fuels, compared with 39% of pet coke and 36% of coal, 7% of fuel oil, 6% of lignite and 2% of gas (EC 2000).

**Table 3.9 Quantities of waste used as alternative fuels in cement industry in the fifteen EU Member States (RDC and Kema 1999)**

<b>Waste type</b>	<b>Quantity in 1997 (x10<sup>3</sup> tonnes per annum)</b>	<b>Future quantities (2003) (x10<sup>3</sup> tonnes per annum)</b>
Tyres/rubber	413	496
Household RDF	115	132
Sewage sludge	81	99
Used oils	446	<1140
Spent solvent and hazardous waste	592	(included in used oils figure)
Plastics	71	85
Waste paper	27	31
Waste wood	9	12
Others	44	53
<b>Total</b>	<b>1800</b>	<b>2050</b>

## Lime kilns

It was reported in 1995 (European Lime Association as reported in RDC and Kema 1999) that about 1% of fuels consumed by industry was derived from waste, compared with 48% of gas, 36% of coal and 15% of heavy fuel. The range and quantities of waste derived fuels are very low because waste can influence the quality of final product and only low ash waste derived fuels can be co-incinerated such as sawdust, shredded tyres, methanol and other low grade solvents, plastics and used oils (RDC and Kema 1999). No quantities were provided.

## Power industry

Co-firing waste derived fuels in coal-fired power and district heating plants is relatively common in Denmark, Finland, Germany, Netherlands and Sweden. There are a few planned initiatives in Belgium, Italy and the UK. The situation as presented in the country reports in Appendix B and in Table 3.10 (RDC and Kema 1999) is changing rapidly due to deregulation, liberalisation and new environmental renewable obligations in the energy sector.

The District heating sector is reported to have grown by 2.4% over the last 5 years which is a slower rate than for the first half of the 1990's due to the maturation of markets such as in Denmark and Finland and the reluctance to invest, as liberalisation is causing uncertainties with regard to the price of energy (Euroheat and Power, 2002).

Power plants and district heating plants co-combust mainly non-hazardous secondary fuels such as waste wood, straw and dried sewage sludge. Other wastes can be used such as processed MSW, coffee husks, maize cobs, cotton residues, palm oil residues as well as liquid or gaseous waste such as waste oils, waste organic fuels and biogas. Solid wastes have to be pulverised to a size of 1mm and impurities removed before the waste is injected with the coal (RDC and Kema 1999).

The co-firing of biomass waste in coal-fired power stations is likely to increase following the implementation of the EC Directive on Renewable Energy as it can account towards renewable obligations. There are other technologies being developed in energy production sector from biomass waste such as gasification, pyrolysis and anaerobic digestion (see Section 6).

**Table 3.10 Overview of co-firing at coal fired power plants (RDC and Kema 1999)**

<b>Plant</b>	<b>Waste type</b>	<b>Capacity</b>	<b>Technology</b>
EPON, NL	Demolition wood (max 10%)	600 Mwe	Pulverised coal
Midkraft Greena, DK	Straw (max 50%)	78 Mwe	Circulating fluidised bed
Midkraft Studstrup, DK	Straw.wood (max 20%)	150 Mwe	Circulating fluidised bed
Uppsala, SE	Wood chips	200/300 Mwe	Pulverised coal
Saarbergwerke, DE	Sewage sludge	75Mwe	Pulverised coal
Rheinbraun, Cologne, DE	Sewage sludge	275 Mwe	Lignite, circulating fluidised bed

## Pulp and paper industry

The production of pulp and paper requires considerable amounts of steam and power. Most mills produce their own steam in one or more industrial boilers which can burn fossil fuels and/or wood/bark residues. Mills that use chemical process also burn their spent liquor in a boiler to recover chemicals and generate electricity. Other wastes can also be burnt such as mercaptans, paper sludge, non-recyclable recovered paper, etc. Some mills also have on site lime kilns to generate quicklime in which waste can also be burnt (RDC and Kema 1999).

Waste derived fuels are only co-incinerated in boilers producing steam. The substitution varies between 0 and 100%. Constraints on co-incineration in pulp and paper industry are not related to product quality except when co-firing spent liquor. The main types of waste used are paper sludge, de-inking sludge, and residues from waste paper (often containing plastics), bark and wood residues and sawdust. The majority of these wastes are produced on site (RDC and Kema 2001).

It has not been possible to quantify the amount of traded waste co-combusted by the paper and pulp industry. Only a few countries (Austria, Germany and Sweden) are reported to have granted authorisation to paper plants for using traded/external secondary fuels. Quantities of secondary fuels and in-house waste co-incinerated for paper production was only available for Austria and Germany (Table 3.11), amounting to nearly 4 million tpa.

**Table 3.11 Co-incineration in the paper and pulp industry in Austria and Germany (x10<sup>3</sup> tpa)**

<b>Secondary fuel</b>	<b>Austria</b>	<b>Germany</b>
Traded waste:	509	NI
In-house waste:		
Bark	200	225
Spent liquor	2,676	1,750
Paper sludge/de-inking sludge	103	870
Sewage sludge	70	-
Other	24	100
<b>Total</b>	<b>906</b>	<b>2,945</b>

### Brick kilns

Industrial wastes are also reported to be co-incinerated in brick kilns in Austria and Germany. The quantities reported for these two countries amounted to 300,000 tpa. The temperature reaches in a brick kiln is lower than in cement kilns. It is however argued by the industry that the use of secondary materials such as straw, sawdust, paper sludge and polystyrol is not for energy requirement but as pore agents and thus constituted recycling and not combustion/incineration.

### Iron production plants

It is reported that most waste/residues used in the iron industry are by-products of the process or waste recycled in-house in the sintering plant for material recycling rather than energy substitution. However, there are recent reports of the use of granulated plastics as a fuel substitute for coke in some blast furnaces. No quantities were given for the whole of Europe

(EUROFER, Pers. Comm reported by RDC and Kema 1999). Quantities reported in our study only refer to Germany and amount to 280,000 tpa.

### 3.3.3 Characteristics of RDF

The composition of RDF from MSW will vary according to the origin of waste material and the sorting/separation process. This will in turn greatly influence the properties of RDF such as calorific value. Typical composition for RDF from MSW origin is presented in Table 3.12.

**Table 3.12 Typical RDF composition**

Waste fraction	Flemish Region <sup>1</sup>		Italy <sup>2</sup>	UK
	Sorting process (%)	MBT <sup>d)</sup> (%)	(%)	(%)
Plastic	31	9	23	11
Paper/cardboard	13	64 <sup>a)</sup>	44	84
Wood	12	25 <sup>b)</sup>	4.5	5 <sup>e)</sup>
Textile	14		12	
Others	30		14 <sup>c)</sup>	
Undesirable material (glass, stone, metal)		2	2.5	
Dry-solid content	66	85		

Ref:

1 VITO 2000

2 ENI/Ambiente, pers comm 2002

Notes:

a) includes paper, textile, wood

b) includes rubber, synthetic material

c) organic degradable waste

d) Mechanical biological treatment

e) Includes glass, wood, textiles and metals

The important characteristics for RDF as a fuel are the calorific value, water content, ash content, sulphur and chlorine content. These values will vary according to the sources (i.e. households, offices, construction, etc), according to the collection system (mixed MSW, source separated) and treatment applied (screening, sorting, grinding, drying).

Average values have been published for the main characteristics of RDF from different sources (Table 3.13) as well as more detailed comparison of RDF quality such as presented in Table 3.14 and extracted from the CEN report (2001). The CEN report provided warnings regarding the reliability of results presented. These were due to the non-homogeneous nature of such materials and the lack of standardised sampling methods (for example the lack of clear rules about taking continuous samples over a period of time or taking grab samples, and potentially low comparability between data-pools from different countries). Another identified problem was the way results below the detection limit were taken into account. It was also reported that the German data-pool included several results from test runs with new materials

which were not necessarily representative of the quality of the final produced fuel. In addition the statistics applied to the data are inconsistent, in that means, medians and 80%-iles have all been reported.

Despite the fact that the fuels have been prepared from different waste sources using different methods of treatment, and that the sampling protocols, analyses and statistical interpretations have not been harmonised, there is remarkable consistency between the analyses of the RDF fuels, at least on an order of magnitude basis.

The net CVs of RDF are fairly consistent (20 – 23 MJ/kg) for all source-separated waste streams. These are higher than the CV for RDF from mixed MSW (13 MJ/kg) and for untreated MSW (8 – 11 MJ/kg) (EA 2001), which would fail the EUTITS requirements for secondary fuels used for clinker production.

The moisture content of RDF is more favourable for non-MSW (i.e. demolition waste, commercial and industrial waste) (11-17 %) than for MSW (25-34%). The ash content of RDF from commercial and industrial waste streams appears to be lower (7-10%) than for the other waste streams (10-16%), but higher than the EURITS requirement.

The chlorine content influenced by the level of plastics in the waste streams is relatively high (0.3-0.7%) for all waste streams compared with the EURITS requirement, with RDF from industrial waste streams being at the lower end of this range. The sulphur content was more consistent across the sources (0.1-0.2%) with a slightly higher content for RDF from MSW.

In addition while metal determinations are variable, they are generally within the same order of magnitude with a net lower content in industrial waste streams. The values however would all meet the EURITS criteria, except manganese from source-separated MSW.

**Table 3.13 Quality of RDF from household and industrial sources**

<b>RDF source</b>	<b>Calorific value (MJ/kg)</b>	<b>Ash residue (% w)</b>	<b>Chlorine content (% w)</b>	<b>Sulphur content (%w)</b>	<b>Water content (% w)</b>
Household waste <sup>1)</sup>	12-16	15-20	0.5-1		10-35
Household <sup>2)</sup>	13-16	5 –10	0.3 –1	01 –0.2	25 -35
Commercial waste <sup>2)</sup>	16-20	5-7	<0.1-0.2	<0.1	10-20
RDF from industrial waste <sup>1)</sup>	18-21	10-15	0.2-1		3-10
Demolition waste <sup>2)</sup>	14-15	1-5	<0.1	<0.1	15-25

Ref:

1) RDC and Kema 1999

2) Data reported for Finland

**Table 3.14 Comparative analysis of waste recovered fuel quality across Europe**

Parameter	Mixed MSW <sup>a)</sup>		Source-separated MSW <sup>b)</sup>	Source-separated ind. and com. waste <sup>c)</sup>	Monostreams of ind. and com. waste <sup>d)</sup>		Demolition and commercial waste <sup>e)</sup>		Range	EURITS limits
	median	80%-ile	mean	mean	Median	80%-ile	median	80%-ile		
Net Calorific Value (MJ/kg)	13.3	16.1	22.3	20.1	22.9	25.3	20.6	25.1	13-22	15
Moisture content (%)	24.7	22.0	33.6	16.6	11.5	17.2	13.4	18.8	11-34	
Ash content (%)	16.0	17.7	10.2	6.7	9.6	11.6	13.8	20.6	7-18	5
Chlorine total (%)	0.6	0.8	0.4	0.3	0.4	0.7	0.7	1.1	0.3-0.7	0.5
Fluorine total (%)	0.01	0.02	nd	nd	0.01	0.04	0.01	0.04	0.01	0.1
Sulphur total (%)	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.4	0.1-0.2	0.4
Cadmium (mg/kg dm)	0.6	1.6	1.2	Nd	0.8	3.2	2.2	4.9	0.6-2.2	10
Mercury (mg/kg dm)	0.4	0.5	0.3	0.1	0.2	0.4	0.2	0.3	0.1-0.4	2
Thallium (mg/kg dm)	<0.8	<0.8	Nd	Nd	0.5	1.5	0.4	0.5	0.4-0.5	2
Arsenic (mg/kg dm)	3.0	4.9	8.8	Nd	1.5	1.7	1.0	2.0	1.0-8.8	10
Cobalt (mg/kg dm)	3.7	5.8	nd	Nd	2.0	3.8	2.9	4.7	2-4	200
Nickel (mg/kg dm)	21.5	33.3	20	Nd	6.2	16.0	13.1	26.3	6-21	200
Selenium (mg/kg dm)	<2	<2	nd	nd	1.0	2.5	0.4	1.7	0.4-1	10
Tellurium (mg/kg dm)	<1	<1	nd	nd	1.0	5.0	0.4	1.0	0.4-1	10
Antimony (mg/kg dm)	10.1	20.3	nd	nd	9.4	33.9	10.8	42.4	9-10	10
Beryllium (mg/kg dm)	0.2	0.3	nd	Nd	0.2	0.3	0.2	0.3	0.2	1
Lead (mg/kg dm)	121	189	52.4	nd	25.0	64.4	89.0	160.0	25-121	200
Chromium (mg/kg dm)	70.0	103	140	Nd	20.0	43.9	48.0	82.9	20-140	200
Copper (mg/kg dm)	59.5	88	80	Nd	48.0	118	97.5	<u>560.0</u>	48-98	200
Manganese (mg/kg dm)	nd	Nd	210	Nd	28.0	47.0	61.0	94.0	28-210	200

Parameter	Mixed MSW <sup>a)</sup>		Source-separated MSW <sup>b)</sup>	Source-separated ind. and com. waste <sup>c)</sup>	Monostreams of ind. and com. waste <sup>d)</sup>		Demolition and commercial waste <sup>e)</sup>		Range	EURITS limits
	median	80%-ile	mean	mean	Median	80%-ile	median	80%-ile		
Vanadium (mg/kg dm)	6.6	10.2	nd	Nd	3.3	10.0	3.6	5.3	3-7	200
Tin (mg/kg dm)	10.5	27.6	nd	Nd	7.0	12.4	4.0	12.2	4-10	200
Zn (mg kg <sup>-1</sup> dm)	225	307	340	nd	nd	nd			225-340	500
PCB (Sum DIN 51527)	nd	Nd	nd	Nd	0.2	0.5	0.2	0.5	0.2	0.2-0.5

Notes:

dm dry matter

nd no data

All percentages are by mass

a) Data from Netherlands

b) Data from Finland. Source-separated MSW from apartments, offices, etc. Mean derived from 742 samples)

c) Data from Finland. Source-separated fractions from industries and companies. Mean derived from 490 samples

d) Data from Germany. Recovered fuel produced from monostreams of commercial and industrial waste from one company.

e) Data from Germany



## **4. ENVIRONMENTAL IMPACT ASSESSMENT**

### **4.1 Introduction**

To assess the environmental impact of a recovery system such as the use of waste derived fuels from processed MSW (RDF), it is necessary to compare this practice with not using RDF as secondary fuels and with the other alternatives for the management of these wastes.

This Section deals with the environmental assessment of different options for the use of RDF while comments on the other options such as material recycling or landfill disposal are presented in Section 6 below.

The different options for RDF utilisation studied below are; co-incineration in cement kilns and in coal fired power plants. The decision was taken to compare the production and use of RDF as a recovery system to incineration in a municipal solid waste incinerator (MSWI) which complies with the new EC Waste Incineration Directive (2000/76/EC).

An evaluation of potential impacts on the products of those industrial processes co-incinerating waste derived fuels is also given comparing the use of five different secondary fuels; ASR, paper-reject pellets, demolition wood, Trockenstabilat® and MBT Nehlsen.

### **4.2 Methodology**

#### **4.2.1 Potential Environmental Impact**

The production and use of waste derived fuels including RDF is associated with diverse potential environmental impacts. From a very general point of view a significant effect is due to the material flow within an industrial society. Secondary materials substitute primary resources with associated benefits as well as the distribution of potentially hazardous compounds. The protection of resources is likely to be the main ecological justification for production and use of secondary fuels. This indirect environmental benefit has to be considered by any assessment of environmental impacts that claims completeness.

The process chain of production and use of RDF is associated with several direct impacts, starting with the collection and transport of waste from which RDF is generated. Because these wastes are often materials of low density, transportation demand is high.

The production of RDF itself causes at least two different types of environmental impacts:

1. the burdens due to consumption of process energy (mostly electricity from the public grid or on-site production of steam),
2. process discharges to the air (particulate matter from mechanical treatments, vapours from drying or pressing processes) or to the water (in the case of aqueous processes like washing or skimming).

Negative impacts due to odour and hygiene problems (microbiological pollutants) can occur at every stage where the waste materials are handled. The impact is a function of the ratio of

native organic substances which are subjected to a rapid biodegradation. If RDF contains household waste (or some fractions of that sort of waste) this impact is likely to occur while most industrial wastes suitable for secondary fuel production are not readily biodegradable.

Another aspect of concern is the potential production of noxious substances in products which are manufactured using RDF. For example, when waste derived fuel is co-incinerated in the cement process, input materials are transferred into the clinker, causing potential exposure during their use in construction material.

#### 4.2.2 Available and useful methodologies

A variety of methodologies have been established as support tools in the decision-making process of environmental issues. The nature of the subject, the issues at hand and the objectives are prevailing factors in the choice of the appropriate methodology. At least four different methodical approaches seem to be applied, each exhibiting overlapping features:

- a) environmental impact assessment (EIA);
- b) risk analysis;
- c) life cycle assessment (LCA); and
- d) material flow analysis (MFA).

Since the implementation of EU Directive on environmental impact assessment (85/337/EEC) (CEC 1985), an **environmental impact assessment** (EIA) has been an obligatory element of licensing procedures for certain public or commercial projects. The EIA shall identify and describe relevant impacts of the project regarding the environmental media and compartments. There are no further EU regulations providing technical guidance on how the EIA is to be carried out. The criteria adopted in the decision about environmental compatibility or incompatibility are usually identical with legal environmental quality standards (EQS). Therefore the EIA normally uses exposure models to infer the impact associated with emissions. The EIA method is suitable when site-specific issues of concrete projects are analysed. It is less useful for assessing techniques or operating procedures (e.g. like RDF production and use) in general.

The **risk analysis** methodology resembles the one above in several aspects. Often an EIA includes elements of a risk analysis when the direct impact of a technique on the surrounding environmental media is estimated. In appropriate cases, specific toxicological aspects are analysed in detail. On the other hand, the instrument of risk analysis is not standardised, the user is free to choose the scope and processing methods. Risk analysis might be a useful approach with regard to the RDF issue but the method itself does not provide concrete operating instructions.

The most standardised environmental assessment methodology is **life cycle assessment** (LCA). The ISO standards 14040 to 14043 define the basic steps of this instrument. Several subsequent standards illuminate or instruct further technical aspects. During the last ten years the LCA method has established itself as one of the most commonly applied instrument to evaluate systems of production (ecological product balance from cradle to grave) or waste management systems. The methodological approach (defining general system boundaries and balancing the material and energetic inputs and outputs) allows the comparison of

different systems of any complexity. In those terms of system analysis this approach can be regarded as unrivalled by any other available method.

Despite these clear advantages, two weak points should be mentioned:

1. The locally unbound LCA-method is not the best approach to evaluate toxic effects. The exposure of targets (humans, plants, animals) is generally not considered. Attempts to solve this problem (for example the so-called CML-method) are not generally accepted.
2. An LCA describes the transition of materials and energy and it is not capable of describing a state or situation. For example, the concentration of toxic substances in products, an important aspect in the context of RDF, evades evaluation by LCA.

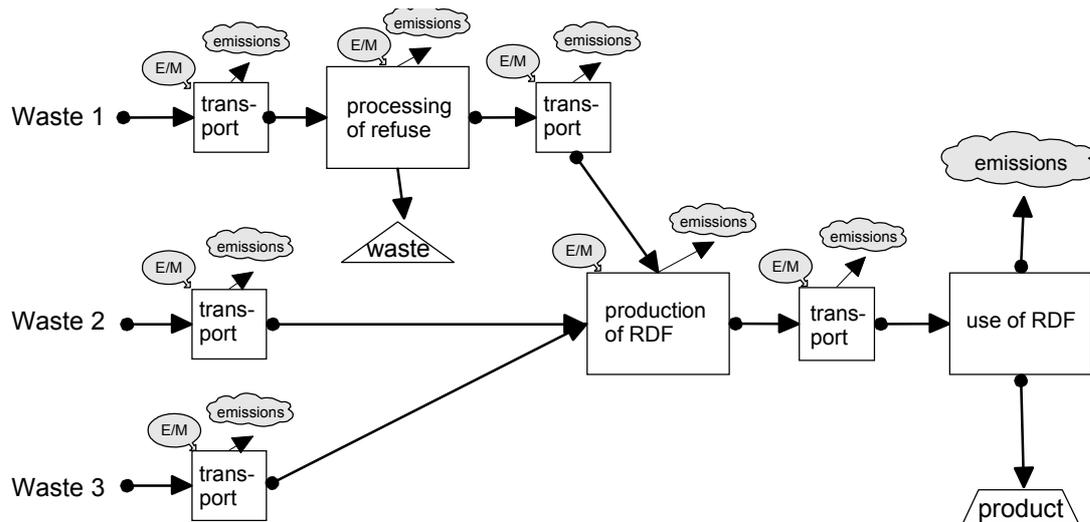
The **material flow analysis** (MFA) method overlaps with LCA, or rather the principle of the MFA (the investigation of the substantial whereabouts of material input into an process or a chain of processes) also proceeds with a LCA-like analysis. The two methods differ in the focus. Whereas an LCA typically comprises a more or less large system and calculates all input and output flows and aims to express all balance data by elementary flows, MFA focuses on a selected number of materials (it might be just one) and follows the distribution of these materials (mostly elements or compounds) into several sinks. An example is the flow of the element nitrogen within the system of agricultural production, food consumption and disposal towards sinks like the air, water and soil.

It seems to us that in order to evaluate environmental effects of RDF production and use, one should not strictly adhere to just one particular methodology from the ones described above. All of them contain specific advantages to operate on the RDF theme but none of them is able to address all questions of interest.

The LCA approach is the most advanced and standardised and should be considered the baseline. This should be amended by MFA to follow the fate of polluting agents within the fuel and analyse the sinks (esp. air – product). The elements of an EIA are useful in the assessment of potential hazards to the surroundings of the RDF processing and firing plants.

#### **4.2.3 Outline of the methodological concept**

The appropriate package of methods must take account of the specific impacts which are likely to be relevant. An outline of the process tree of RDF production and use and the relevant environmental effects is given in Figure 4.1. The LCA approach to the environmental impact (emissions and depletion of resources) includes the relevant pre-chains (transport emissions, processing of petrol for transport).

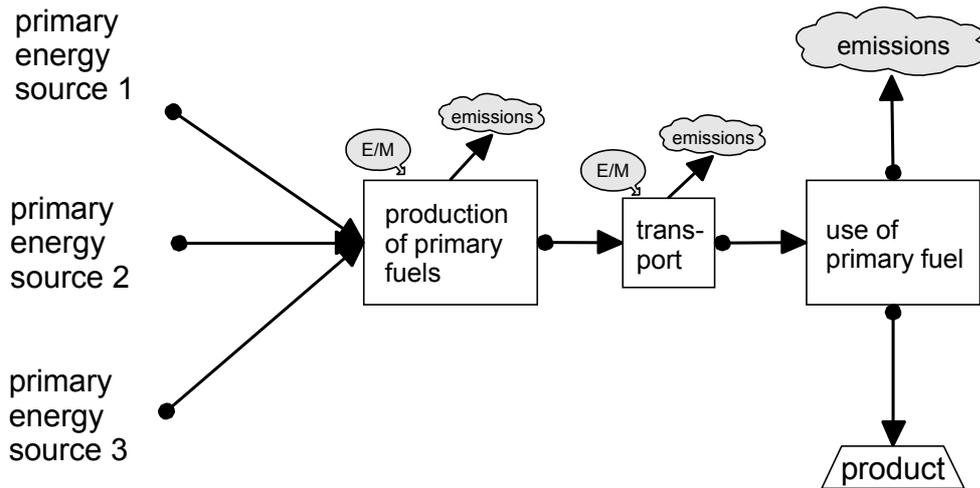


*system of RDF production and use*

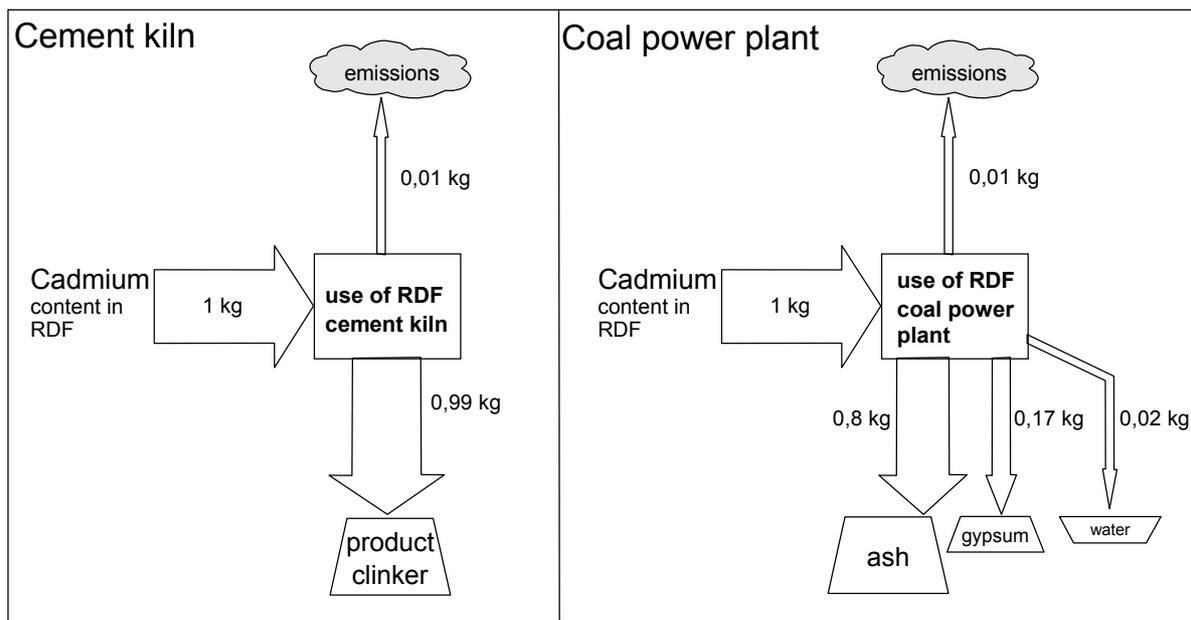
**Figure 4.1 Scheme of the system for RDF production and use (E/M: input of energy and/or material resources)**

In order to get a correct evaluation of the different systems of RDF production and use (e.g. different types of waste materials), the benefit of the specific RDF-types has to be considered. The balance results of each RDF system must be compared with the substituted primary situation for RDF i.e. substitute primary fuels (see Figure 4.2). The relationship between specific energy content (heat value) and content of pollutant (e.g. heavy metals) can differ considerably between RDF types as well as between primary fuels.

The illustrated concept covers the system based LCA approach. The MFA will be an integrated element within this concept at least with regard to modelling the RDF use (possibly including the production if pollutant containing material fractions were segregated). Using cadmium as an example, Figure 4.3 shows how this will be carried out. The distribution of the pollutant is calculated on empirical transfer coefficients to off-gas and solid products and also waste water if wet scrubbing systems are involved.

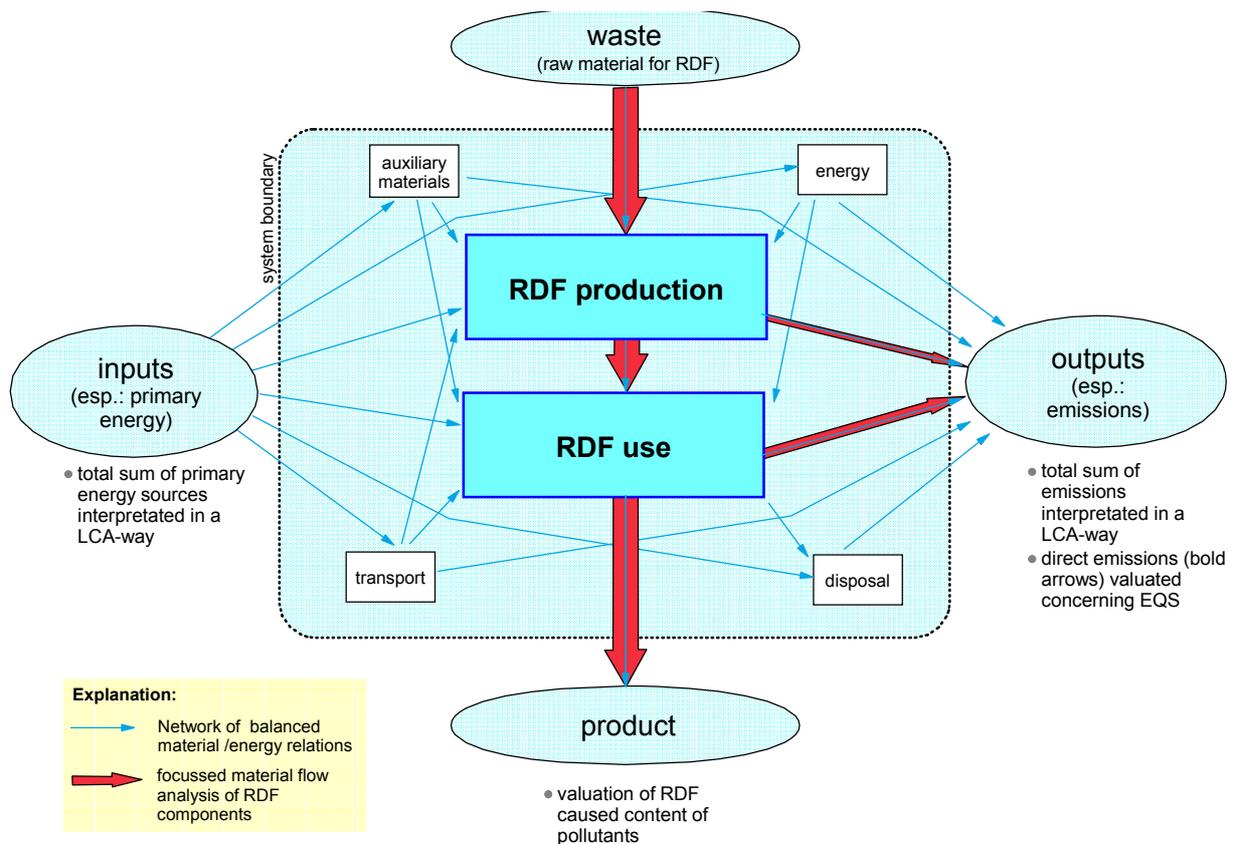


**Figure 4.2** Scheme of the system for substituted primary fuels (E/M: input of energy and/or material resources)



**Figure 4.3** Scheme of a material flow analysis for RDF-inherent cadmium distribution in a cement kiln and in a coal power plant (figures are used as examples and do not represent exactly the real situation)

The LCA and material flow approach, results in an input/output balance and an impact assessment typical for LCA (classification, characterisation, normalisation and grouping) (See ISO-standard 14042: Life Cycle Impact Assessment). In addition, site-specific impacts can be undertaken, allowing ambient concentrations of pollutants in the vicinity of plants (from RDF production and use) to be estimated and compared to environmental quality standards. This method package supplements an element typical for EIA element. Figure 4.4 shows the methodological concept with the mix of methods discussed above.



**Figure 4.4 Proposed methodological approach supplementing elements of the MFA, EIA and risk analysis to a LCA-framework**

#### 4.2.4 Selection of relevant data categories and impacts relevant to co-incineration

##### Data Categories

Firstly, data categories should be selected due to their specific relevance in terms of co-incineration of RDF. Parameters that are not significantly influenced by the decision of using RDF or not, can be omitted. The focus is thus strengthened on the really sensitive aspects and the scope can be limited.

1. Data categories selected with respect to discharge of air pollutants by combustion:

- CO<sub>2</sub>
- SO<sub>x</sub>
- HCl
- HF

diverse metals (As, Cd, Co, Cr, Hg, Ni, Zn)

PAH

PCDD/PCDF

2. Data categories selected with respect to specific emissions caused by processing RDF:

particulate matter

volatile organic compounds

N<sub>2</sub>O

NH<sub>3</sub>

3. Data categories selected with respect to primary fuels substituted by RDF for supplying material auxiliaries, process energy and transport:

crude oil

natural gas

hard coal

brown coal (lignite)

CO<sub>2</sub>

SO<sub>x</sub>

NO<sub>x</sub>

HCl

HF

N<sub>2</sub>O

NH<sub>3</sub>

particulate matter

volatile organic compounds (esp. CH<sub>4</sub>)

4. Combusting the substituted primary fuels claims the same range of data categories as combustion of RDF.

### Impact categories

Table 4.1 shows a list of impact categories that represents in some way the state of discussion in the community of LCA experts in Europe. Apart from the toxicity theme the listed impacts have been analysed in most LCAs carried out during the last few years. The examples of toxicity indicators were often applied in German studies.

**Table 4.1 Impact categories and indicators and classified data categories**

<b>Impact categories and indicators</b>	<b>Data categories of the inventory</b>
• Global warming	• CO <sub>2</sub> fossil, CH <sub>4</sub> , N <sub>2</sub> O
• Summer smog	• NO <sub>x</sub> , div. volatile organic compounds
• Nitrification, terrestrial	• NH <sub>3</sub> , NO <sub>x</sub>
• Acidification	• SO <sub>2</sub> , NO <sub>x</sub> , NH <sub>3</sub> , HCl, HF
• Human toxicity	<ul style="list-style-type: none"> <li>• represented by the indicator “carcinogenic risk potential“ (As, Cd, Cr-VI, Ni, Benzo(a)pyrene, Dioxin/Furan)</li> <li>• represented by single data categories (Hg, Pb)</li> </ul>
• Consumption of resources	• fossil energy resources (oil, gas, coal)

#### 4.2.5 Methods of evaluation

##### Evaluation in LCA-type assessments

The chosen method for evaluation in the LCA-type assessment refers closely to the ISO 14042 (LC Impact Assessment) adopting the following elements:

- *Normalisation*: Calculation of the magnitude of the category indicator results relative to reference values (specific contribution). In this case the total inventory of resource consumption and emissions in the European Union (15 Member States) were used as reference values. Dividing the total inventory by the number of inhabitants as an average value for the impact attributable to one person can be calculated. This “person equivalency value” (PEV) is used as a reference to make results by normalisation more impressive.
- *Grouping*: Ranking the impact categories in a given order of hierarchy, such as very high, high, medium low priority. The Federal Agency of Environment in Germany has published a list of impact categories ranked by judgement of an expert panel using a matrix of ranking criteria. That ranking list is adopted within this assessment.

Table 4.2 compiles the basic information for normalisation (PEV) and ranking.

**Table 4.2 Reference values for normalisation and grouping of the impact categories and indicators**

	Normalisation		Ranking
	Burden by one	reference	Ecological
	person in the EU PEV <sup>a)</sup>		Priority <sup>b)</sup>
Global Warming	10.6	kg CO <sub>2</sub> -Äq/a	■ „very high“
Summer smog	21.8	kg NcPOCP/a	■ „medium“
Nitrification, terrestrial	4.33	kg PO <sub>4</sub> <sup>-3+</sup> Äq/a	■ „high“
Acidification	55.3	kg SO <sub>2</sub> -Äq/a	■ „high“
Carcinogenic pollutants	8.3	g As-Äq/a	■ „very high“
Mercury emission	0.65	g/a	■ „high“
Lead emission	51.1	g/a	■ „medium“
Fossil energy resources	31.9	GJ/a	■ „medium“
a) Inventories cited in (Rentz <i>et al</i> 1998)			
b) Ecological priority based on (UBA 1999)]			

### Evaluation in EIA-type Assessment

The LCA approach cannot make a judgement on the severity of a localised impact. To balance this weakness, a strongly simplified approach of environmental impact assessment will be applied. This approach was originally developed to evaluate technologies for BAT determination as requested under the IPPC Directive in case of cross-media-conflicts (ARCADIS/ifeu 2002).

Additionally emissions from a combustion plant can generally be adequately quantified using predictive calculations in suitable models and model assumptions. This requires information about specific location conditions and plant characteristics, topography and meteorology. For emissions to air, the size of the plant, the quantity of waste gas and the height of chimneys have a considerable influence on the magnitude of the additional pollution that can be expected. In regards to water, the size and type of receiving body is decisive.

This location relationship is in conflict with a location-independent assessment. The latter is required when the general differences between technologies are to be demonstrated from an ecological point of view and assessed in an abstract and generalised form. In order to solve this conflict it is proposed that **standard scenarios for unfavourable but still plausible cases** (= standard scenarios) are defined, analogous to exposure estimates within the scope of other media-related regulations.

The assessment for air emissions is based on propagation calculations of emission forecasts for waste incinerators in various regions of Germany. The Gaussian model according to Appendix C of the German TA Luft (Technical Instruction on Air Pollution) is generally used in such cases. For several years now in extreme location conditions, more complex models (e.g.

the so-called Lagrange propagation model) have been used. Comprehensive practical results are available for both types.

Where the same type of emissions (loads as well as the height of the chimney), are involved, the air assessment shows that only in extreme plant locations (e.g. narrow valleys), the local meteorology and topography cause considerable deviations in the propagation factors.

Thus, a practical simplification is to assume a standard propagation or, respectively, dilution factor, based on just a few essential emission characteristics. This allows an estimate to be made of the maximum additional emission ( $AE_{max}$ ) that can be expected for all pollutants. Depending on the industry or type of emitting plant, a standard factor such as this must be derived separately. For instance the chimneys of waste incineration plants are usually around 60 to 80 m high (in very large plants, well above 100 m) and the volume of waste gas is in the range of 60,000 to 100,000 m<sup>3</sup> per hour. In “normal” location conditions the waste gas is diluted by at least a factor of 10<sup>5</sup> by the time it reaches the ground.

Guide and limit emission values can be regarded as a quality target for the respective pollutant, which – also taking account of emissions from other sources – can be regarded as still acceptable. The further removed a value is from this pollutant value, the greater the “safe distance” to possible damage. A unit of measurement for this could be the quotient from the (calculated for “standard conditions”) pollutant emission concentration and the emission limit value. The smaller the quotient, the lower the (absolute) significance of the respective pollutant.

In these terms the discussion about the adequate list of guide values or air quality benchmarks is ongoing. There are proposals from the UK EA as well as the German UBA (Table 4.3). At this stage in the discussions the values proposed by UBA are in most cases more strict than those proposed by the UK EA.

**Table 4.3 Guide values for the EIA-type valuation**

Pollutant	German proposal (Arcadis, ifeu 2002)	UK proposal (Whitehouse <i>et al</i> 2002)
	[µg/m <sup>3</sup> ]	[µg/m <sup>3</sup> ]
SO <sub>2</sub>	20	53
HCl	100	20
HF	1	0
As	0.004	0.2
Cd	0.005	0.05
Cr	0.05	0.5
Cu	10	10
Hg	0.13	0.25
Ni	0.01	1
Pb	0.5	-
	0	
PCDD/PCDF	0.000000016	-

### **4.3 Technological Assumptions**

The following paragraphs present the technologies chosen in this environmental assessment for describing the different RDF production and RDF utilisation. It is assumed that RDF production has been carried out according to the best available technology in order to prevent strong environmental impacts. Similarly, the technologies chosen for RDF utilisation are based on an average high standard and represent BAT in the sense of the IPPC Directive. For specific cases, the developed modules could be specified to other standards. By this way it is possible to create various models for existing standards in each region of Europe.

The specified standards for MSW incinerator in the module used for the environmental assessment are ensuring compliance with the new Waste Incineration Directive (2000/76/EC). For cement works and power plants, a general compliance with the threshold values specified in the same Incineration Directive (2000/76) cannot be guaranteed within this assessment, as it will depend on the pollution concentration in the specific waste type used as secondary fuel and on the ratio of energy substitution for waste derived fuels.

#### **4.3.1 RDF production**

The environmental assessment has focused on two representative processes for production of high calorific fraction from MSW; mechanical biological treatment (MBT) and a dry stabilisation process developed by a German company Herhof in Aßlar. The output of this process is commercialised under the trade name of 'Trockenstabilat®'.

#### **4.3.2 RDF utilisation**

The co-incineration processes considered in this assessment are a hard coal fired power plant, a brown coal fired power plant and a cement works. These are compared to a mass-burn MSW incineration plant.

##### **Brown coal fired power station**

The module uses a rehabilitated crude brown coal-fired power station with steam turbine for brown coal. A gas desulphurisation plant (GDP) is connected to reduce the sulphur dioxide emissions. It operates using the wet process: the additive limestone meal ( $\text{CaCO}_3$ ) is blown into the flue gas with water. The limestone meal is added in a stoichiometric ratio to the  $\text{SO}_2$ . The resulting GDP-gypsum can be used in the building construction industry. The GDP plant reduces  $\text{SO}_2$  by 95%, HCl by 92.5%, HF by 95% and dust by 90%. The NOx emissions are reduced solely by primary measures. The power station has an electric efficiency of 39%.

##### **Hard coal fired power station**

The module uses a hard coal power station for imported coal. The power station has a power rating of 500 MW, a net electrical generation ratio of 43.5%. A gas desulphurisation plant (GDP), a DeNOx plant and an electrostatic precipitator are connected to reduce emissions. The GDP operates using the wet method which relies on a stoichiometric ratio of limestone- $\text{SO}_2$ . This reduces the  $\text{SO}_2$  emissions by 90%, the dust emissions by 90% and the HCl and the HF emissions by 95% each. The DeNOx plant operates in accordance with the SCR-

process (selective catalytic reduction) with ammonia as sorbent in a stoichiometric relation. The Nox-emissions are thus reduced by 85%. The electrostatic precipitator reduces the dust emissions by a further 99.5%. For this assessment, compliance with the threshold values specified in the Incineration Directive (2000/76) cannot be guaranteed.

### **Cement works**

The cement process chosen for the module is a dry kiln equipped with cyclone or grid preheater. Dust is minimised by an electrostatic precipitator. The basic primary fuel used in the cement process is hard coal. The technology used in this module can be considered to be typical for a large number of cement kilns in Europe.

### **Waste incinerator**

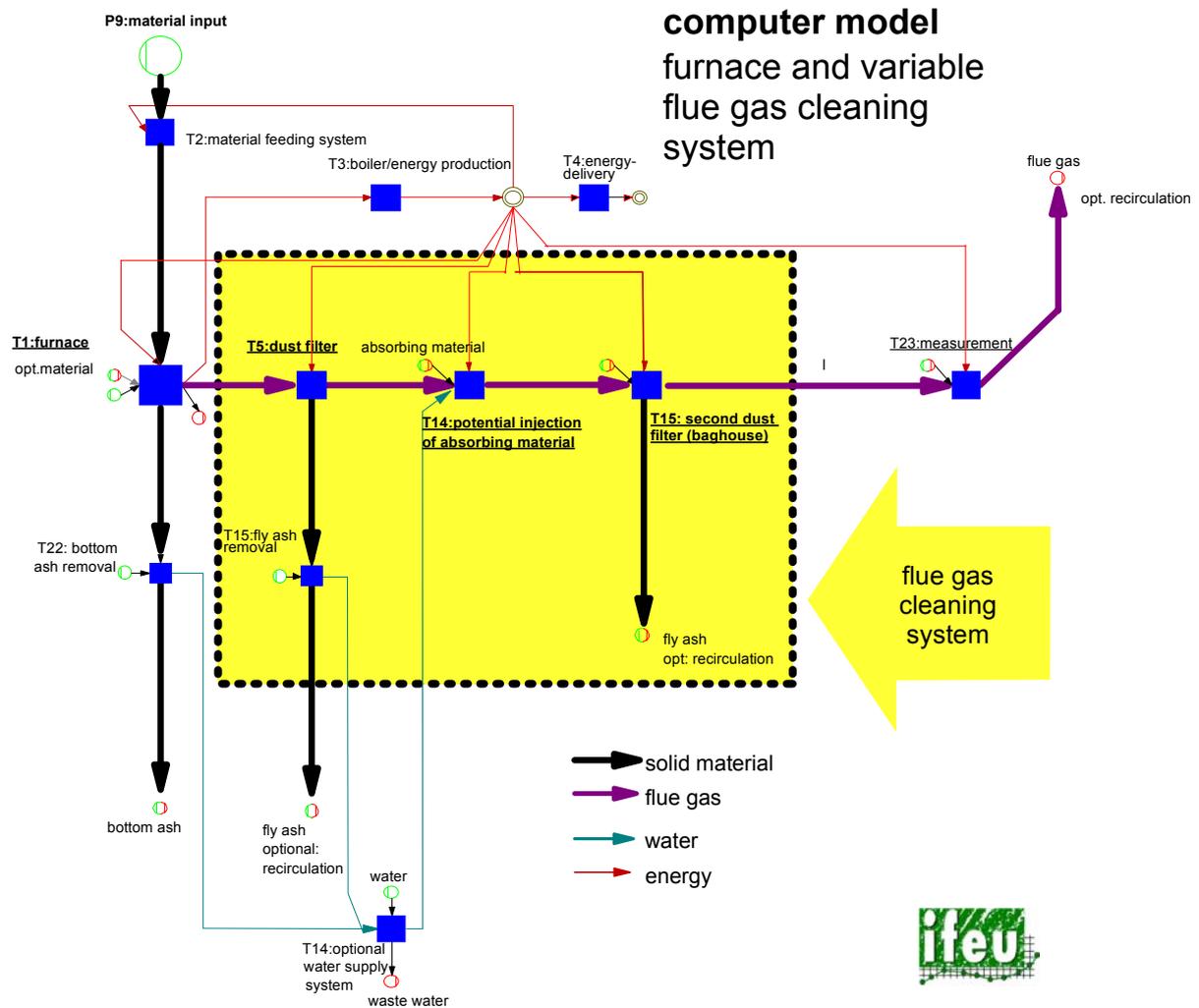
The chosen module for waste incinerator is a municipal solid waste incineration plant with grate firing (Figure 4.5) and energy recovery. It represents an average standard. The flue gas cleaning technology ensures compliance with the threshold values of the new EC Waste Incineration Directive (2000/76).

Flue gas emissions via the chimney are the main emission pathway. Other material flows are the incineration residues and the by-products resulting from flue gas cleaning. The plant works without any process wastewater.

Flue gas cleaning is divided in several steps. At first an electrostatic precipitator (three cells) is installed to minimise dust and ashes. Furthermore, a spray-dryer, a fabric filter, an acid scrubber for HCl reduction, a gas desulphurisation plant (GDP) and a SCR for NOx reduction are installed.

It is assumed that a modern boiler system is used with ninety percent (90 %) of the furnace heat transformed to steam. In general, the gross efficiency of power generation from waste incineration is no higher than twenty five percent (25 %). After plant consumptions (i.e. for Nox abatement), it can be assumed that there will be an electricity surplus of ten percent (10%) that is fed to the public grid.

There are also MSWI with combined heat and power (CHP) generation with a lower output of electricity but a feed to district heating systems. The most efficient concept would be a year-round supply of process steam to an industrial consumer. But this is not typical of the European situation.

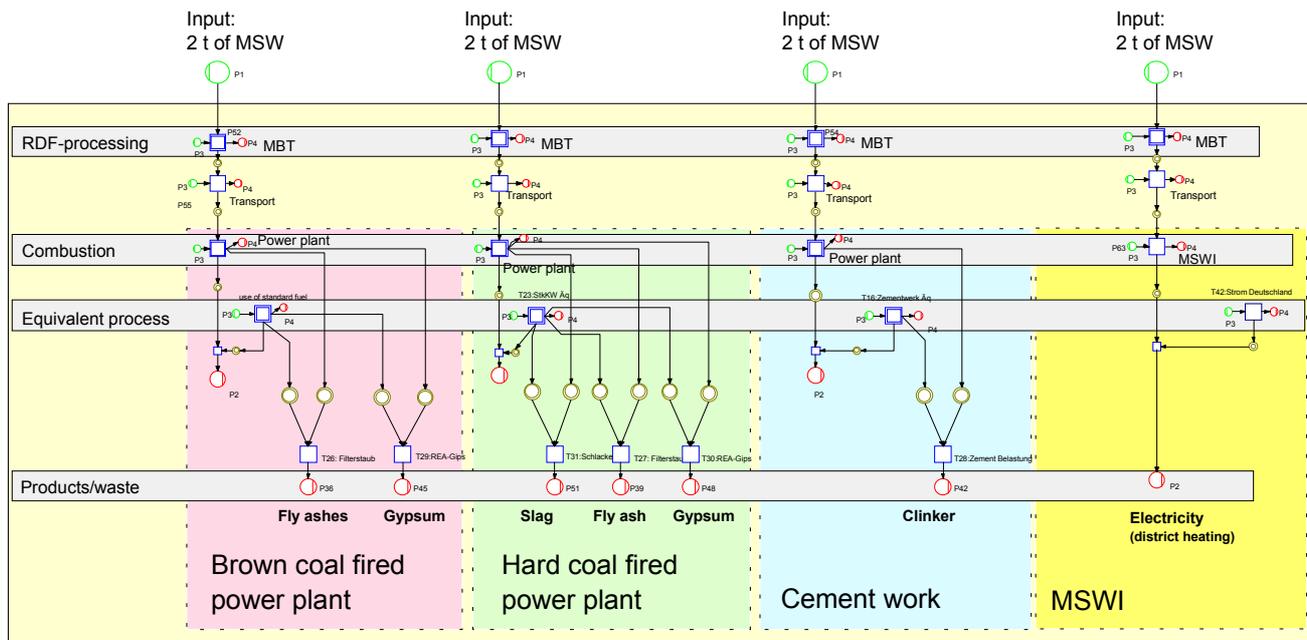


**Figure 4.5 Schematic description of furnace and flue gas cleaning system for MSW incinerator**

#### **4.4 Scenario Assumptions**

A model including the different co-incineration processes has been devised based on a program called “Umberto®”. In this model, it is possible to show the environmental impacts with respect to emissions and the product quality by using different types of RDF or secondary fuels in various amounts. It is also possible to change the system requirements to different standards.

As previously mentioned, the co-incineration techniques considered in this model are a hard coal fired power plant, a brown coal fired power plant and a cement works. These are typical co-incineration installations with significant capacities and emissions. Furthermore a large amount of output stocks are generated which are in use as products – mainly in the construction sector. The products considered in our assessment are fly ash, gypsum, slag and cement clinker. The model used for the different scenarii is shown in Figure 4.6 below.



**Figure 4.6** Scheme of modelling the systems of RDF use

In the two types of power plant the co-incineration ratio is set to 5% of the thermal energy supply and in the cement kiln, the co-incineration ratio is set to 50%. These values seem to be realistic values where no technical problems with the combustion process are expected.

Nevertheless the other components should not be neglected. For instance the preparation of the RDF in a mechanical biological treatment plant (MBT) may be of no significance to the impacts of the overall waste management system if operated properly according to given environmental standards. Such a MBT had been modelled in the system adopted above. But if e.g. drying processes may be applied in a RDF production plant with no scrubbing systems for process flue gas it is possible that volatile components like organic compounds or mercury are emitted quantitatively already at the RDF production facility.

As a consequence a specific option of using RDF in a power plant or cement work may be favourable but the emission of critical pollutants may have occurred already during the RDF production. This warning is made to ensure that on the one hand the system approach is used in a complete and appropriate way and that all components have to be modelled in the right way.

- For general comparisons the different stages of the RDF recovery such as transportation, disposal of residual waste from RDF production, the production of the alternative substituted fuel, etc. has to be considered completely.
- The RDF production step itself has to be carried out according to the best available technology in order to prevent strong environmental impacts at that stage in the system.

#### 4.5 RDF assumptions

In the following sections the impacts of co-incineration of different secondary fuels are calculated. A first group of secondary fuels includes automotive shredder residue (ASR) from car shredding (high calorific fraction mainly consisting of plastic materials), pelletised paper-rejects and demolition wood. These fractions were chosen because of their large mass potential.

The toxic loads as presented in Table 4.4 and Figure 4.7 show extreme variations; the ASR and demolition wood are two examples for fractions with a high burden. These fractions show typically high pollutants concentrations. Regarding ASR, it is worth mentioning that the EC Directive 2000/53 is tightening the standards for car manufacture and waste management of old vehicles especially regarding cadmium and other harmful substances which, in the long term, should reduce the toxic load in these wastes.

A second group includes two different MSW derived fuels - RDF; the Trockenstabilat<sup>®</sup> produced by Herhof in Aßlar and a RDF produced in a mechanical-biological treatment plant in Nehlsen. The toxic load of MBT-output is not as high as the toxic load of the ASR- or demolition wood fraction, nevertheless there might be a significant increases of heavy metals in the products.

**Table 4.4 Toxic load of selected waste derived fuels compared with hard and brown coal**

Content	Unit	ASR	Demolition wood	Paper Reject Pellets	Trockenstabilat <sup>®</sup>	MBT Nehlsen	Hard coal	Brown coal
CV	MJ/kg	18.3	17	25	16.5	13	28	9.1
N	%	2.0	2.93	0.14	1.7	1.5	1.4	1.0
S	%	0.32	0.17	0.10	0.2	not specified	0.88	1.5
Cl	%	0.56	0.118	0.67	0.44	0.4	0.14	0.11
As	mg/kg	10.6	4	<0.06	0.8	4	6.9	2.1
Pb	mg/kg	2,710	762	60	230	200	33	2.1
Cd	mg/kg	31.9	4.1	3.12	2.2	0.35	0.35	0.07
Cr	mg/kg	489	48	25.9	60	100	30	5.3
Cu	mg/kg	5,320	1,390	207	200	not specified	21	2.1
Ni	mg/kg	366	15.8	9.3	25	40	24	3.4
Hg	mg/kg	not specified	1.5	< 0.01	0.75	1.5	0.4	0.1
Zn	mg/kg	8,510	500	309	400	not specified	42	5.8

Sources: ASR (Moorman and Creuzen 2000), demolition wood (Scheurer 2000), Paper Reject Pellets (Rofire-Kappa), Trockenstabilat<sup>®</sup> (Heering 2001), MBT Nehlsen (VKS, ASA 2000), hard and brown coal (typical average values figured out by ifeu based on different sources)

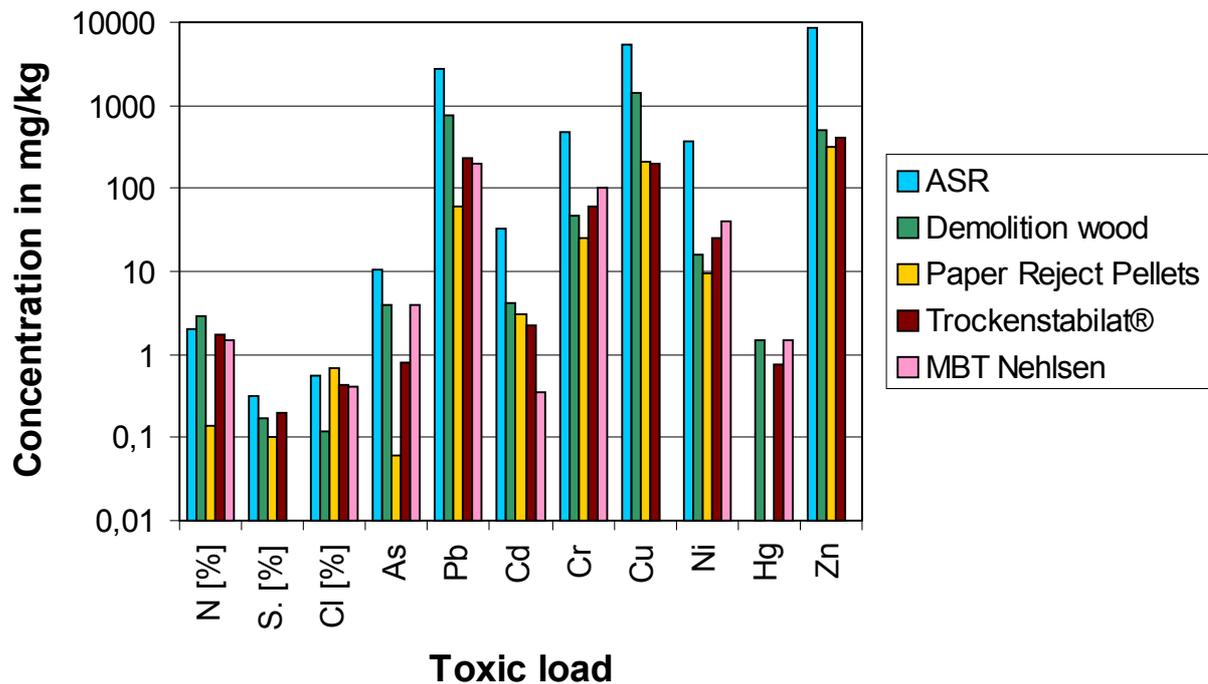


Figure 4.7 Toxic load of selected secondary fuels

#### 4.6 Substitution effects

In principle users of waste derived fuels aim to substitute costly conventional fuels/fossil fuels such as coal, fuel oil or natural gas. From the point of view of an ecological assessment this substitution is sparing natural resources and emissions from processing and firing these primary fuels. Therefore it is inevitable to consider the substitution effects in a system assessment approach for waste management options. Experience shows moreover that these effects may govern the evaluation results of recovery options in total (Kolshorn and Fehrenbach, 2000).

However, the use of waste derived fuel does not imply which kind or quality of fossil fuel is exactly been substituted. So there is a wide range of possibilities and the decision between a “clean” and a “dirty” fuel can change considerably the results of an LCA. This can be a reason for interested parties to use “clean” or “dirty” primary fuels as fuel substitute to generate desired results.

Considering this, average conditions for the substituted fuels have been chosen for the comparison. Even if fuel qualities with high concentrations of heavy metals exist (and are in use) it would not be helpful for a fair assessment of the waste management options to use these extreme situations. The same warning has to be made for the comparison of industrial installations which may use waste derived fuels. The method of how a substitution is calculated, the most polluting installations (e.g. with no scrubbing systems) may reveal the best net effect for the environment if they are using “clean” waste derived fuel instead of a

fossil fuel with average or even high loads. As a consequence the most polluting installations might be the best for using waste derived fuel and conserve this non-desirable situation.

The LCA type assessment as described in Section 4.4.1 will be modelled with typical even above average technologies in Europe but the RDF discussion could be distorted if it is used to maintain non Best-Available-Technology options in industry. Considering export of waste derived fuels to countries outside the EU the same problem may arise. Waste derived fuel recovery connected with its use in old technologies within non-EU countries will give an environmental preference compared to BAT technologies. This warning is necessary when using the applied assessment instruments. In conclusion:

- Average conditions for the substitution of fossil fuels must be the baseline for further assessments. Extreme values show possible existing situations but should not be used for the assessment of waste management options.
- The substitution effects of the systemic environmental assessment for waste derived fuel may prioritise old non-BAT technologies in or outside the EU. Further discussion about the use of waste derived fuel must pay attention to this fact and only concentrate on average or even BAT technologies for comparisons.

## **4.7 Results**

### **4.7.1 Results of LCA-type evaluation**

The LCA-type evaluation for the four utilisation options has looked at the different stages; RDF processing, transport to combustion plant, combustion, resourcing of auxiliary materials, transport and disposal of wastes. This assessment has focused on the use of RDF produced from a dry stabilisation process - Trockenstabilat® as substitute fuel in these plants. The Trockenstabilat® was chosen as being representative of main type of RDF currently produced in Germany.

#### **Inventory**

The results of the inventory are shown in Table 4.5. The functional unit of this calculation is one tonne (1 t) of RDF (Trockenstabilat®).

With respect to the material properties shown in section 4.3 (scenario assumptions) this input material can:

- generate 1,500 kWh of electricity, if combusted in a brown coal power plant, substituting 1,230 kg of brown coal
- generate 1,500 kWh of electricity, if combusted in a hard coal power plant, substituting 550 kg of hard coal
- deliver heat to produce 4,080 kg of clinker, if combusted in a cement works, substituting 550 kg of hard coal
- generate 520 kWh of electricity, if combusted in a municipal solid waste incinerator, substituting the equivalent amount by public power generation (European electricity mix).

## Impact Assessment

In Table 4.5 the impacts for all three scenarios of co-incinerating RDF (processing plus use) are compared with incineration in a MSW incinerator. The results for single impact categories are also highlighted in Figures 4.8-4.11.

In order to consider impact categories the inventory results are always aggregated to the impact category results. For example, to get the sum in "global warming potential (GWP)", the value of CO<sub>2</sub> is added to the value of CH<sub>4</sub> which is multiplied by 21 (the impact equivalency of methane related on the effectiveness of CO<sub>2</sub>) and added to the value of N<sub>2</sub>O which is multiplied by 320 (see also Table 4.1).

An initial assessment of the figures shows that none of the options is advantageous with respect to any of the impact categories. Each option has specific advantages and disadvantages.

**Table 4.5 Results of inventory and impact assessment of four technical options for combusting 1 Mg RDF Trockenstabilat®**

		Brown Coal fired Power Plant		Hard Coal fired Power Plant		Cement Work		MSWI	
		RDF	Subst. fuel (brown coal)	RDF	subst. fuel (hard coal)	RDF	subst. fuel (hard coal)	RDF	subst. electricity mix
<b>Fossil Resources</b>									
Raw oil	kg	5.03E+00	1.22E+00	5.22E+00	5.80E+00	2.17E+01	2.28E+01	4.64E+00	7.80E-01
Natural Gas	kg	3.60E+00	3.17E+00	4.33E+00	1.16E+00	8.34E+00	5.50E+00	4.14E+00	1.13E+01
Hard coal	kg	2.15E+01	1.69E+00	2.14E+01	5.70E+02	3.70E+01	5.84E+02	2.16E+01	4.70E+01
Brown coal	kg	6.40E+01	1.33E+03	6.32E+01	5.09E+00	1.05E+02	5.38E+01	7.04E+01	1.78E+02
<b>Total (CED)</b>	<b>kJ</b>	<b>1.88E+06</b>	<b>1.78E+07</b>	<b>1.74E+06</b>	<b>1.62E+07</b>	<b>3.17E+06</b>	<b>1.78E+07</b>	<b>2.10E+06</b>	<b>3.36E+06</b>
<b>Global Warming</b>									
CO <sub>2</sub> (fossil)	kg	4.75E+02	1.71E+03	4.72E+02	1.47E+03	2.46E+03	3.93E+03	4.79E+02	3.29E+02
CH <sub>4</sub>	kg	3.27E-01	2.48E-02	3.31E-01	6.89E+00	7.46E-01	7.41E+00	3.28E-01	6.41E-01
N <sub>2</sub> O	kg	1.15E-02	5.08E-02	3.82E-02	2.98E-02	1.53E-02	1.01E-02	1.44E-02	4.18E-03
<b>GWP</b>	<b>kg CO<sub>2</sub>-Eq</b>	<b>4.85E+02</b>	<b>1.72E+03</b>	<b>4.91E+02</b>	<b>1.62E+03</b>	<b>2.48E+03</b>	<b>4.09E+03</b>	<b>4.91E+02</b>	<b>3.44E+02</b>
<b>Summer Smog</b>									
CH <sub>4</sub>	kg	3.27E-01	2.48E-02	3.31E-01	6.89E+00	7.46E-01	7.41E+00	3.28E-01	6.41E-01
NM VOC	kg	3.67E-01	6.17E-02	3.67E-01	6.33E-02	3.63E-01	6.08E-02	3.17E-01	1.07E-02
Nox	kg	1.24E+00	1.24E+00	1.14E+00	1.18E+00	6.85E+00	7.21E+00	1.11E+00	4.69E-01
<b>NCPOCP</b>	<b>kg</b>	<b>4.22E-01</b>	<b>1.79E-01</b>	<b>4.05E-01</b>	<b>2.97E-01</b>	<b>1.03E+00</b>	<b>7.89E-01</b>	<b>3.69E-01</b>	<b>6.47E-02</b>
<b>Acidification</b>									
SO <sub>2</sub>	kg	6.38E-01	1.37E+00	1.01E+00	1.47E+00	1.01E+00	1.00E+00	6.19E-01	2.55E-01
Nox	kg	1.24E+00	1.24E+00	1.14E+00	1.18E+00	6.85E+00	7.21E+00	1.11E+00	4.69E-01
NH <sub>3</sub>	kg	2.06E-01	1.76E-01	1.04E-01	4.44E-02	6.16E-02	9.55E-04	7.82E-02	2.95E-03
HCl	Kg	3.82E-01	8.75E-01	4.27E-01	7.52E-02	3.36E-02	2.05E-02	2.89E-02	1.06E-02
HF	kg	2.68E-03	5.94E-03	2.68E-03	2.41E-03	4.51E-03	2.46E-03	4.92E-03	1.50E-03

		Brown Coal fired Power Plant		Hard Coal fired Power Plant		Cement Work		MSWI	
		RDF	Subst. fuel (brown coal)	RDF	subst. fuel (hard coal)	RDF	subst. fuel (hard coal)	RDF	subst. electricity mix
<b>AP</b>	<b>kg SO<sub>2</sub>-Eq</b>	<b>2.23E+00</b>	<b>3.35E+00</b>	<b>2.38E+00</b>	<b>2.45E+00</b>	<b>5.96E+00</b>	<b>6.07E+00</b>	<b>1.57E+00</b>	<b>6.00E-01</b>
<b>Nutrification</b>									
Nox	kg	1.24E+00	1.24E+00	1.14E+00	1.18E+00	6.85E+00	7.21E+00	1.11E+00	4.69E-01
NH <sub>3</sub>	kg	2.06E-01	1.76E-01	1.04E-01	4.44E-02	6.16E-02	9.55E-04	7.82E-02	2.95E-03
<b>NP</b>	<b>kg PO<sub>4</sub><sup>3+</sup>-Eq</b>	<b>2.32E-01</b>	<b>2.21E-01</b>	<b>1.84E-01</b>	<b>1.69E-01</b>	<b>9.11E-01</b>	<b>9.38E-01</b>	<b>1.71E-01</b>	<b>6.20E-02</b>
<b>Human Toxicity</b>									
<i>Carcinogenic risk potential</i>									
As	kg	8.63E-06	3.90E-05	8.59E-06	2.70E-05	1.46E-06	2.99E-06	8.39E-07	5.51E-06
Cd	kg	2.64E-04	1.70E-05	7.87E-05	5.42E-06	2.56E-06	1.47E-06	1.07E-05	7.65E-07
Cr	kg	6.01E-05	3.81E-06	2.88E-05	7.16E-06	2.83E-07	4.72E-07	2.45E-06	2.29E-07
Ni	kg	2.68E-04	4.33E-05	7.74E-05	4.09E-04	4.74E-05	4.07E-04	2.08E-05	3.65E-05
BaP	kg	3.12E-08	1.33E-08	3.12E-08	8.63E-08	2.23E-07	2.90E-07	3.17E-08	1.21E-08
PCDD/PCDF	kg	5.28E-11	6.80E-11	5.22E-11	5.17E-11	1.71E-10	1.78E-10	1.49E-10	6.61E-12
<b>CRP</b>	<b>kg As-Eq</b>	<b>1.53E-04</b>	<b>5.07E-05</b>	<b>5.52E-05</b>	<b>5.65E-05</b>	<b>3.42E-05</b>	<b>5.81E-05</b>	<b>9.41E-06</b>	<b>8.26E-06</b>
<i>Single data categories</i>									
Hg	kg	4.63E-04	6.53E-05	3.31E-04	5.96E-05	7.24E-04	3.03E-04	1.08E-04	7.63E-06
Pb	kg	2.30E-03	1.41E-05	8.97E-04	8.23E-05	5.81E-06	1.68E-06	6.21E-05	8.43E-06

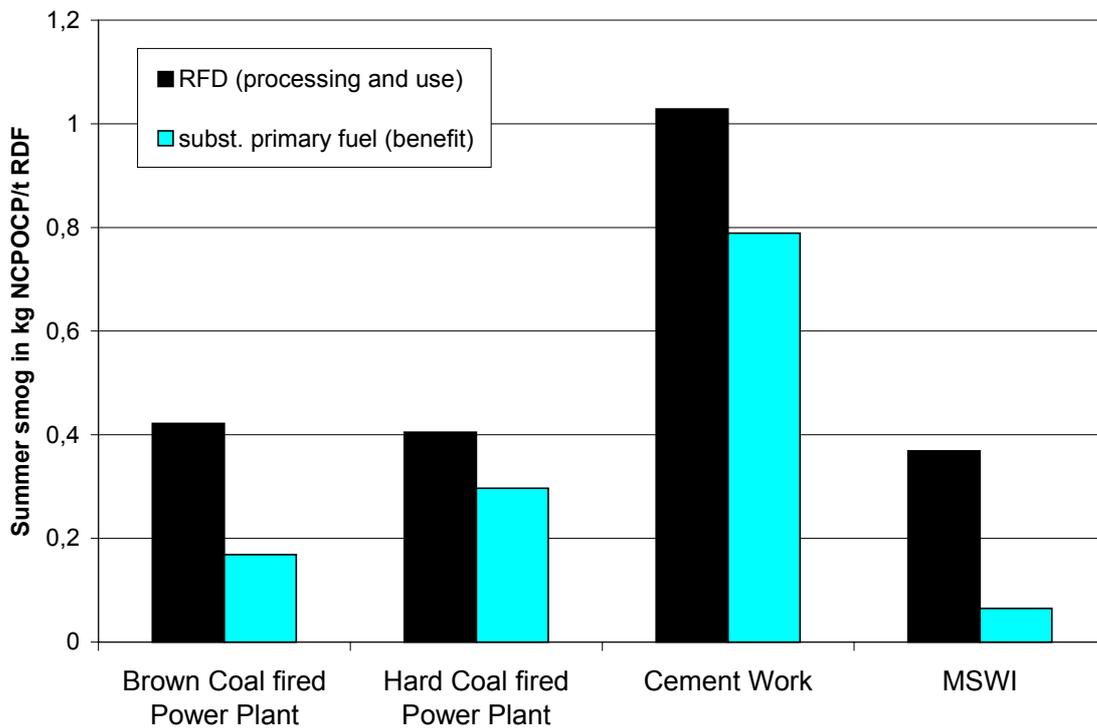
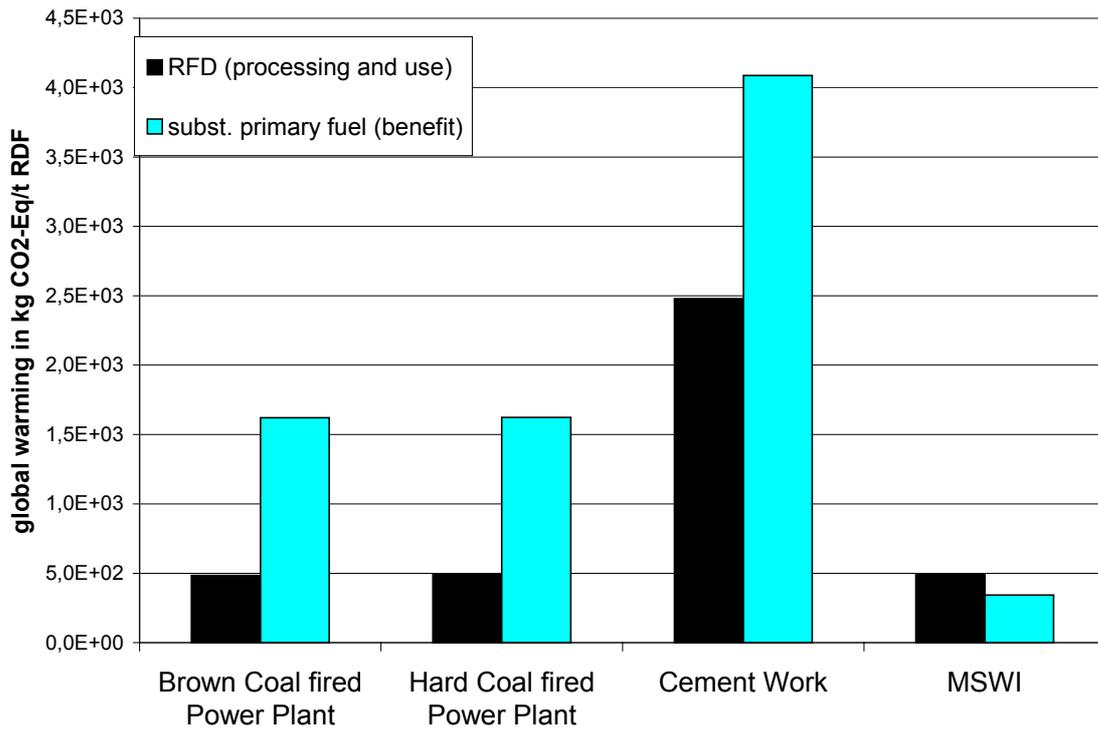
Notes:

1 Mg Trockenstabilat® = 2 Mg processed household waste

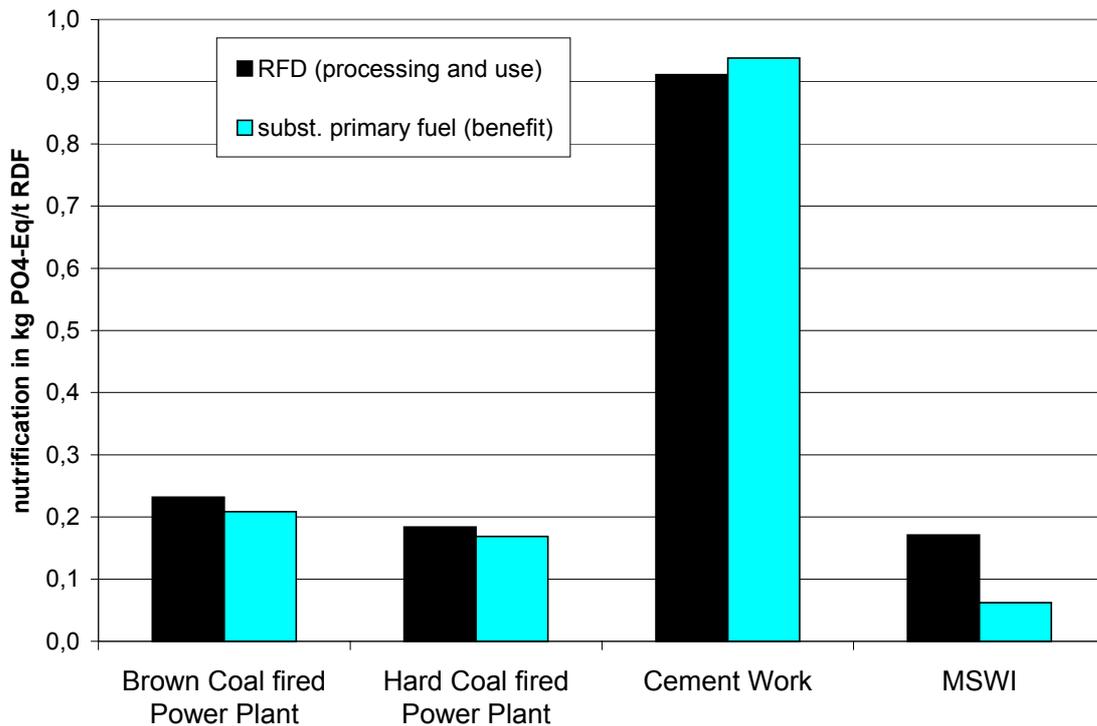
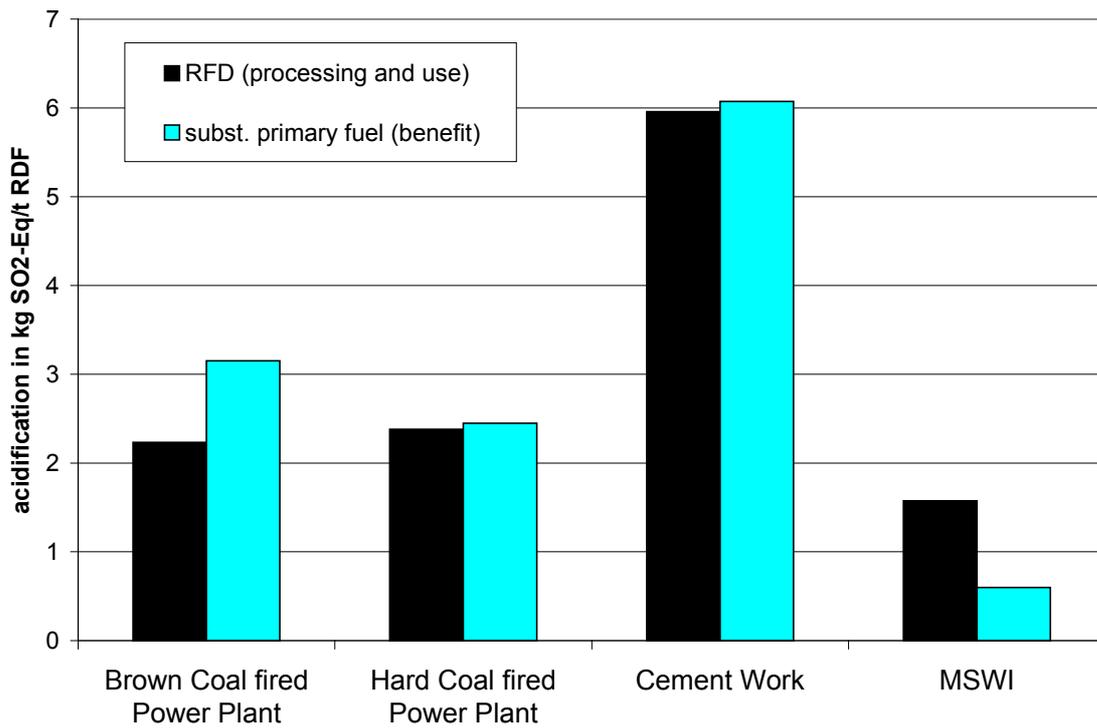
“subst. fuel”: processing and use of primary fuels like hard or brown coal;

“subst. electricity mix”: generation of electricity according to the average situation in Europe, incl. processing of primary fuels and use in power plants

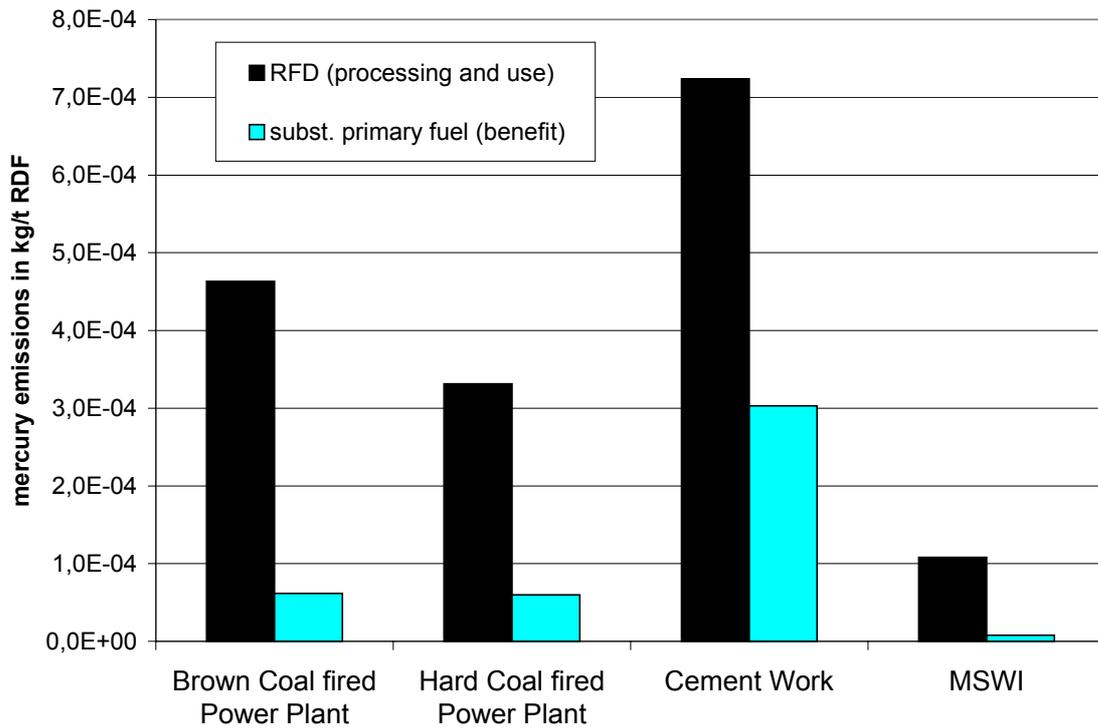
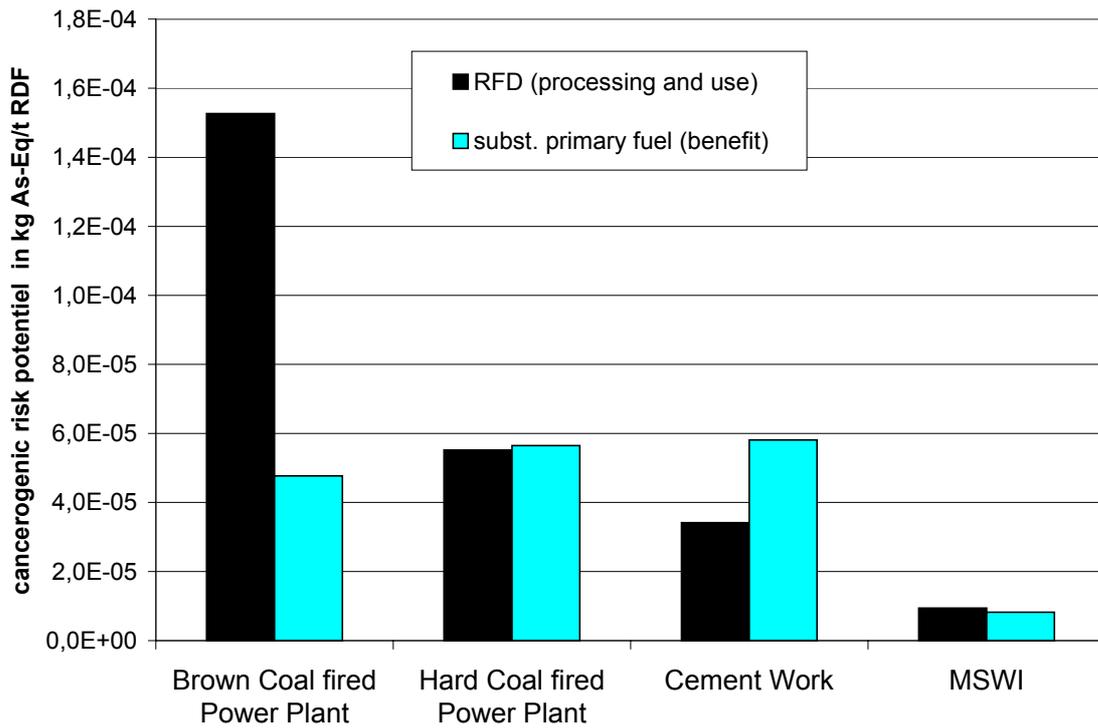
CED: cumulated energy demand; GWP: Global warming potential; NMVOC: non-methane volatile organic compounds; NCPOCP: NOx-corrected photooxidantial creation potential; AP: Acidification potential; NP: Nutrification potential; CRP: Carcinogenic risk potential; BaP.: Benzo(a)pyren; PCDD/F: polychlorinated Dibenzodioxines and –furanes (summed as toxic equivalents).



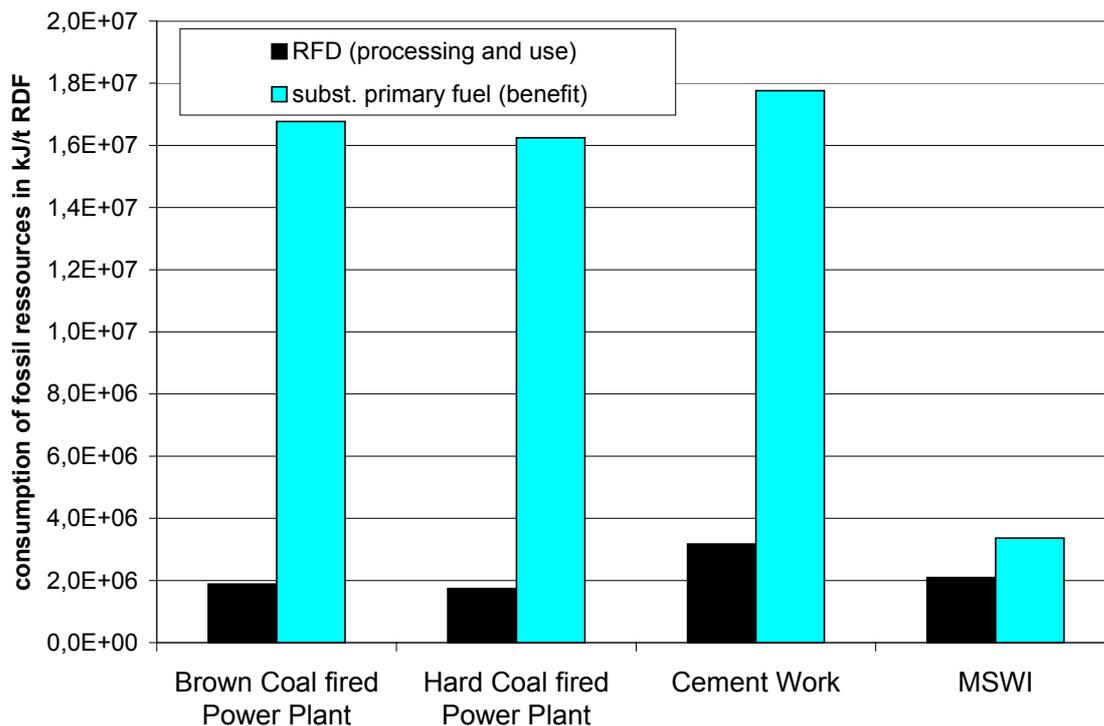
**Figure 4.8** Results for “global warming”(top) and “summer smog” (bottom) for the combustion of 1 Mg Trockenstabilat® by four different options



**Figure 4.9 Results for “acidification” (above) and “nitrification” (below) for the combustion of 1 Mg Trockenstabilat® by four different options**



**Figure 4.10 Results for “human toxicity”, represented by the indicators “cancerogenic risk potential” (above) and “mercury emissions” (below) for the combustion of 1 Mg Trockenstabilat® by four different options**



**Figure 4.11 Results for “consumption of fossil resources”, for the combustion of 1 Mg Trockenstabilat® by four different options**

### Evaluation by normalisation and grouping

To illustrate the dimension of the decisions between the alternative options for combusting RDF – in this case the use of Trockenstabilat® - the differences of impacts are scaled up to an estimated capacity potential of RDF across Europe. There is no reliable database to give a dependable estimate. However, it is not unrealistic to propose that household waste from a population of 380 millions could generate 10 million tonnes of RDF. (This number does not need to be exact but to give an order of magnitude scale for the caused impacts).

Table 4.6 shows the results of the normalisation. It points out the best of all four options according to each impact category and indicates by numbers of squares the difference of each option to the respective best option.



#### 4.7.2 Results of EIA-type evaluation

Table 4.7 presents the air pollutant emissions by the four technical options combusting RDF (respectively Trockenstabilat®) assuming a standardised dispersion factor based on typical examples for the plants. Due to the smaller plant size of MSWI (chimneys mostly around 80 m, power and cement plants mostly more than 150 m) a higher dispersion factor is applied. As for the rate of substitution of co-combustion, 5% is assumed for coal power plants with an installed load about 300 MW. The same thermal load is assumed for the cement works but a rate of 50% is assumed to be typical when RDF is incinerated. The MSWI is presumed to treat 30 t/h.

The table also presents the results of the calculation for additional emissions due to the combustion of RDF.

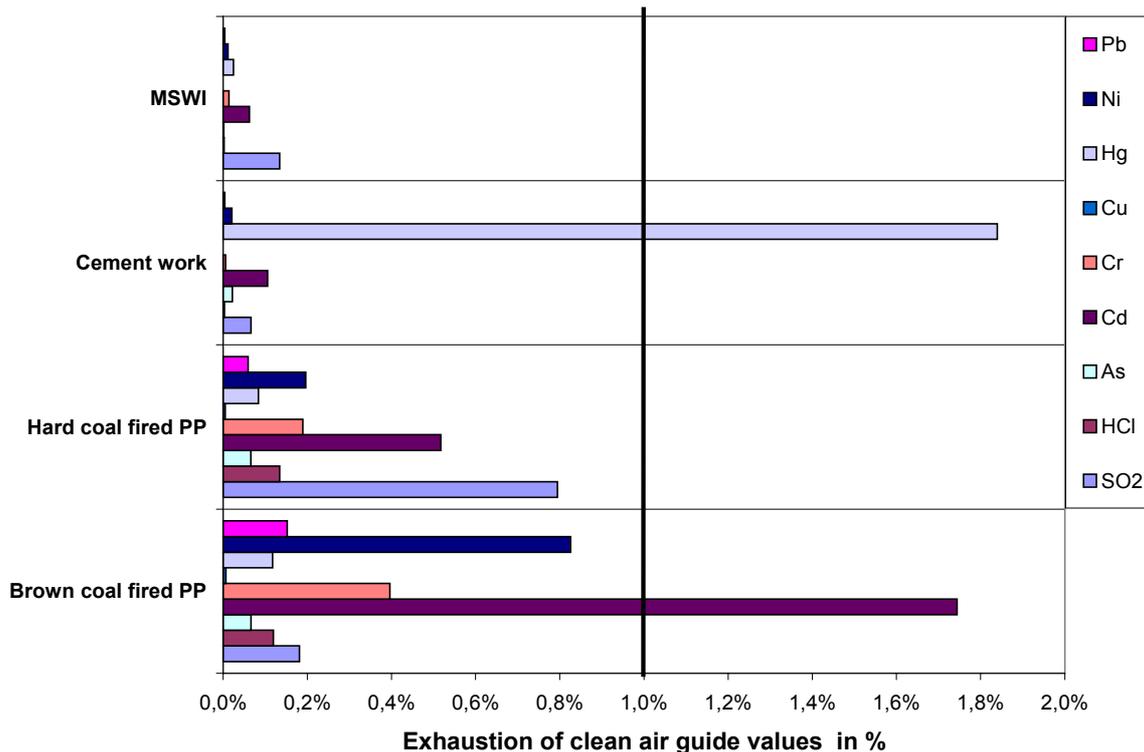
By comparing these estimated emissions with guide values proposed in Germany (see Table 4.3), the technical options and pollutants with significant influence on the surroundings of the plant can be identified (Figure 4.12). Using the 1% - threshold as a measure of significance, two cases can be evaluated to be sensitive: mercury and cadmium - the first one for the cement works, the second one for the brown coal power plant. A couple of other pollutants show burdens slightly below 1% of guide values. Only the MSW incinerator is well below the threshold for all considered pollutants

It has to be stressed that this interpretation cannot be applied to every combustion plant in Europe. It just gives some indications that for a few plants, mercury, cadmium and perhaps nickel or sulphur dioxide, **might** be problematic when RDF – type Trockenstabilat® - is co-incinerated.

Another question might be local environmental impact caused by the plant processing RDF. In this assessment all scenarios include the same MBT process. So this step does not lead to differences between the results of co-incineration and MSWI and - respecting a high technical standard MBT processing – does not constitute essential burdens to the LCA outcome in total. On the other hand the local surroundings of a MBT facility might be affected as the stack discharging exhaust gas is normally lower than the one of an incineration plant. In case of lower technical standards significant disadvantages can not be definitely excluded.

**Table 4.7 Discharge of air pollutant by combusting 1 t of RDF, assumed capacity for RDF-combustion of typical plants, assumed dispersion factor for typical plants and resulting maximum air emissions in the ambience of a typical plant**

	<b>Brown coal fired power plant</b>	<b>Hard coal fired power plant</b>	<b>Cement work</b>	<b>MSWI</b>
<b>Emission (kg / t combusted RDF)</b>				
HCl	3.62E-01	4.08E-01	9.05E-04	8.78E-03
SO <sub>2</sub>	1.10E-01	4.81E-01	4.00E-03	8.95E-02
As	8.00E-06	7.96E-06	2.60E-07	2.16E-07
Pb	2.30E-03	8.97E-04	5.81E-06	6.21E-05
Cd	2.64E-04	7.83E-05	1.60E-06	1.03E-05
Cr	6.00E-04	2.87E-04	8.97E-07	2.34E-05
Cu	2.00E-03	1.42E-03	1.32E-06	8.40E-05
Ni	2.50E-04	5.93E-05	6.27E-07	3.75E-06
Hg	4.63E-04	3.31E-04	7.24E-04	1.08E-04
Zn	4.00E-03	1.56E-03	3.18E-06	2.40E-05
<b>Capacity of (co-)incinerated RDF</b>				
t / h	66	66	660	30
<b>Dispersion factor (kg/h → µg/m<sup>3</sup>)</b>				
h/m <sup>3</sup>	0.005	0.005	0.005	0.01
<b>Predicted maximum additional emission (µg/m<sup>3</sup>)</b>				
HCl	3.63E-02	1.59E-01	1.32E-02	2.69E-02
SO <sub>2</sub>	1.20E-01	1.35E-01	2.99E-03	2.63E-03
As	2.64E-06	2.63E-06	8.60E-07	6.48E-08
Pb	8.72E-05	2.59E-05	5.28E-06	3.10E-06
Cd	1.98E-04	9.46E-05	2.96E-06	7.02E-06
Cr	6.61E-04	4.70E-04	4.37E-06	2.52E-05
Cu	1.53E-04	1.09E-04	2.39E-03	3.24E-05
Ni	8.26E-05	1.96E-05	2.07E-06	1.13E-06
Hg	7.60E-04	2.96E-04	1.92E-05	1.86E-05
Zn	1.32E-03	5.15E-04	1.05E-05	7.20E-06



**Figure 4.12 Results for EIA-type valuation of combustion of RDF by four different technical options**

### 4.7.3 Impacts of products and by-products

The most difficult part of the environmental assessment of co-incinerating RDF is the evaluation of potential impacts on the products and by-products of those industrial processes which operate with RDF. Chlorine, sulphur, heavy metals, etc. are substances which can influence the quality of the generated products and have a subsequent impact on the environment.

Products or by-products are defined as the material output that will be used in manufacturing industry. In contrast waste is destined to be excluded from material cycles and be disposed of in landfills. The cement process has only one output of solid material. So the product clinker contains all substantial input apart from the substances leaving the process with the flue gas. Depending on the applied furnace technique the fly ash of hard coal fired power plant is partly used as clinker substitute and can also be declared to be a product. Bottom or fly ashes that are recovered by the construction industry can be defined as by-products. Also a typical by-product is gypsum produced by scrappers installed in coal power plants.

Slag and ashes from MSWI is not covered in this analysis even if the practise of recovering these materials in road construction is on the increase. This type of material originates totally from waste and the decision to recover it has to be done by careful weighting of economic pros and ecological cons. If recovery is not ecological viable – e.g. because of incineration of

highly loaded waste as ASR – it should be stopped. Slag is not produced to be a building material but cement is.

In assessing the environmental risks posed by these products and by-products, it is necessary to examine the displacement of pollutants to them. Using material flow analysis (MFA) which is already part of the LCA methodology (see Section 4.1) shows that these chemical elements will not be destroyed but distributed in the different output flows of the processes. While the main emphasis of the system assessment and the local environmental assessment had been laid on the pollutants which are emitted to the atmosphere the question of the whereabouts of the rest remains unsolved. The LCA method counts a pollutant when it is released to the environment. But what happens when the release to the environment is not known exactly?

The use of five different secondary fuels (ASR, paper-reject pellets, demolition wood, Trockenstabilat®) and MBT Nehlsen) were compared with not using RDF. The quality of products was also compared with some standard like the Swiss orientation standard for heavy metals in clinker. Furthermore some figures were presented looking at enrichment factors from different points of view.

In the Section below, calculations have been presented showing where the heavy metals and the chlorine may end up. The transfer factors of the considered heavy metals from RDF into the products may be disputed but the fact is that they will be found somewhere. However, some questions cannot be answered easily- in which binding conditions are they in the product? If that product is further processed such as the clinker into cement, how these products are applied and furthermore disposed of after their lifespan, how they may interact with the environment e.g. by leaching, etc?

It is not the intention of this chapter to give an ultimate answer to the environmental assessment of the products but to give some guidance on the basis of the calculations presented below.

Two fundamental possibilities have to be considered when approaching the assessment of products. One is to make estimations about time, quantity and characteristics of the releases of the pollutants to the environment which must be followed by estimations of the environmental impact caused by these releases.

The other one is to set standards for the content of the pollutants in the products and along the line of their use looking at, for example, possible heavy metals leaching from construction material during use or after recycling, etc. While the first is the more scientific and reliable possibility it would need a lot of assumptions and further investigation to get results. The second one is a more pragmatic approach, and may cause more conflicts but can be based on the precautionary principle for unknown environmental impacts in the future.

Beside the fact that all these considerations do not deal with environmental impacts directly they all depend on assumptions which may lead to very different numbers. While comparing the “with and without RDF” - products it depends a lot on the original contents of heavy metals in the fossil fuels which for coal or fuel oil for example show also large ranges in their content. With regard to a rather “dirty coal” a high concentration of heavy metals in a product might be part of the reality. But choosing “worst practise” as reference would not be in line with the precautionary principle. To compare scenarii between “with and without RDF”, it will always be important to define an average fossil fuel content of heavy metals and use it for benchmarking. It can be used for direct comparison of different types of RDF or even serve as basis for the development of a material specific standard. That standard could be defined as

an average content of heavy metals in a product and have the regulations specify e.g. an enrichment factor not higher than 2.

The following assessments and considerations are based on average numbers that have been available for the authors of the study. They are based on reliable source but do not pretend to represent the “exact” average situation. They just serve to show the principle of the proposed approach to assess the difficult issue of “impact of products” in terms of RDF use.

## Cement plant

The co-incineration of different secondary fuels in cement kilns will have a large impact on the quality of clinker produced as shown in the Table 4.8 and Figure 4.13. In the first column, the toxic load of the cement clinker is shown where no secondary fuel is used. As described above the process is calculated for a co-combustion ratio of 50 %.

The strongest effects are observed when using ASR: The load rises for Cl, Pb, Cd, Cu and Zn by about one order of magnitude. Even using demolition wood the effects are clear to see.

Compared with product specifications for cement as specified by the Swiss BUWAL (see Table 4.8), much higher loads for lead, cadmium, copper and zinc are observed when ASR is co-incinerated. The exceedance factors are lower for demolition wood (e.g. lead and copper).

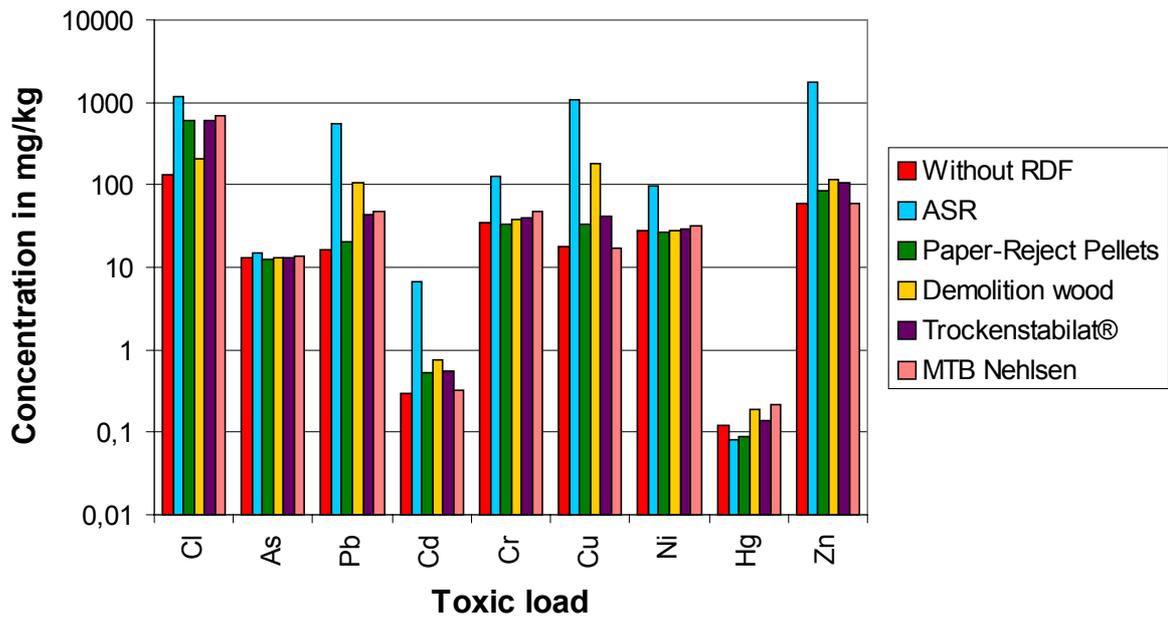
Also regarding the guide values for Portland cement with a clinker ratio of 95 to 100%, the chlorine concentration is about 12% higher than tolerated limit of 1,000 mg Cl/kg. There is no exceedance for the mercury limit (0.5 mg Hg/kg).

**Table 4.8 Calculated toxic load in cement clinker; co-incineration ratio: 50%**

Element	Unit	Without RDF	ASR	Paper- Reject Pellets	Demo- lition wood	Trocken- stabilat®	Nehlsen, MBT	Buwal <sup>1</sup>
Cl	mg/kg	134	1,180	606	205	606	692	
As	mg/kg	13	14.9	12.7	13.2	12.9	13.4	40
Pb	mg/kg	16.2	554	20.3	105	43.7	46.8	100
Cd	mg/kg	0.3	6.6	0.52	0.75	0.54	0.33	1.5
Cr	mg/kg	34.6	129	33.8	37.6	39.3	47.6	150
Cu	mg/kg	17.9	1,070	33.5	180	41.4	(16.9)*	100
Ni	mg/kg	27.3	98.5	26.4	27.8	29	32.2	100
Hg	mg/kg	0.12	(0.08)*	0.09	0.19	0.14	0.22	
Zn	mg/kg	59.6	1,750	83.3	117	108	(58.8)*	350

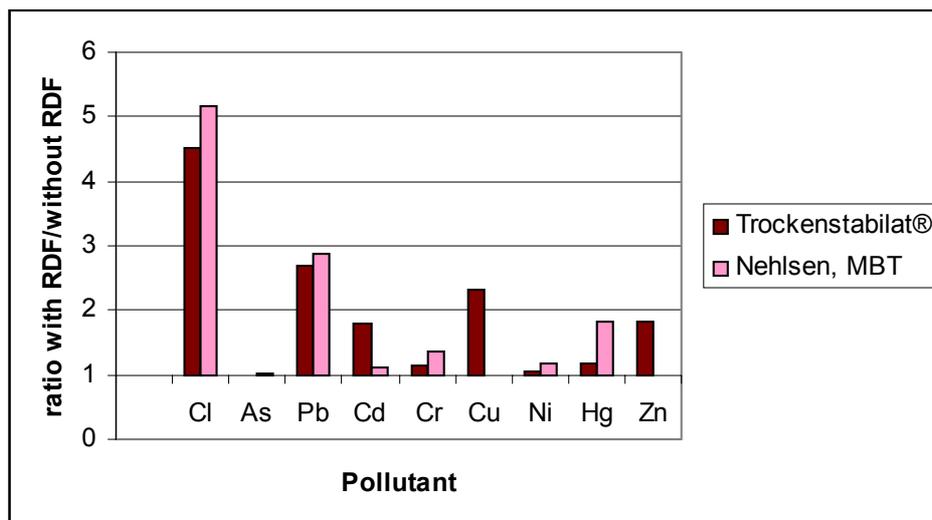
( )\* no concentration in secondary fuel specified

1 Swiss product specifications for clinker



**Figure 4.13 Impacts of co-incineration on the cement clinker; co-incineration ratio: 50%**

The effects of co-incinerating a mechanical-biological treated fraction (Figure 4.14) compared with no use of RDF are not as clear except for chlorine, lead and copper where concentrations in the clinker are in general 2 to 5 times higher.



**Figure 4.14** Changes in the toxic load cement clinker by co-incineration of MBT-output; co-incineration ratio: 50%

#### Availability of pollutants

Among the potentially harmful ingredients in cement, chromium is renowned to be a very critical one. Table 4.9 shows to what extension chromium can be eluted from cement. It is obvious that depending on the type of cement and the test conditions for elution a large amount of the chromium is available. For example, type CEM I shows very high mobility of chromium (up to 100%) when the acidity of the solvent is around pH 7.

**Table 4.9** Availability of chromium in cement under various conditions (Abfallbericht 2001)

Cement Type <sup>a)</sup>	Cr content [mg/kg]	Availability NEN 7341 <sup>b)</sup>		Availability pH-stat			Availability at pH 12.5	
		[mg/kg]	% <sup>c)</sup>	[mg/kg]	% <sup>c)</sup>	pH	[mg/kg]	% <sup>c)</sup>
SPCEM	89	1.98	2.2	2.5	2.8	4	0.18	0.2
SPCEM	67	0.68	1	2.69	4	10	0.72	1.1
CEM I	181	131	72.4	142	78.5	6	34	18.8
CEM I	31	20	64.5	31	100	7	5	16.1
CEM I	47	3.8	67.7	25.8	54.9	8	7.3	15.5
CEM I	27	10.9	40.5	10.7	39.6	10	2.26	8.4
CEM I	21	1.1	5.2	1.41	6.7	10	0.6	2.9
CEM IIB	18	1.81	10.1	2.12	11.8	8	0.6	3.7

Cement Type <sup>a)</sup>	Cr content	Availability NEN 7341 <sup>b)</sup>		Availability pH-stat			Availability at pH 12.5	
		[mg/kg]	[mg/kg]	% <sup>c)</sup>	[mg/kg]	% <sup>c)</sup>	pH	[mg/kg]
CEM IIB	29	10.1	34.8	7.52	25.9	9	3.3	11.4
CEM IIB	14	2.04	14.6	2.07	14.8	10	0.49	3.5
CEM IIIB	22	0.52	2.4	1.3	5.9	10	1.32	6
CEM VA	25	15.9	63.6	15.75	63	10	3.05	12.2

Notes:

- a) The different cement types represent different product specifications, mostly according to clinker content and rate and type of additives
- b) NEN 7341 is a standardised elution test with pure water, the pH-stat test is using constant acidity with buffered solvents,
- c) The percentage shows the rate of eluted chromium during the test

### Hard coal fired power plant

In this paragraph the effects on the outputs of a hard coal fired power plant are discussed. In detail these outputs are fly ashes, gypsum from flue gas cleaning and slag. The relations of the effects of the output streams and detailed concentrations are listed in the relevant tables. The calculations are based on a ratio of 5% secondary fuels.

#### *Fly Ash of a coal fired power plant*

Fly ashes from power plants are in use as aggregates in the cement industry. Only if the toxic load of the ashes is in an accepted range, it is possible to use them further on – otherwise they must be landfilled. Generally applied specifications cannot be quoted.

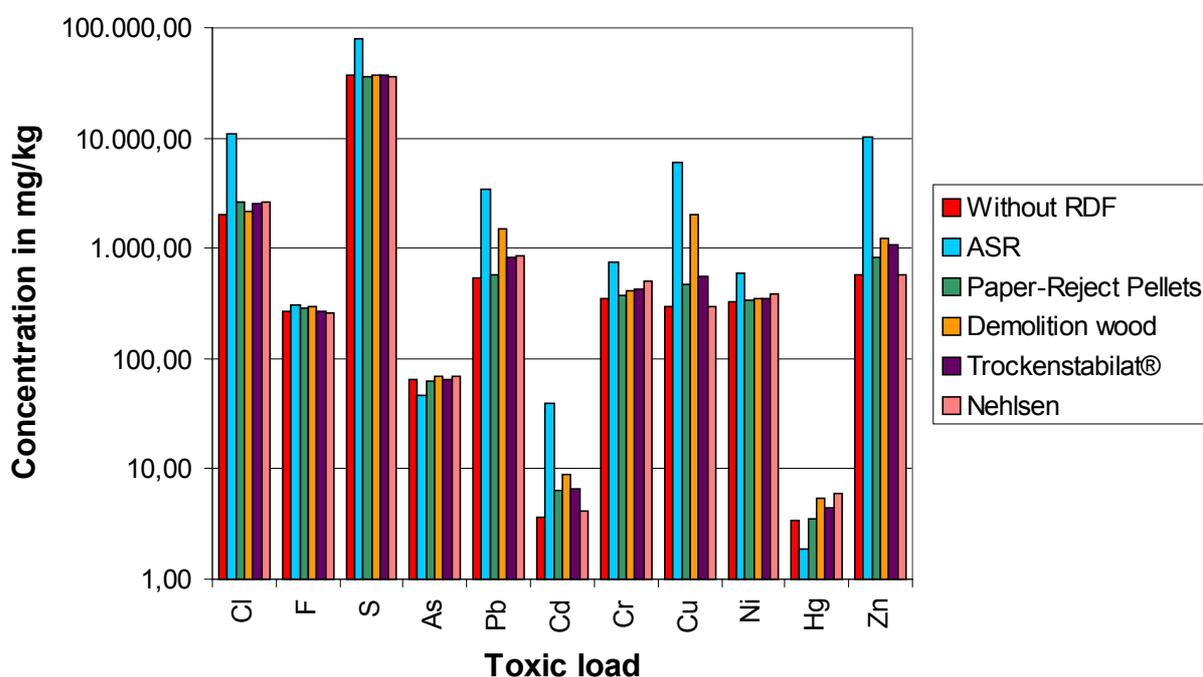
The effects on fly ash are comparable to the effects on cement clinker (Table 4.10 and Figure 4.15). Data for sulphur, copper and zinc are not specified for Nehlsen MBT-output.

Especially the co-incineration of ASR causes a strong rise of the toxic load for most elements by several orders of magnitude. For the other RDF, the impacts are limited to cadmium lead, copper and zinc concentrations.

**Table 4.10** Calculated toxic load in fly ash of a hard coal fired power plant; co-incineration ratio: 5%

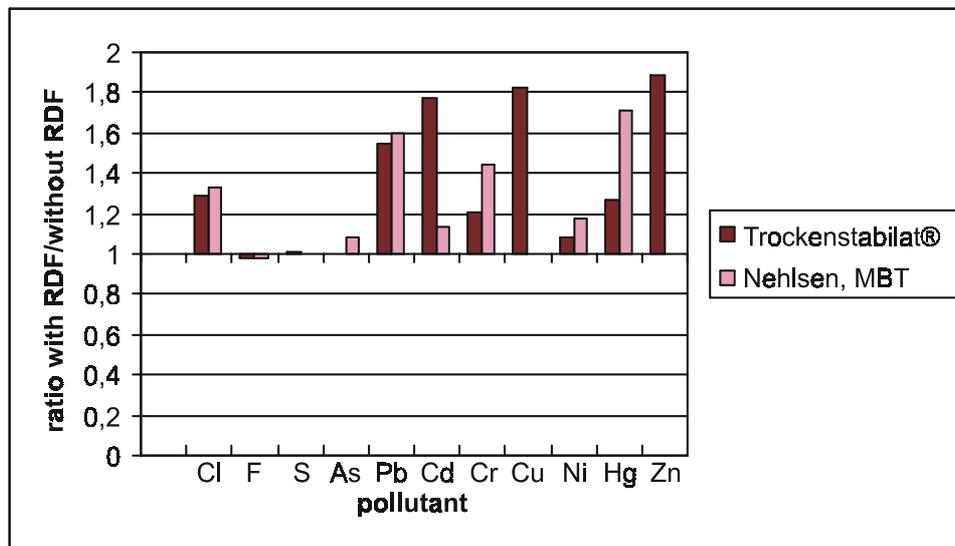
Element	Unit	Without RDF	ASR	Paper-Reject Pellets	Demolition wood	Trockenstabilat®	Nehlsen, MBT
Cl	mg/kg	2,000	11,000	2,590	2,150	2,570	2,660
F	mg/kg	269	304	285	292	264	263
S	mg/kg	36,500	78,500	36,400	37,100	36,700	(35,800)*
As	mg/kg	64.1	47.0	63.5	69.1	64.1	69.6
Pb	mg/kg	530	3,400	577	1,490	820	849
Cd	mg/kg	3.69	39.0	6.37	8.92	6.53	4.20
Cr	mg/kg	353	739	372	412	424	508
Cu	mg/kg	299	6,090	470	2,000	547	(293)*
Ni	mg/kg	329	586	333	348	355	387
Hg	mg/kg	3.45	(1.86)*	3.50	5.37	4.38	5.89
Zn	mg/kg	578	10,000	838	1,200	1,090	(566)*

\* no concentration in secondary fuel specified



**Figure 4.15** Impacts of co-incineration on the toxic load of fly ash of a hard coal fired power plant; co-incineration ratio: 5%

Figure 4.16 shows the changes of the toxic load by co-incinerating Trockenstabilat® and MBT-output (Nehlsen). Although the rate of co-combustion is only 5% the load of cadmium, copper and zinc in the total flue ash will be nearly doubled.



**Figure 4.16 Changes in the toxic load of fly ash from a hard coal fired power plant by co-incineration of MBT-output; co-incineration ratio: 5%**

#### *Gypsum and slag from coal-power station*

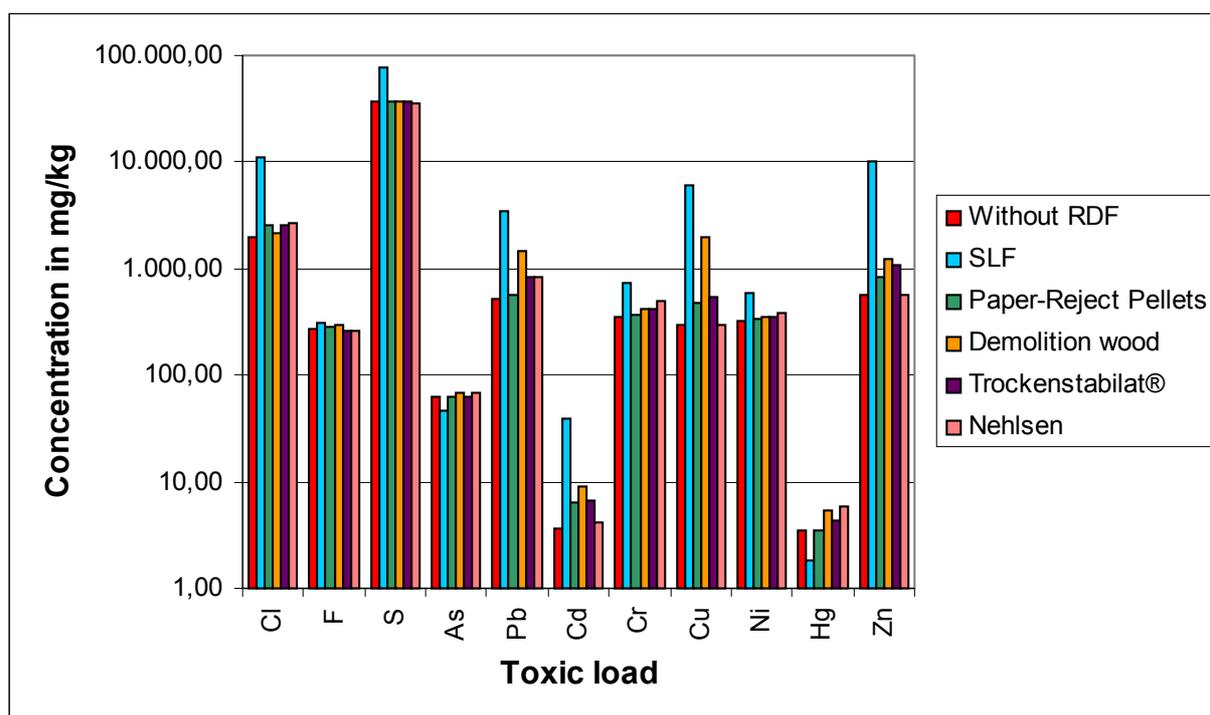
These materials are commonly used in construction industries. Gypsum from scrubbing systems replaces natural gypsum and slag is used for road building instead of gravels.

The effects of co-incinerating secondary fuels on these by-products (Table 4.11 and Figure 4.17 for gypsum and Table 4.12 and Figure 4.18 for slag) are also comparable to the effects on cement clinker or fly ash. Again the co-incineration of ASR causes a strong rise of the toxic load for most elements by several orders of magnitude. For the other RDF, the impacts are limited to cadmium lead, copper and zinc concentrations.

**Table 4.11 Gypsum from flue gas cleaning of a hard coal fired power plant**

Element	Unit	Without RDF	ASR	Paper-Reject Pellets	Demolition wood	Trockenstabilat®	Nehlsen, MBT
As	mg/kg	1.48	3.73	1.47	1.57	1.47	1.64
Pb	mg/kg	4.90	108	5.34	13.57	7.54	8.01
Cd	mg/kg	1.23	44.7	2.13	2.93	2.16	1.42
Cr	mg/kg	4.08	29.3	4.30	4.68	4.87	5.98
Cu	mg/kg	5.19	363	8.16	34.20	9.43	(5.19)*
Ni	mg/kg	1.90	11.60	1.93	1.98	2.04	2.28
Hg	mg/kg	3.85	(7.13)*	3.92	5.89	4.86	6.71
Zn	mg/kg	5.34	320	7.77	11	10	(5.34)*

\* no concentration in secondary fuel specified

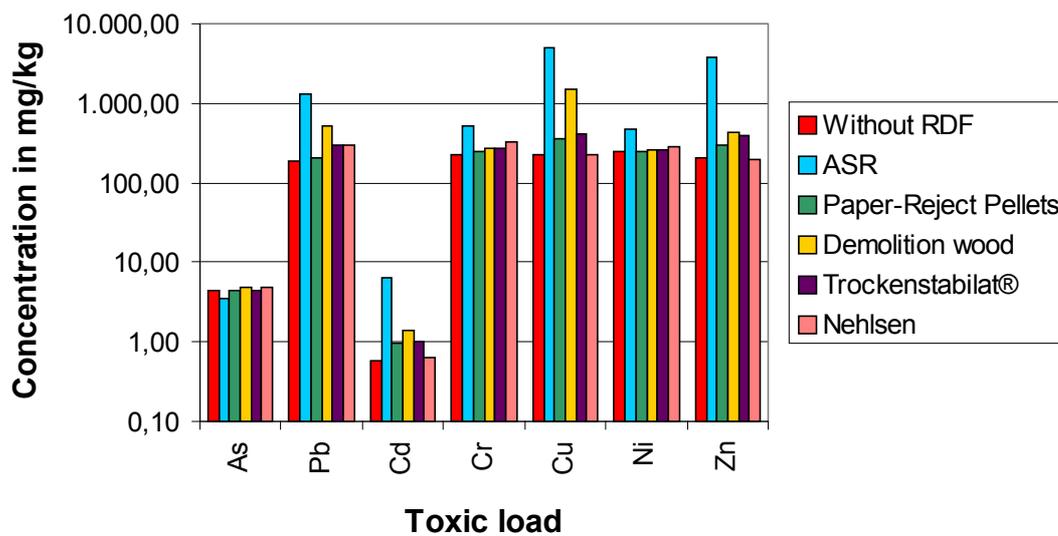


**Figure 4.17 Impacts of co-incineration on the toxic load of gypsum of a hard coal fired power plant; co-incineration ratio: 5%**

**Table 4.12 Slag of a hard coal fired power plant**

Element	Unit	Without RDF	ASR	Paper-Reject Pellets	Demolition wood	Trockenstabilat®	Nehlsen, MBT
As	mg/kg	4.46	3.49	4.41	4.82	4.46	4.83
Pb	mg/kg	188	1,290	204	530	291	301
Cd	mg/kg	0.57	6.41	0.98	1.38	1.01	0.64
Cr	mg/kg	230	514	242	269	276	331
Cu	mg/kg	227	4,930	356	1,520	415	(222)
Ni	mg/kg	245	464	248	259	264	287
Zn	mg/kg	205	3,810	297	430	386	(201)

\* no concentration in secondary fuel specified



**Figure 4.18 Impacts of co-incineration on the toxic load of slag of a hard coal fired power plant; co-incineration ratio: 5%**

## Brown coal fired power plant

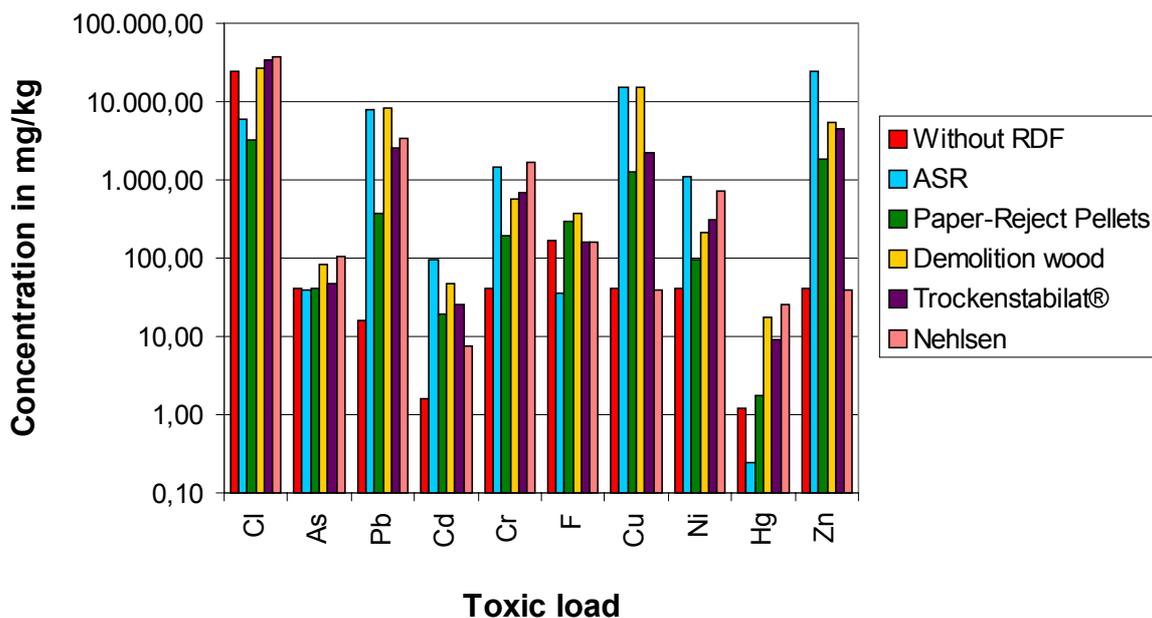
### *Fly Ash of a brown coal fired power plant*

The results for fly ashes from a brown coal fired power plant are very different to those from a hard coal fired power plant. The use of any waste derived fuel increases by several orders of magnitude the toxic load of heavy metals in fly ash compared with the conventional use of brown coal. Table 4.13 and Figure 4.19 show these results.

**Table 4.13 Calculated toxic load in fly ash of a brown coal fired power plant**

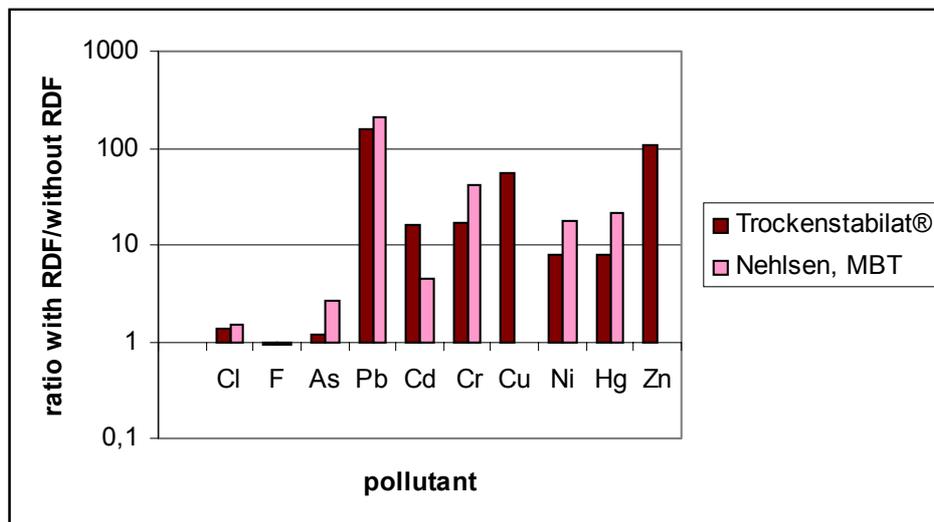
Element	Unit	Without RDF	ASR	Paper- Reject Pellets	Demolition wood	Trocken- stabilat®	Nehlsen, MBT
Cl	mg/kg	25,000	5,990	3,260	26,600	33,700	37,769
F	mg/kg	171	35.7	290	366	163	163
As	mg/kg	40.5	39.6	40	82.5	47.3	105
Pb	mg/kg	16.2	7,950	365	8,340	2,530	3,360
Cd	mg/kg	1.62	93.5	19.7	46.2	25.5	7.39
Cr	mg/kg	40.5	1,440	191	563	695	1,710
Cu	mg/kg	40.5	15,600	1,250	15,200	2,230	(39)*
Ni	mg/kg	40.5	1,080	94	211	312	708
Hg	mg/kg	1.2	(0.25)	1.76	17.3	9.27	26
Zn	mg/kg	40.5	24,900	1,840	5,500	4,410	(38.8)*

no concentration in secondary fuel specified



**Figure 4.19 Impacts of co-incineration on the toxic load of fly ash of a brown coal fired power plant; co-incineration ratio: 5%**

Even co-incineration of MBT-output increases significantly (between 10 to 100 times) the concentration of heavy metals as shown in Figure 4.20. This is a very interesting effect when it is considered that the substitution ratio is only 5% of the thermal energy.



**Figure 4.20 Changes in the toxic load of fly ash from a brown coal fired power plant by co-incineration of MBT-output; co-incineration ratio: 5%**

### Gypsum from flue gas

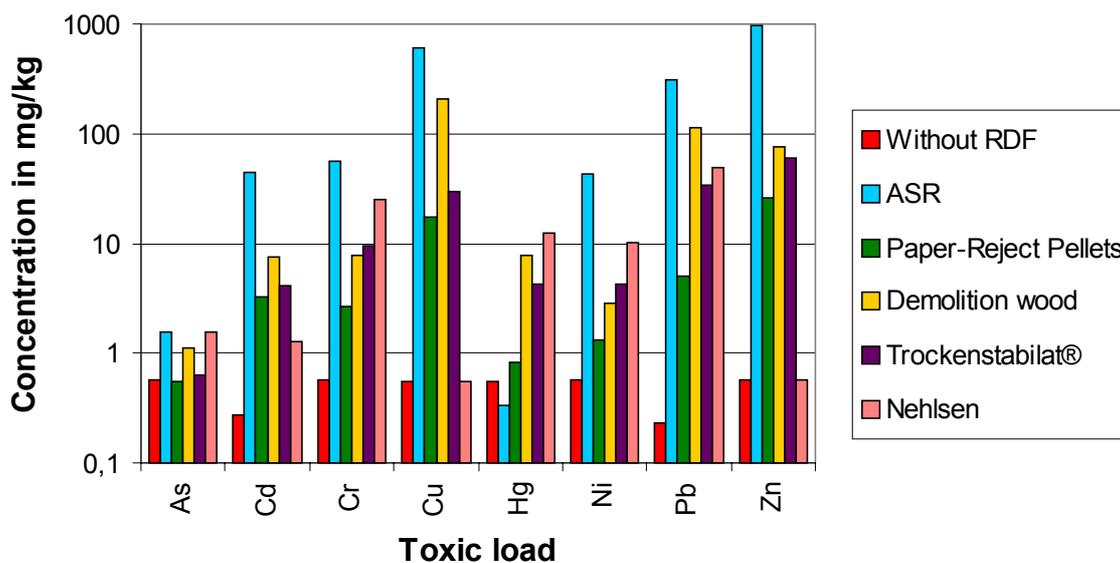
Gypsum from flue gas cleaning in brown coal fired power plants is re-used in construction industry similarly to the gypsum from coal power plants. Due to the fact that brown is less loaded with heavy metals compared to hard coal, the concentration of these pollutants in the produced gypsum is correspondingly lower. So as shown in Figure 4.21 the magnitude of the influence of waste derived fuels on the quality of the gypsum is increased. Just focussing on the RDF produced from MBT (Figure 4.22), a 10 to 100-fold augmentation on load of nearly all considered heavy metals is shown.

But the absolute level of metal content remains considerably lower in the gypsum from brown coal firing compared to hard coal firing as it is plain to see when Table 4.14 is compared with Table 4.11.

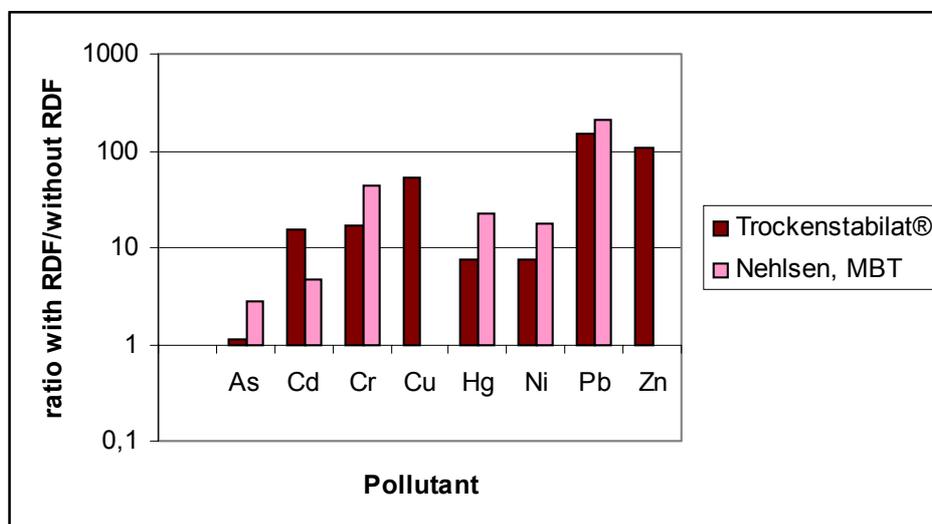
**Table 4.14** Calculated toxic load in gypsum of a brown coal fired power plant

Element	Unit	Without RDF	ASR	Paper-Reject Pellets	Demolition wood	Trocken-stabilat®	Nehlsen, MBT
As	mg/kg	0.57	1.56	0.56	1.13	0.64	1.55
Cd	mg/kg	0.27	44.1	3.31	7.58	4.17	1.29
Cr	mg/kg	0.57	56.4	2.66	7.68	9.43	24.9
Cu	mg/kg	0.56	607	17.3	206	30.1	(0.56)*
Hg	mg/kg	0.56	(0.33)*	0.82	7.91	4.2	12.6
Ni	mg/kg	0.57	42.3	1.31	2.88	4.23	10.3
Pb	mg/kg	0.23	312	5.11	114	34.4	49
Zn	mg/kg	0.57	978	25.7	75.1	60	(0.57)*

\* no concentration in secondary fuel specified



**Figure 4.21** Impacts of co-incineration on the toxic load of gypsum of a brown coal fired power plant; co-incineration ratio: 5%



**Figure 4.22** Changes in the toxic load of gypsum from a brown coal fired power plant by co-incineration of MBT-output; co-incineration ratio: 5%

## 4.8 Conclusions

The assessment of the environmental impact of the use of RDF has been undertaken by a multiple approach which comprises:

- an LCA type system analysis that considers general benefit or disadvantage of the total recovery system of RDF;
- an EIA type estimation of local impacts of the production and use of RDF; and
- an assessment of impacts on the products from the industry co-combusting RDF.

In our assessment, the calculations were based on assumptions that:

- fossil fuels and secondary fuels were of average quality to avoid distortion of the results.
- RDF production has been carried out according to a high technical standard and does not constitute essential burdens to the assessment outcome,
- All scenarios include the same RDF production process so this step does not lead to differences between the results of co-incineration and MSWI,
- Technologies chosen for RDF utilisation are based on an average to advanced high standard (in respect to BAT).
- MSW incineration plant is complying with the new waste incineration directive 2000/76 while it was not possible to guarantee compliance with these values for the cement and coal power plants as this will depend on the pollution concentration of the specific waste type used as secondary fuel and the ratio of substitution.

It is important to mention that the results of these different assessments all depend on these assumptions which may lead to very different numbers. But choosing “worst practise” as reference would not be in line with the precautionary principle.

The LCA focussed on RDF processed from municipal solid waste, especially from dry stabilisation process-Trockenstabilat and on three technical options of RFD use: brown and hard coal fired power plants, cement works compared with MSW incinerators.

The main conclusions of the LCA on the production and use of RDF are that none of the options is globally advantageous. On the one hand, due to the effective substitution of primary fossil fuels by RFD use in coal power plants and cement works, these options show a large number of ecological advantages when they are compared with the alternative combustion in a MSWI. On the other hand, this general statement has, however, to be qualified by the tendency of industrial plants to cause higher emission rates (especially of mercury) than a modern MSWI. The benefit of using RFD as fossil fuel substitute at industrial plants must be secured by adequate controls on emissions and the quality of input materials.

The simplified environmental assessment on possible negative impacts of the surroundings of a plant burning RDF leads to similar conclusions: With the given assumptions of average to advanced technologies in the EU for power generation, cement works and MSWI, and typical conditions regarding chimney stack controls and climate, no severe environmental impacts will

be observed on a local level. Nevertheless mercury at the cement works and cadmium at the brown coal-fired power plant are the weak points for the use of RDF even if they are still below a 2% threshold of air quality guidelines. Primary (regarding content of these heavy metals in RDF) and secondary (cleaning systems at the plants) measures are needed to control these potential weak points.

The most difficult part of the environmental assessment of incinerating RDF is connected with the potential impacts on the products and by-products or solid waste for recovery or disposal. Five waste derived fuels were compared with no use of RDF; Automotive Shredder Residues (ASR), paper reject pellets, demolition wood, Trockenstabilat and MBT-RDF. A preliminary estimate of the toxic load of the produced materials (e.g. cement clinker, gypsum, fly ash) shows increases in the content of contaminants, especially with ASR. There may be further environmental implications resulting from this. It is important to remember that the comparison of impact on products and by-products of the "with and without RDF" option depends a lot of the original contents of heavy metals in the fossil fuels. To compare scenarii between "with and without RDF", it will always be important to define an average fossil fuel content of heavy metals and use it for benchmarking. It can be used for direct comparison of different types of RDF or even serve as basis for the development of a material specific standard. That standard could be defined as an average content of heavy metals in a product and have the regulations specify e.g. an enrichment factor not higher than 2.



## 5. ECONOMIC ASSESSMENT

The economics of RDF are affected by a number of important factors which are reviewed below. Whilst the economic drivers may be increasingly strong and complex, they are influenced by legislation and policies for waste, climate change and energy as presented in Section 2 above.

### 5.1 Municipal Waste Management Perspective

The cost drivers moving materials through one or other channel in the wake of the Landfill Directive have to be considered in the context of the available possibilities. For simplicity, it is worth considering two cases:

**Case One:** in which the municipality concerned was already, by 1995 (the reference point for Article 5 of the Directive), capturing *a significant quantity* of biodegradable municipal waste (BMW) through source separation. In other words countries were, in 1995, there were many municipalities separately collecting bio-waste (e.g. Austria and Germany are the best examples) and where opportunities for increasing separate collection are now limited.

**Case Two:** in which the municipality concerned was, in 1995 (the reference point for Article 5 of the Directive), capturing *very little* biodegradable municipal waste through source separation (best examples are Greece, Spain, Ireland, Italy, Portugal, UK).

#### Case One

Here, to the extent that one believes opportunities for separate collection are approaching limits, the options for landfill diversion are:

1. Mass-burn incineration – unit costs  $C_i$ ;
2. Thermal treatment – unit costs  $C_t$
3. Mechanical biological treatment – unit costs (before revenues)  $C_m$  – generating outputs:
  - a.  $r$  tonnes recyclable material per tonne input, generating revenue  $R_r$  per tonne;
  - b.  $f$  tonnes of RDF per tonne input, which are assume capable of use in thermal treatment plants, incinerators and co-incineration plants;
  - c.  $g$  tonnes of residue per tonne input, in need of disposal to landfill at  $C_l$  per tonne; and
  - d.  $e$  kWh per tonne of input waste (where biodegradable treatment is through digestion) deriving revenue  $R_e$  per tonne.

For the sake of argument here, we have assumed that MBT will be the more likely mechanism for RDF preparation, though this analysis could be extended to other forms of RDF manufacture. It should be borne in mind that the different configurations of MBT imply that from a given tonne of residual waste, the costs of the treatment, and the relative partitioning of the different waste fractions can both vary.

Purely on a cost basis, the decision reduces to one of whether the costs of the MBT process are less than that of incineration or thermal treatment. In other words,

$$[C_m - (r \times R_r) + (g \times C_i) - (e \times R_e)] + (\text{net costs of treating RDF}) < C_t \text{ or } C_i \text{ (whichever is lower)}$$

Re-arranging the equation, and assuming that  $C_i < C_t$  (the assumption is not important for the results since the opposite case is easy to consider)

$$\text{net costs of treating RDF} < C_i - [C_m - (r \times R_r) + (g \times C_i) - (e \times R_e)]$$

Costs for incineration in different countries are shown in Table 5.1. Generally, the unit costs of incineration are a function of, amongst other things:

- Scale: other things being equal, these are such that significant diseconomies begin to appear at capacities below 100,000 tonnes per annum;
- Capital requirement, related to performance in terms of environmental emissions and energy generation (is the plant a CHP plant?): tighter emissions standards imply more capital investment ;
- Revenues for energy recovery: this is a significant factor in the net cost calculation for incineration. Typical energy output might be 500kWh for plant generating electricity only. For those generating thermal energy, electricity production might be lower but net energy production will be higher (almost three times higher). It is relatively common for electricity prices to be supported;
- Revenues associated with packaging recovery: some countries, notably the UK and Italy, offer support for incinerators in respect of their role in packaging recovery;
- Costs of flue gas treatment (which vary to the fact that different countries apply different standards, notably for NOx); Costs associated with treatment of ash residues: this frequently overlooked variable is an important one, varying from €3-20 per tonne of waste across depending upon the degree to which ash residues are recycled / re-used and the unit costs of disposal for remaining ash, upon the classification of the materials, requirements for pre-treatment prior to landfilling, and the regulations applicable to the use of ash in construction materials; and
- Taxes on incineration (notably in Denmark and Flanders).

Consequently costs for a plant of the same capacity can vary considerably across Europe. In countries offering revenues for all energy generated, such as Sweden, the costs are particularly low. In Germany, on the other hand, flue gas treatment is well regulated, there is little financial support for energy generation and the costs of disposing of ash residues is relatively high. Similar capacity plant may vary in the unit costs (net of revenue) by as much as €50. In between these two cases lies Denmark, with low pre-tax costs (net of energy revenues) but a high tax on incineration.

**Table 5.1 Comparative Costs of Incineration in Different Member States (Hogg *et al*, 2002)**

	Pre-tax Costs	Tax (for plant with energy recovery)	Revenues from Energy Supply (per kWh)	Costs of Ash Treatment
AU	€332 @ 60ktpa €172 @ 150ktpa €113 @ 300ktpa €97 @ 340ktpa		Electricity €0.036 Heat €0.018	Bottom ash €63/t Flue gas residues €363/t
BE	€71-75 @ 150ktpa €83 per tonne <sup>BE1</sup>	€12.7/tonne (Flanders)	Electricity €0.025	Not available
DK	€43/tonne @ 380kt	€44/tonne	Electricity €0.027	Bottom ash €34 /t Flue gas residues €34/t
FI	None		For gasification: Electricity €0.034 Heat € 0.017	
FR	€118-129 @ 18.7 ktpa €91-101 @ 37.5ktpa €86-101 @ 37.5ktpa €80-90 @ 75ktpa €67-80 @ 150ktpa		Electricity €0.023	€13-18 per tonne input
DE	€250 @ 50 ktpa and below) €105 @ 200ktpa €65 @ 600ktpa		Electricity €0.046	Bottom ash €28.1 /t Fly ash / air pollution control residues €255.6/t
GR	None		Not known	Not known
IR	€46 @ 200 kt (est)		Not known	Not known
IT	€41.3 – 93 @ 350kt (depends on revenues for energy and packaging recovery)		Electricity €0.14 (old) €0.04 (market) €0.05 (green cert.)	Bottom ash €75/t Fly ash and air pollution control residues €129/t
LUX	€97 @ 120kt		Electricity €0.025 (est)	Bottom ash €16/t input waste Flue gas residues €8/t input waste
NL	€71-110 <sup>NL1</sup>		Electricity	
PO				
SP	€34-56		Electricity €0.036	
SW	€21-53		Electricity €0.03 Heat €0.02	
UK	€86 @ 110ktpa €65 @ 220ktpa		Electricity €0.032	Bottom ash recycled (net cost to operator) Fly ash circa €100/t

Notes:

BE1 This is the average gate fee for incineration of municipal waste in Flanders. In Brussels Capital Region, 'Net Brussel', which is the operator of the SIOMAB-incineration plant, charges €62 per tonne for incineration of municipal waste originating from municipalities in the Brussels Region.

NL1 These figures are gate fees, not cost

Hence, though it is difficult to generalise, where  $C_i$  is low, the desirability of MBT will rest upon the ability to make use of RDF in a low cost manner.  $C_i$  must be low (where there are fractions to be landfilled),  $R_e$  must be high and the net costs of treating RDF must be kept to a minimum. This would be most likely where:

- The energy regime favours the use of RDF in co-incineration facilities (for example, the costs of energy are high);
- The RDF has high calorific value;
- Use of RDF requires no additional investment; and
- The RDF is homogeneous.

Where  $C_i$  is high – and this is the case in those ‘Case One’ countries where source separation is well developed - the MBT route is still more favourable. This partly reflects the fact that moderate sized composting equipment (circa 20,000 tonnes) tends to cost of the order €35-50 per tonne whereas incineration in countries where costs are high will be of the order €90 per tonne. Indeed, it may become a cheaper option even where RDF is combusted in dedicated incinerators since the mass reduction achieved and the higher calorific value of the remaining material may ‘pay for’ the separation and treatment process. Although equally, declining plant scale for such dedicated facilities might make unit costs prohibitive as, at the smaller scales required, thermal treatment technologies become as, if not more competitive.

This analysis is one which is based upon costs. Costs are not always reflected clearly in the market place for waste treatments. Market prices for waste treatments depend upon local market conditions. These ‘gate fees’ are often quite unrelated to costs. This is especially true for the case of capital intense, ‘constant throughput’ facilities such as incinerators, and also for landfill where void space is scarce and where high landfill taxes are in place. Where these have excess capacity, gate fees can fall significantly below costs (indeed, marginal costs of operation may fall close to zero). In these cases, it is entirely possible that the lowest cost treatment of RDF may be its use in an incinerator. Indeed, subject to transport costs, this might make cross-border movements of waste cost-effective. However, this might not be a viable alternative for the longer-term.

## **Case Two**

In ‘Case Two’ countries, the cost drivers in respect of residual waste treatment are the same as for ‘Case One’ countries. However, in most ‘Case Two’ countries, the costs of incineration are slightly lower. The cost factors involved are complicated by the potential for considerable improvements in respect of source separation. Indeed, for the worst performers as of 1995, depending upon waste growth rates, the Landfill Directive Article 5 targets could be met through source-separation alone.

The complications relative to the ‘Case One’ analysis are twofold:

1. The available residual waste (and therefore, the degree to which the co-incineration issue arises) depends upon the intensity with which source-separation is pursued; and
2. In order to pursue an intensive source-separation strategy, the treatment of residual waste ought to be a flexible one.

There are good reasons for proposing MBT as a more flexible solution to mass-burn incineration. Not only can the biological treatment aspect of the process be made modular (to allow switching away from treatment of mixed waste to composting of source-separated waste) but also the use of RDF in co-incineration plants removes the need to invest in capital intense, dedicated incineration (or thermal treatment) facilities.

On the other hand, some countries could apply a lax interpretation of the term 'treated' in respect of the clause concerning 'untreated municipal waste' in the Incineration Directive. If minimal treatment (such as low-level source separation) were to be considered as 'treatment', large quantities of MSW could be considered as 'treated', and thus suitable for combustion in co-generation facilities with lower emissions standards than MSW incinerators. Such an approach could easily be a cost-minimising solution to the Landfill Directive, though far from desirable from an environmental perspective.

For 'Case Two' municipalities, therefore, the potential of MBT for RDF production is double-edged. It could be used very positively in support of intensive source separation. Alternatively, it could be used to minimise the costs of compliance with Article 5 of the Directive with minimal environmental benefit, and little or no effort made in terms of source separation.

### **Key Policy Variables**

It should be noted that factors affecting decision making in this area are:

- the development of policies on source separation – where countries implement requirements for source separation, the 'cheap compliance' route is less likely to be followed. In this context, this cost drivers become similar to those for Case One countries, though Case Two countries are more likely to be in a position where substantial quantities of residual waste can under the Landfill Directive still be landfilled;
- the development of targets for recycling and 'composting', resultant practices being intimately affected by whether or not 'composting' is defined in such a way as to exclude 'mixed waste' composting - if composting is defined in such a way, as in the previous paragraph, the issues reduce to broadly the same ones affecting 'Case One' countries;
- the development of policies on climate change – if it transpires that industrial facilities are encouraged to replace fossil fuels with waste (as an energy source), at the margin, this favours RDF co-incineration at the expense of other treatments (including recycling and composting). This is true only to the extent that other policies (such as requirements for source separation / targets for recycling and composting, supported by differentiated direct charging of households for residual waste) do not seek to maximise source separation;
- the development of policies on renewable energy and energy from waste – in a similar manner to the point made previously, where energy from waste is considered as 'renewable energy', and where this is supported by State Aids (or incentive mechanisms), the tendency will be to favour, at the margin, all forms of energy from waste which fall under the support mechanisms at the expense of recycling and composting. As with the above case, this is true only to the extent that other policies (such as requirements for source separation / targets for recycling and composting, supported by differentiated direct charging of households for residual waste) do not seek to maximise source separation.

## 5.2 Co-Incineration Plant Perspective

From the perspective of a co-incineration plant, the use of RDF by a given facility may or may not be worthwhile. Let us assume that the material is technically acceptable from the perspective of the plant's operation (as opposed to limit values etc.).

- Let the cost of the waste to the plant be  $p_w$  per tonne (and this may be negative)
- Let the net calorific value of the material be  $c_w$  MJ per tonne
- Let the cost of the fuel being replaced be  $p_f$  per tonne
- Let the net calorific value of the fuel be  $c_f$  MJ per tonne

In this case, the quantity of waste used to displace one tonne of fuel (in simplistic terms) is  $(c_f/c_w)$  tonnes

The cost of this is:

$$(c_f/c_w)*p_w$$

implying a net saving of:

$$p_f - [(c_f/c_w)*p_w] \text{ per } c_f \text{ MJ generated, in terms of fuel use only}$$

Clearly, in generating this quantity of energy, it is necessary to run the plant. Suppose the running costs of the plant are  $O(f)$  when using  $(c_f/c_w)$  tonnes of waste fuel and  $O(w)$  when using  $c_f$  tonnes of waste, where  $O$  is a function relating operating costs to the nature of the fuel itself, then the total saving is:

$$\{p_f - [(c_f/c_w)*p_w]\} + [O(f) - O(w)]$$

It is clear from this that the saving increases as:

- Conventional fuel prices rise (and fuel taxes may increase in future, and Greenhouse Gas abatement measures may have a similar effect)
- The ratio  $(p_w/c_w)$  becomes smaller (or large if negative). In other words:
  1. If the price paid for the waste is negative (a gate fee is charged), the operator may, subject to other constraints, become relatively indifferent to the calorific value as long as the operating costs do not increase unduly (though clearly, the higher the calorific value, the better);
  2. If the price paid for the waste is positive, the calorific value is rather more important since net losses will occur if the lower price is not offset by calorific value.

All this suggests that from the point of view of co-incineration plants, there may be significant benefits to making use of substitute fuels. This will be especially true where the facility is able to charge a gate fee. This situation is likely to prevail where there is no strong competition (competing outlets) for the wastes being combusted and where alternative waste treatments

are non-zero in price (though the gate fee charge has to take into account what may be additional transport costs to the co-incineration facility).

### **Key Policy Variables**

Key policy variables in this context are those related to climate change and renewable energy / energy from waste. These affect the financial calculus in respect of the use of waste as a source of energy. Climate change policy may increase the benefits associated with fossil fuel displacement (on the basis that greenhouse gas emissions are displaced – see Section 4).

Renewable energy policy may affect the fate of the waste in a more complex way. If some options for co-incineration of waste were not included in Member State support schemes for renewable energy (for example, cement kilns do not produce electricity and might not fall under the scope of schemes designed to promote electricity production from renewable source), but other forms of energy from waste are, the effect would be to favour, at the margin, those energy from waste options which are included. The key point is that matters are affected by whether or not there is 'differential treatment' of different combustion / thermal treatment options for the RDF/waste under legislation designed to support renewable energy.

### **5.3 Cost Implications of Environmental Considerations**

This far, we have assumed that society is indifferent to the end-use to which the fuel is put. The problem here is that the existing regulations (such as Directive 2000/76/EC) regarding the acceptable level of emissions suggests that the public might not be so indifferent. The reasons for this have been outlined above – the limit values applicable to different plants are not the same. Hence, the movement of materials away from incineration plants and into co-incineration plants – which may be entirely rational from other points of view – may be legal, but may cause increased levels of emissions to the environment. The potentially undesirable nature of this switch does not arise out of deliberate attempts to 'evade legislation'. It arises as a consequence of the failure of legislation to ensure even-handedness in the treatment of incineration and co-incineration facilities. There are three possible solutions:

1. Prohibit the co-incineration of waste so that waste is combusted only in dedicated facilities which meet specific emissions standards for incinerators;
2. Inhibit the co-incineration of waste so that waste is combusted only in dedicated facilities which meet specific emissions standards for incinerators and those co-incineration facilities that meet those same standards;
3. Make the regulation even-handed and apply the same emission standards across all combustion facilities as far as possible. This may not be 'completely' possible given the fact that some emissions are more closely associated with the process itself rather than the nature of the material combusted. For example, regarding NO<sub>x</sub>, whilst the material affects generation of NO<sub>x</sub>, the higher temperatures and the pressure at which cement kilns operate are major determinants of NO<sub>x</sub> emissions.

Unless technical considerations make this impossible, the last of these seems the most obvious and logical solution.

The question then arises as to what might be the economic impact of these changes. There are two key actors who need to be considered: the local authority / waste management organisation; and the owner of the co-incineration facility.

### **5.3.1 Co-Incineration Facility Perspective**

For the co-incineration facility, if the requirement for investment in additional flue gas cleaning equipment arises from the use of MSW, it is clear that the co-incineration facility might take the view that use of MSW as fuel is not cost-effective. In this case, what benefits might flow from the use of MSW would not accrue.

Alternatively, it would seem quite possible that the local authority or waste management company could enter into an agreement with the co-incineration facility in which, rather than paying for a dedicated energy recovery facility, the local authority or waste management company itself makes the necessary investment (fully or in part) to enable the plant to make use of MSW whilst adhering to limit values established.

If, on the other hand, the co-incineration facilities were required to make the investment irrespective of the use of MSW (and this would seem quite reasonable from an environmental perspective) the issue would be one of the competitiveness and survival of the co-incineration facility. The incremental cost of using RDF would be zero. Greater use of RDF would probably become more of an imperative for the industry than it already is.

### **5.3.2 Municipality / Waste Management Company**

From the perspective of a municipality or waste management company, if the cement kiln is required to make the investment in order to make use of MSW as RDF, it seems likely that the cost would fall upon the municipality if the decision was taken to undertake the investment. Hence, as described above, in the absence of some sharing of investment costs, the costs to the municipality or waste management company of dealing with the RDF would be expected to increase.

If the situation were such that co-incineration facilities were required to make the investments in additional flue gas emissions control, it seems likely that more local authorities would be approached by co-incineration facilities with a view to ensuring quality RDF is available for utilisation by co-incineration facilities.

## **5.4 Market dynamics**

A recent paper by Dijkgraaf *et al* (2001) sought to model different simulations in respect of the freedom of movement of waste across borders and the impact upon gate fees for incineration. The paper, though not without its limitations (not discussed here) makes some points which are likely to hold up under further scrutiny. First of all, the significance of the 'non-contracted' incineration capacity (as opposed to total capacity) is recognised. It is this which determines the ability of waste to move from one treatment / location to another. Secondly, the modelling shows that opening borders is likely to lead to lower prices for incineration.

The paper is limited to the Dutch context but this observation seems likely to hold for all countries. Hence, the paper argues for the need for greater harmonisation in policy instruments. It is easy to see why this might occur. Looking at Table 5.1, for example,

although gate fees at Danish and Swedish incinerators are similar, Denmark applies a tax on incineration of €44 per tonne. This would imply that uncontracted waste streams would be likely to flow from Denmark to Sweden. That this is not already a major problem probably reflects the pattern of ownership of Danish incinerators. Furthermore, Denmark has been somewhat hesitant to encourage source-separation of kitchen wastes. This might reflect the perceived problem of over-capacity which would emerge in the event of such collection being introduced on a more widespread basis than currently.

Dijkgraaf *et al* (2001) make the point that: *'Although the opening of borders for all waste is attractive from a competition point of view, it results in less incentives for prevention and recycling.[...] If the environmental welfare effect is larger than the competition effect on the costs of waste treatment, national borders should not be opened [to flows of waste] from a welfare point of view.'*

This statement which, though it may be a correct observation in certain specific conditions, belies the complexity of the arguments underpinning what determines the degree to which minimisation and recycling are driven by incinerator gate fees as opposed to other policy instruments. To the extent that other policy instruments (producer responsibility, variable charging at the household level, voluntary agreements on recycling, mandatory provision of separate collection, mandates placed upon households to participate in separate collection schemes, etc.) seek to ensure that what is in residual waste is *only* residual waste, the opening of borders is less problematic. Even in this context, however, the strength of the incentives provided by variable charging and producer responsibility, at least in terms of their impact on minimization behaviour (if not recycling), may be linked to the disposal fees faced by a local authority or industry.

At the other extreme, some nations do relatively little in terms of producer responsibility and incentives for minimisation. In this context, price may be an important determinant in the movement of uncontracted waste streams. Equally, especially in those countries which are beginning the process of moving large quantities of material from landfill, price may be a significant determinant in the way in which contracts are re-structured to ensure Landfill Directive targets are met. In other words, the contracted flows will be affected by the price of treatment options also.

These comments can be extrapolated to the case under consideration in this report. They suggest that if significant quantities of material begin to flow to co-incineration facilities, so the gate fee at incinerators will fall. This will reflect increasing competition for the uncontracted streams of material. This process may already be underway in countries where the mechanical biological treatment of waste is being used to produce RDF for co-incineration. If this does occur, then other things being equal, the radius from which waste might be attracted actually increases (because the lower gate fees offset increased transportation costs).

Our research suggests that the welfare losses involved in moving waste from incineration facilities to co-incineration facilities are difficult to estimate, but that where materials are sent to cement kilns, the avoided burdens imply there may even be a net benefit. Suppose that this is taken to be the case. The focus then swings to whether or not the likely decline in gate fees at incinerators (in certain countries where significant uncontracted capacity already exists) actually acts as a disincentive to minimization, recycling and composting. Where waste treatments are driven by price alone, this is clearly likely. In situations where waste treatments are partly determined by other incentives and regulatory instruments, then to the extent this ensures that residual waste is 'genuinely residual' (i.e. that which cannot reasonably be recycled and composted), then one would have less concern for this dynamic.

Therefore, we have two extremes:

- The case where residual waste is not 'genuinely residual waste' (i.e. countries with low recycling and composting rates), in which case, lower prices for these waste treatments seem likely to entrench this low rate of recycling and composting; and
- The case where residual waste is 'genuinely residual waste' in which case, lower prices for thermal valorisation are likely to be beneficial. The situation in these countries is made more complex by virtue of the fact that the operators of incinerators which are having to reduce gate fees are often in these countries.

At the heart of this problem is the inflexibility of waste incineration facilities. There are arguments to be made for ensuring high-quality processing of waste for use as fuel, and high environmental standards for those co-incineration plants utilising the fuel, so as to enable the thermal valorisation of RDF. Where this occurs, there may well be disequilibria in local markets where plenty of capacity of incineration is already in place. In the medium- to long-term, however, one might argue that the reduction of 'fixed throughput' treatment facilities for waste enhances the prospects for the application of strong measures to encourage minimisation and recycling. Indeed, one would argue that this is a pre-requisite for allowing what may ultimately be seen as a cheaper route for non-landfill waste-to-energy.

To this extent, far from suggesting a need for harmonisation in policies on incineration (as the paper by Dijkgraaf et al suggests), on the contrary, the principal spotlight for policy development then falls upon harmonisation of policies designed to guarantee high rates of source separation and minimisation. Although higher disposal / recovery fees are one weapon in seeking to encourage minimisation, equally, variable charging (for households and commerce) and sectoral voluntary agreements (for industry) may enable progress to be made in this regard. The principle objective of policy ought not to be to ensure a guaranteed future for the operation of incinerators. This is especially true in those countries now shifting large quantities of waste away from landfill, since these should be encouraged to avoid the potential over-specification problem through developing more flexible strategies for dealing with waste.

There are strong arguments to be made for suggesting that in a successful waste management strategy, the need for residual waste treatment should be in decline, not on the increase. In countries (and within countries, in specific municipalities) where incineration is the principal treatment route for residual waste, it is the inflexibility of the incinerators which gives rise to problems. This is a well-established fact. The same comments can be applied to pyrolysis and gasification plants which are attracting much attention at present. To the extent that inflexibility is an obstacle to developing recycling and minimisation in the future (and it should be born in mind that incinerators have a typical operating lifetime of twenty years or so), such inflexibility should, to the same extent, be actively discouraged.

## **5.5 Cost information**

Information on cost for production and utilisation of waste derived fuels was not readily available for all the Member States, thus the limited data provided below (Table 5.2). These figures are to be taken with caution as there are site and country specific.

**Table 5.2 Cost of waste derived fuels production and utilisation in some Member States**

Country	RDF production	Gate fee for cement works
Belgium <sup>1</sup>	€ 50-75 per tonne of RDF-MSW	€ 100 per tonne of MSW-RDF € 0 – 446 per tonne of solvent € 74-124 for bone meals
Luxembourg	-	Free for tyres
Netherlands	-	Free for sewage sludge and PPDF but not paper sludge (NI)
Sweden	-	Free for SLF
UK	-	€ 50 – 65 per tonnes of tyres

Ref 1 De Wachter, pers comm 2001, Nizet, pers comm 2001

## 5.6 Conclusion

In summary, there are a number of factors which would seem to be favouring an increased use of RDF in co-incineration facilities. Whilst the economic drivers may be increasingly strong, they are somewhat complex. A range of cost factors influence the situation, including all of the major factors determining the costs of incineration, the costs and revenues associated with the output of MBT processes, and the market for the calorific value produced in the process itself.

Waste and energy policies interact to make this a complex and a dynamic area. Different Member States make use of different economic instruments, and there is some flexibility in the interpretation of European Directives. As such, it is difficult to make clear predictions as to what is likely to happen in future. What does seem clear, however, is that the policies being put in place are accelerating the overlapping of energy and waste policies.

In summary, the decision for a municipality or waste management company to produce RDF through MBT or to rely on MSW incineration to comply with the Landfill Directive will depend whether the costs of the MBT process are less than that of incineration or thermal treatment. Hence, though it is difficult to generalise, where cost for incineration is low, the desirability of MBT will rest upon the ability to make use of RDF in a low cost manner, e.g. if the energy regime favours the use of RDF in co-incineration facilities. For example, the costs of energy are high and/or the use of RDF requires no additional investment.

Where cost for incineration is high and where source separation is well developed, the MBT route is still more favourable. This partly reflects the fact that moderate sized composting equipment (circa 20,000 tonnes) tends to cost half the cost of incineration. Indeed, it may become a cheaper option even where RDF is combusted in dedicated incinerators since the mass reduction achieved and the higher calorific value of the remaining material may 'pay for' the separation and treatment process.

This analysis is one which is solely based upon costs, however, costs are not always reflected clearly in the market place for waste treatments and depend upon local market conditions. For example, the 'gate fees' for capital intense, 'constant throughput' facilities such as incinerators, and also for landfill where void space is scarce and where high landfill taxes are in place are often quite unrelated to costs. Where these have excess capacity, gate fees can

fall significantly below costs. In these cases, it is entirely possible that the lowest cost treatment of RDF may be its use in an incinerator.

There are additional reasons for proposing MBT as a more flexible solution to mass-burn incineration. Not only can the biological treatment aspect of the process be made modular (to allow switching away from treatment of mixed waste to composting of source-separated waste) but also the use of RDF in co-incineration plants removes the need to invest in capital intense, dedicated incineration (or thermal treatment) facilities.

The way in which markets for the calorific value of material in RDF develop is an interesting one. It is difficult to know how matters will unfold in future years. However, it seems reasonable to make some observations about the way that the overlapping markets for calorific value and waste treatments – as represented by the ‘competition’ between co-incineration, and incineration and other waste treatments – might evolve.

It is suggested that if significant quantities of material begin to flow to co-incineration facilities, so the gate fee at incinerators will fall. The degree to which this may or may not occur will be affected by existing contractual arrangements. The likely decline in gate fees at incinerators which could follow may act as a disincentive to minimisation, recycling and composting. Where waste treatments are driven by price alone, this is clearly likely. In situations where waste treatments are partly determined by other incentives and regulatory instruments, then to the extent that ensure that residual waste is ‘genuinely residual’ (i.e. that which cannot reasonably be recycled and composted), then one would have less concern for this dynamic.

## **6. ALTERNATIVES MANAGEMENT ASSESSMENT**

One argument against co-incineration of waste derived fuels is the concern that it encourages their removal from the material recovery/re-use cycle, thus going against the waste hierarchy which supports prevention/reuse above energy recovery.

This Section has focused on the assessment of alternative waste management options if RDF was not produced and used in dedicated facilities or industrial processes such as separate collection and recycling or mixed collection and landfill. This Section has also reviewed the alternative utilisation and conversion processes for RDF instead of conventional co-combustion.

### **6.1 Alternative waste management options**

#### **6.1.1 Landfilling**

##### *Environmental assessment*

A number of studies about waste management alternatives show that from a system specific point of view, landfill is the least favourable option in terms of environmental impacts and efficient use of resources (Franke et al 1992, Oeko-Institut, ITU 1994, Heyde and Kremer 1999). For each waste type, no net benefit can be obtained from the final disposal of that waste. As long as any kind of well managed recovery – ranging from recycling to energy recovery even reclamation of energy in a MSW incinerator – deliver environmental benefits, the lack of benefit from the landfill option clearly devalues the landfill alternative. In particular this type of assessment shows that high calorific value wastes are literally wasted when landfilled. Applying the landfill option for a possible RDF waste stream should only be considered for waste material for which the energy recovery might cause a high environmental impact.

##### *Policy assessment*

As previously said (section 2.3), RDF production and utilisation is viewed by some countries as way to reach their reduction targets of biodegradable materials going to landfill as required under the 1999 Landfill Directive. Mechanical biological treatment plants (MBT) could be utilised with a more specific objective of stabilising the biodegradable fraction of residual waste as a means to comply with the Landfill Directive. In such conditions, the non-biodegradable component of residual waste could be recycled, re-used or co-incinerated and the stabilised biowaste would fall out of the scope of the Article 5 targets in the Landfill Directive by virtue of the reduction in fermentability so achieved and be landfilled.

#### **6.1.2 Recycling/Source separation**

##### *Environmental assessment*

Comparing RDF utilisation to recycling alternatives is more complex. On the one hand recycling preserves the material itself. For instance this holds true for any kind of plastic material or wood products. On the other hand recycling substitutes primary or virgin material.

The environmental benefit for substituting primary material is obvious since many processes, from the extraction to the refinement of that material, can be saved by using secondary materials. If recycling preserves a material's high grade of refinement, e.g. reintroducing Polyethylene as Polyethylene into the production process, this waste management option results in a substantial overall environmental benefit. However there are waste streams with major obstacles to recycling for technical or economical reasons. Research has already started with waste oil, used solvents, plastic packaging, etc. – well-definable secondary fuels. More will be needed to increase knowledge about the borderline – waste materials characterised typically assigned to disposal ways.

### *Policy and economic assessment*

MBT and thus RDF production from MSW is also view as offering more flexibility in waste management over mass-burning incineration as it does not preclude for a growth in recycling in the future. Not only can the biological treatment aspect of the process be made modular (to allow switching away from treatment of mixed waste to composting of source-separated waste) but also the use of RDF in co-incineration plants removes the need to invest in capital intense, dedicated incineration (or thermal treatment) facilities.

However, a key concern is whether the manufacture of RDF is likely to jeopardise prospects for higher rates of recycling of materials. For example, if the waste collector is paid for the delivery of waste which can be used as fuel, and if this exceeds the material value which could be derived from material recycling, the use of material as fuel is likely to persist.

Regarding minimisation, the economic calculus is more complex, but certainly, waste minimisation may be discouraged by the development of markets for waste as a fuel. It should be noted that notwithstanding the climate change benefits of recycling, the policy instruments which are emerging in seeking to address climate change seem more heavily geared towards the use of waste for energy production than they are to the encouragement of recycling.

## **6.2 Alternative RDF utilisation processes**

Conventional combustion is well known for converting solid organic materials, including wastes, to energy and ultimately electrical power. Gasification and pyrolysis have entered the market recently and provide an alternative utilisation option for RDF. These thermal conversion processes can recover value either in the form of energy or as recyclable materials such as methanol. However, gasification and pyrolysis are not new technologies. What is new is their application in the field of municipal waste management.

Until now, the emphasis for waste combustion has generally been on energy recovery in processes for MSW and RDF, one exception being SVZ Schwarze Pumpe where RDF and other wastes are converted to electrical power and methanol. In the long term it is likely that deriving products will become increasingly attractive. However, in the near-term, recovering energy will remain the most attractive solution from an economic perspective. While recovering products may be perceived as more desirable, it will be necessary to take into account whether or not stable markets exist for those products and whether an economically attractive solution can be developed, which will probably require financial incentives to be provided by government.

A description of combustion, gasification and pyrolysis processes are given in Appendix D. The major difference between combustion and the other thermal conversion processes is that

the majority of the chemical energy inherent within the organic waste is conserved by the gasification and pyrolysis process routes whereas the chemical energy is irreversibly converted to heat energy by the combustion process.

In theory, the reasons for considering gasification and pyrolysis technologies for the treatment of residual waste are:

- compatibility with kerbside collection programmes, green waste composting and pre-sorting in a MRF (Materials Recovery Facility);
- viability at a smaller scale than mass burn incineration allowing a modular approach to recovering value from the residual fraction;
- more flexibility over energy recovery allowing the produced syngas to be converted to electricity via gas engines and gas turbines with increased efficiency;
- potential for higher value usage of the solid residues from some processes, which employ high temperature slagging within the reactor;
- in some cases, a shorter stack than would be required for a mass burn incinerator of the same capacity creating a reduced environmental impact from a planning perspective;
- the whole-life costs of a solution based on local gasification or pyrolysis plants are potentially lower than solutions based on landfill or centralised mass burn;
- possibly quicker and easier to obtain planning and authorisation consents due to the more favourable perception of these technologies;
- thermal conversion processes such as gasification and pyrolysis can recover value either in the form of energy or as recyclable materials such as methanol.

Consequently, gasification and pyrolysis provides more downstream flexibility for waste recycling by providing the opportunity to increase the level of material recycling by the production of chemicals such as methanol or the recovery of hydrogen.

It is important to note that many of these advantages would also apply to some of the modern, smaller-scale incineration processes. Indeed, the distinction between incineration and gasification is not always clear cut.

The amount of energy obtained for a given amount of waste varies significantly between specific gasification and pyrolysis processes and plays an important role in determining the overall economics of a project.

The capacity of the process also plays a part in the selection of the energy recovery option. A small sized plant (10-30ktpa) is unlikely to be economically viable for an energy efficient Integrated Gasification Combined Cycle (IGCC) system simply because the economics might not permit. The high capital costs of equipment for power generation and heat recovery, combined with the gas cleanup implications of using a gas turbine might not be offset by gate fees, the value of the recovered energy and that of "value-added" products. Conversely, the operating economics might be acceptable for a larger facility.

Turbines become a more attractive power generation option at larger sizes, usually estimated to be above 10 MWe (~75kTpa MSW), when higher efficiencies can be achieved and economies of scale become more significant. Higher efficiencies are most probably connected with the lower energy losses associated with larger turbines and the lower impact on design tolerances by contaminants in the gases from the gasification/pyrolysis stage. Below 10 MWe, the orthodox view is that gas engines are more efficient than comparable sized gas turbine. The energy efficiency of a gas turbine IGCC cycle is 47-50%, compared with 30-46% for gas engines and 20-30% for a traditional Rankine cycle steam turbine.

Fuel gas specification for gas turbines is known to be more demanding than that for gas engines; steam turbines do not come into contact with the process gases. The higher gas specification for gas turbines is due to the high air velocities, temperatures, pressures and small mechanical tolerances associated with gas turbines.

The above considerations must be taken into account when deciding on whether to build a single large-scale plant or a number of smaller facilities.

Thermal conversion processes differ in their approach to processing the char or solid inorganic residue. Some use a portion of the energy generated by the thermal conversion process to melt the inorganic materials to form a glassified slag. This glassified slag may be regarded as a recyclable material, however, there is no certainty at present as to whether this would be accepted as counting toward recycling targets rather than just being classified as “beneficial use” in the same way as ash or ferrous metals recovery from incineration.

Processes that use a high temperature pyrolysis reactor to maximise the production of syngas also produce tars, which are a complex mixture of heavy organic molecules. The tar handling strategy depends partly on how the syngas is used. Spark ignition gas engines and gas turbines require a “clean” syngas whereas boilers or thermal oxidisers can burn “dirty” syngas, destroying the tars and releasing their energy content. Clean syngas can be produced either by removing condensable tars and particulate or by cracking the tars. Removal introduces liquid handling requirements and possible disposal problems. Cracking increases the capital cost, but enables the energy content of the tars to be realised.

Gasification and pyrolysis processes are generally promoted as “greener” alternatives to incineration. Whilst in theory, there may be reasons to believe this, the failure of many facilities to function in continuous operation for extended periods of time still casts a shadow over these technologies.

Although gasification is a well proven technology which has been in use in the petrochemical industry for more than fifty years, for the processing of solid wastes this is not the case. In fact, the major negative factor about adopting gasification and pyrolysis for waste treatment is that they are less proven in operation than mass burn incineration. In some instances, the type of company supplying the technology may also be of concern, since many are relatively new with quite low capitalisation relative to the scale of projects. Process guarantees from engineering partners or finance institutions can at least partially address this issue. The inflexibility of the incinerators can also be applied to pyrolysis and gasification plants.

Juniper (2001) has identified more than eighty technologies (Table 6.1 below) utilising gasification, pyrolysis or combinations of both that are currently being developed for the treatments of solid wastes, including RDF, recovered fuels and MSW. The status of development varies from pilot to commercial scale with the majority of process only at the pilot stage and few able to claim commercial operation experience.

**Table 6.1 Main technologies and supplier for gasification and pyrolysis processes in Europe**

<b>Supplier/Process Name/Country</b>	<b>Process Type</b>	<b>Main product</b>	<b>Technology Status</b>
Compact Power/ /UK	Pyrolysis + Gasification + Combustion	Flue gas	Demonstration
Ebara/TwinRec/Japan	Gasification + Melting + Combustion	Flue gas	Commercial
Enerkem/Biosyn/Canada	Gasification	Syngas	Semi-commercial
Foster Wheeler/ /Finland	Gasification	Syngas	Commercial
Graveson/GEM/UK	Thermal gasification	Syngas	Pilot
JND/ /UK	Thermal gasification	Syngas	Design
Lurgi/BGL/Germany	Gasification (slagging)	Syngas	Demonstration
Organic Power/ /Norway	Gasification + Combustion	Flue gas	Semi-commercial
PKA/ /Germany	Pyrolysis + Gasification + Melting (optional)	Syngas	Commercial
RGR Ambiente/ /Italy	Thermal gasification + Melting	Syngas	Pilot
Serpac/Pyroflam/Belgium	Pyrolysis + Gasification + Combustion	Flue gas	Demonstration
Texaco	Gasification (slagging)	Syngas	Commercial (refinery wastes), Demonstration (mixed plastic wastes)
Thermoselect/ /Switzerland	Pyrolysis + Gasification (slagging)	Syngas	Semi-commercial
Thide/Eddith/France	Thermal gasification + Combustion	Flue gas	Demonstration
TPS/ /Sweden	Gasification	Syngas	Semi-commercial
WasteGen/Pyropleq	Thermal gasification	Syngas	Commercial

Source: Juniper 2001

Most systems that are available today are only proven at relatively modest scale, consequently a number of modules will be required when adopting these systems. Moreover, in contrast to mass burn incineration, which is optimised around large-scale single site implementation, many gasification and pyrolysis processes lend themselves to economic implementation at smaller scale. This is a significant advantage of such processes.

Table 6.2 lists European examples (operating and planned) of gasification plants processing RDF, PDF or PEF.

**Table 6.2 Gasification plants processing RDF in Europe**

<b>Plant/Location</b>	<b>Technology/Supplier</b>	<b>Status</b>
Lahti, Finland	Foster Wheeler	50MW plant operating since 1998 co-gasifying PEF with other industrial wastes
Varkaus, Finland	Foster Wheeler	40MW plant planned to gasify core board and recover aluminium
SVZ Schwarze Pumpe, Germany	Lurgi	Large scale dedicated facility using fixed bed and slagging gasifiers to co-gasify various waste derived fuels with coal to produce electricity (50MW) and methanol (120 kTpa). The plant processes pelletised RDF produced by a MBT (Mechanical Biological Treatment) plant in Dresden
Aalen, Germany	PKA	Plant operating since 1999 converting 25 kTpa 'grey bin' waste to syngas and then via gas engines to electricity
Rotterdam, Netherlands	Texaco	The PAX project has been planned for several years with the intention of gasifying 40 kTpa of mixed plastic wastes to produce syngas for use on an adjoining chemical plant. Economics and market conditions are blamed by Texaco for the delays to the project
Greve-in-Chianti, Italy	TPS	A twin CFB gasification plant operated from 1992 on RDF. The produced syngas was used by an 'over the fence' cement kiln or burnt in on-site boilers to produce steam. Due to local market conditions the plant has switched to gasifying biomass fuels

Source: Juniper 2001

An economic comparison is an essential part of any review process. However, this is not a straightforward issue on which it is easy to provide conclusions. "Real" cost data do not exist for many processes because they are at an early stage of development and, even where they do exist, the economics are very sensitive to site, local and regional factors, making direct comparison from a reference site to another specific project potentially misleading. Nevertheless, un-normalised, public domain capital cost data for individual systems can be useful as guide values. Operating costs are not generally in the public domain and are highly project-specific. Table 6.3 below provides some indicative capital cost comparisons for a number of processes.

**Table 6.3 Capital cost for alternative processes in Europe**

Supplier/Process Name/Country	Typical Feedstock	Euro/Tpa installed capacity (typical)	
		Low	High
Compact Power/ /UK	RDF, Tyres	149	324
Ebara/TwinRec/Japan	RDF, ASR	N/A	N/A
Enerkem/Biosyn/Canada	MPW	343	660
Foster Wheeler/ /Finland	Packaging waste	N/A	N/A
Graveson/GEM/UK	RDF	N/A	N/A
Lurgi/BGL/Germany	RDF + other wastes	N/A	N/A
Organic Power/ /Norway	RDF	445	445
PKA/ /Germany	RDF	712	712
RGR Ambiente/ /Italy	RDF/Carpet waste	N/A	N/A
Serpac/Pyroflam/Belgium	Packaging waste	578	578
Texaco	MPW	N/A	N/A
Thermoselect/ /Switzerland	RDF	636	781
Thide/Eddith/France	RDF	N/A	N/A
TPS/ /Sweden	RDF	N/A	N/A
WasteGen/Pyropleq	RDF, MPW	182	515

N/A = Not Available

Source: Juniper 2001



## 7. CONCLUSIONS AND RECOMMENDATIONS

The study has reviewed the current practices of production and utilisation of RDF in the fifteen Member States. It has addressed the different concerns and questions regarding the environmental impacts of co-incineration of RDF compared with dedicated incineration. The study has also tried to clarify the main political and economical drivers for the production and utilisation of RDF.

The responses to all these questions are not always straightforward as the specific local conditions (i.e. quality of fossil fuel substituted, localisation of a high energy demand industry) and policies (level of recycling of biodegradable waste, cost of incineration, support for waste energy generation, etc) will influence the market and potentially impact on RDF production and utilisation.

The main conclusions of the study are that:

- With regard to the concern that RDF encourages removal from the material recovery/re-use cycle, it can be concluded that on the contrary, Refuse Derived Fuels (RDF) from MSW can be a strategic component of an integrated waste management system to reach the recycling and reduction targets for biodegradable materials going to landfill as specified under the 1999 Landfill Directive. Sorting of biodegradable materials from MSW typically produces a residual fraction of high calorific value which can be converted in RDF.
- However, the potential for RDF production is double-edged as it could also be used to minimise the cost of compliance with Article 5 of the Directive with minimal environmental benefit and little effort made in terms of source separation if a lax interpretation of term 'treatment' in the new Waste Incineration Directive is applied.
- Market mechanisms may favour inclusion in RDF of fractions that could be recycled in favourable environmental and economic conditions. For example, competition between incineration and co-incineration facilities for calorific material may drive a decrease in gate fee for incineration plants which would act as a disincentive to minimisation, recycling and composting in situation where waste treatment are driven by price alone. However, waste treatment is usually determined by other incentives and regulatory instruments which would ensure that residual waste is genuinely residual.
- This phenomenon could increase for some types of RDF (i.e. biomass waste) as a consequence of Directive 2001/77/EC on renewable sources of energy.
- Use of RDF in industrial processes offers more flexibility than incineration as it leaves the door open for future recycling programmes as this can be made modular, it does not need to be fed with a constant amount of waste and it does not require the need to invest in capital intense dedicated incineration facilities.
- As long as any kind of well managed recovery – ranging from recycling to energy recovery even reclamation of energy in a MSW incinerator – deliver environmental benefits, the lack of benefit from the landfill option clearly devalues the landfill alternative for high calorific value wastes.

- With regard to an environmental assessment of RDF utilisation, co-incineration of RDF in coal power plants and cement works shows ecological advantages when compared with incineration in a MSW incinerator primarily due to the effective substitution of fossil fuels, as long as the plants comply with the New Waste Incineration Directive 2000/76.
- This more positive result for co-incineration, however, depends on the energy effectiveness of the incineration plants which can be nearly the same as a power plant or cement plant when MSW incineration plants deliver most of their processed energy for district heating.
- However, mercury emissions might be problematic when RDF is co-incinerated in industrial processes and special measures should be developed (permits, amending 2000/76, and/or minimum quality standards for RDF).
- Co-incineration of ASR (Automotive shredder residues) causes a definitive increase of heavy metals such as lead, cadmium, copper and zinc in cement and other by-products produced from coal power plants when compared with fossil fuels of average quality. The latest End-of-Life Directive which aims to reduce the contaminants level in vehicles should ultimately improve quality of these materials.
- These effects are even more evident when co-incineration takes place in brown coal power station compared with hard coal power station.
- There is a need to investigate further possible environmental and health consequences linked to this increase as these materials are commonly used in the construction industry and these contaminants could potentially be re-mobilised. It was not possible to assess within this study the binding conditions, bioavailability and leaching of these contaminants in these products and by-products.
- The key parameters which if changed would influence the results of the environmental impact assessment are the level of technical standard for incineration and co-incineration plants; the quality of substituted fossil fuels and the energy efficiency of the MSW incineration plants.
- The new Waste Incineration Directive while aiming to close the gap in the requirements for emission control equipment between incineration and co-incineration, has left divergence in emissions (i.e. dust, NO<sub>x</sub> and SO<sub>2</sub> emissions limit values) and has not entirely reassured environmentalists.
- There are technologies other than combustion which can convert MSW into energy sources; gasification and pyrolysis. However, the major negative aspect of using these technologies for waste treatment is that they are less proven in operation than mass burn incineration and can be just as inflexible as mass burn incineration.

## REFERENCES

Abfallbericht (2001) Bundesminister für Land- und Forstwirtschaft Umwelt und Wasserwirtschaft 2001: Bundes-Abfallwirtschaftsplan – Bundesabfallbericht 2001 Österreich, ISBN 3-902010-70-3

ADEME (2000) Agence de l'Environnement et de la Maitrise de l'Energie. Les centres collectifs d'élimination et de valorisation énergétique de déchets industriels dangereux. Ademe editions, Angers. ISBN 2-86817-559-7.

ADEME (2000b) Agence de l'Environnement et de la Maitrise de l'Energie. Recyclage et valorisation énergétique des huiles usagées. Atouts et faiblesses. Ademe editions, Angers ISBN 2-86817-496-5.

ANPA (2001) Rapporto Rifiuti by the Agenzia Nazionale per la Protezione dell'Ambiente (ANPA-ONR), Rome, 2001.

Arcadis/Ifeu (2002) Medienübergreifende Bewertung von Umweltbelastungen durch bestimmte industrielle Tätigkeiten; Research project No. 298 94 312 commissioned by the German Federal Environmental Agency, Berlin, Darmstadt, Heidelberg; public. in preparation. Veröff.

BZL GmbH (2001) Kommunikation und Projektsteuerung - Ecodumping by Energy Recovery. A report on Distortions of Environmental Standards between Disposal and Recovery and Approaches to overcome them. Report for the European Environmental Bureau (EEB).

BREF (2001) Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries. European Commission, December 2001. See European IPPC Bureau web site: [eippcb.jrc.es](http://eippcb.jrc.es).

CEC (1975) Council of the European Communities. Directive on waste (75/442/EEC). Official Journal L 194, 25 July 1975.

CEC (1985). Council of the European Communities. Directive on Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment. Official Journal L 175 , p. 40 , 5 July 1985

CEC (1988). Council of the European Communities. Directive on the limitation of emissions of certain pollutants into the air from large combustion plants (88/609/EEC). Official Journal L 336, 7 March 1988.

CEC (1989a). Council of the European Communities. Directive on the prevention of air pollution from new municipal waste incineration plants (89/369/EEC) Official Journal L 163, 14 June 1989.

CEC (1989b) Council of the European Communities. Directive on the prevention of air pollution from existing municipal waste incineration plants (89/429/EEC) Official Journal L 203, 15 July 1989.

CEC (1991) Council of the European Communities. Directive amending Directive (75/442/EEC) on waste. Official Journal L 78, 26 March 1991.

CEC (1994) Council of the European Communities. Directive on the incineration of hazardous waste (94/67/EC) Official Journal L 365, 31 December 1994.

CEC (1996) Council of the European Communities. Directive on Integrated Pollution Prevention and Control (96/61/EC). Official Journal L 257, 10 October 1996.

CEC (1999) Council of the European Communities. Council Directive on the landfill of waste (1999/31/EC). Official Journal L 182, 16 July 1999.

CEC (2000a) Council of the European Communities. Council Directive on the incineration of waste (2000/76/EC) Official Journal L 332, 28 December 2000.

CEC (2000b) Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of-life vehicles. Official Journal L269, 21 October 2000.

CEC (2001a) Council of the European Communities. Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market. Official Journal L 283, 27 October 2001.

CEC (2001b) Council of the European Communities. Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants. Official Journal L309, 21 November 2001.

CE (2001) Eco-dumping by energy recovery – Peer review of the EEB- report.

CD (2000a) Commission Decision of 3 May 2000 (2000/532/EC) replacing Decision 94/3/EC establishing a list of waste pursuant to Article 1 (a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste. Official Journal L226, 6 September 2000.

CD (2000b) Council Decision 2000/766/EC of 4 December 2000 concerning certain protection measures with regard to transmissible spongiform encephalopathies and the feeding of animal protein

CEN (2001) Draft Report from CEN TF 118 on Solid Recovered Fuels (Part 1)

CER (2001) Club Espanol de los Residuos. Cuadernos del CER N° 3 “Contribución de la industria del cemento a la gestión de residuos en Europa”, Septiembre, 2001

DETR (2000) Department of the Environment, Transport and Regions. Waste Strategy 2000 for England and Wales. Stationary Office, Norwich.

DEFRA (2002) Department for Environment Food and Rural Affairs. Digest of Environmental Statistics – Waste and Recycling. [www.defra.gov/environment/statistics/des/waste/alltext.htm](http://www.defra.gov/environment/statistics/des/waste/alltext.htm)

De Vries, R, Meijer, R et al (2000) Evaluation of the Dutch and Finnish situation of energy recovery from biomass and waste, National Technology Agency, Finland, Helsinki 2000. Technology Review 99/2000. KEMA/TEKES.

Dijkgraaf, R.F.T. Aalbers and M. Varkevisser (2001) Effects of open national borders on waste incineration: the Netherlands, Paper prepared for the 2<sup>nd</sup> Annual International Management Industry Even Waste-to-energy 2002, 22-23 January 2002, Brussels.

EA (1999a) Environment Agency. Substitute Liquid Fuels (SLF) used in cement kilns – Life Cycle Analysis (R&D Technical Report P274).

EA (1999b) Environment Agency. International use of Substitute Liquid Fuels in cement kilns – R&D Technical Report P282

EA (1999c) Environment Agency. Substitute Fuels protocol for use in cement and lime kilns, August 1999.

EA (2001a) Environment Agency (2001a) Solid Recovered Fuels in cement and lime kilns – an international perspective. R&D Technical Report P4-087/TR/1.

EA (2001b) Environment Agency (2001b) Consultation on a tyres Protocol For Use on Cement Kilns. A Supplementary Note to the Substitute Fuels Protocol..

ECR (2001) Regulation (EC) No 999/2001 of the European Parliament and of the Council of 22 May 2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies. Official Journal L147, 31 May 2001.

Entec (2000) Life Cycle Analysis of Substitute Liquid Fuels used in Cement Kilns. Entec UK Ltd For Cleanaway June 2000.

ENCI (2001). Eerste Nederlandse Cement Industrie. <http://www.enci.nl/>

ENEA (2000) Ente per le Nuove tecnologie, l'Energia e l'Ambiente. Rapporto Energia e Ambiente.

EURITS - Criteria for quality of waste for co-incineration in cement kilns (European Use for Responsible Incineration and Treatment of Special Waste). [www.eurits.org](http://www.eurits.org)

Euwid 47 (2001) Europäischer Wirtschaftsdienst. Recycling und Entsorgung. Heft 47, 20.11.2001, 11. Jahrgang.

Franke, A., Franke, B., Knappe, F. (1992) Vergleich verschiedener Verfahren der Restmüllbehandlung auf die Umwelt und die menschliche Gesundheit, ifeu-Institut für Energie- und Umweltforschung Heidelberg, im Auftrag des Umweltministeriums des Landes Baden-Württemberg, Stuttgart 1992, IFEU report.

Grech, H., Ragossnig, A., Nelles et al. (1999) Mitverbrennung heizwertreicher Abfallfraktionen in industriellen Feuerungsanlagen. ED-Schau, Schriftenreihe Abfall – Umwelt. Montanuniversität Leoben, Ausgabe 9, May.

Grech, H. (2000) Mitverbrennung von Abfällen und Reststoffen in industriellen Feuerungsanlagen. Umweltbundesamt GmbH Wien. February.

Grech, H. (2001a) Stand der Abfallbehandlung in Österreich in Hinblick auf das Jahr 2004. Umweltbundesamt GmbH Wien. Jänner 2001

Grech, H. (2001b) Bestandsaufnahme der thermischen Entsorgung von verarbeiteten tierischen Proteinen in Österreich. Umweltbundesamt GmbH Wien. September 2001

Hackl, A., Mauschwitz, G.(2001) Emissionen aus Anlagen der österreichischen Zementindustrie III. Jahresreihe 1997 – 1999. Wien, Mai 2001.

Hellberg, T. (1998), Incineration by the back door, Cement Kilns as Waste Sinks.

Heering, B.-M. (2001) Untersuchungen zur Herstellung von verwertbaren Stoffen aus Restabfall nach mechanisch-biologischer Behandlung; doctoral thesis; Rheinisch-Westfälische Technische Hochschule, Aachen, edited by Shaker , Aachen.

Heyde, M., M. Kremer (1999) Recycling and Recovery of plastics from Packagings in Domestic Waste – LCA-type Analysis of Different Strategies; LCA Documents ecomed-Verlag.

Hogg *et al* (2002) Costs for Municipal Waste Management in the EU, Final Report to DG Environment, European Commission

IFEN (2001) Institut Francais de l'Environnement. May 2001.

IMPEL (1998) IMPEL Workshop on Licensing and Enforcement Practices in Cement Plants using Alternative Fuels (11 to 13 May 1998, Austria). Final Report.

Juniper (2001) Pyrolysis & Gasification of Waste – A Worldwide Technology & Business Review, 2<sup>nd</sup> Edition, October 2001, Juniper Consultancy Services, Limited, UK

Kolshorn, K.-U., Fehrenbach, H. (2000) Ökologische Bilanzierung von Altöl-Verwertungswegen; commissioned by the German Federal Environmental Agency, UBA-Texte 20/00, Berlin, Darmstadt, Heidelberg, Arcadis, ifeu report.

Köster (2001) Mitverbrennung von Abfällen in Industrieanlagen. In: Abfall - Recycling - Altlasten No. 26, Stand und Perspektiven der Industrie- und Sonderabfallentsorgung am Beispiel bedeutender Stoffgruppen. Proceeding 14. Aachener Kolloquium Abfallwirtschaft. Published by M. Dohmann. RWTH Aachen 2001.

LAP (2001) Voor-ontwerp van het beleidskader van het Landelijk Afvalbeheersplan (LAP), Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (VROM), Direktorat Generaal Milieubeheer, Den Haag, 18. Juni 2001, VO-BK-LAP/180601

Manninen, H., Peltola, K. and Ruuskanen J. (1997) Co\_combustion of refuse-derived and packaging-derived fuels (RDF and PDF) with conventional fuels. Waste Management and Research, 15, 137-147.

MoE (2000) Ministry of Environment – Portugal - State of the Environment in 2000.

Moorman, S.A.H., Creuzen, H.J. (2000) Emissies uit bijstoken, verbranden en vergassen van niet gevaarlijke afvalstromen in vergelijking tot BLA en AVI. Centrum voor energiebesparing en schone technologie, Delft (CE-Delft). January 2000.

Oeko-Institut, ITU (1994) Systemvergleich Restabfallbehandlung; im Auftrag der HfU.

OFICEMEN (2000) Spanish Association for cement industry. Annual Report 2000.

Prognos (2001) Abfallverwertung in Industrieanlagen. Untersuchung über die energetische und stoffliche Verwertung von Abfällen in der Zementindustrie, bedeutenden Kraftwerken und der Metallindustrie. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz NRW. Düsseldorf, 2001.

RDC/KEMA (1999) Comparative study on the Environmental Performance of Co-Incineration and Specialised Incineration.

Rentz, O., Geldermann, J., Jahn, C. and Spengler, T. (1998) Vorschlag für eine medienübergreifende Bewertungsmethode zur Identifikation der "Besten Verfügbaren Techniken" BVT in der Europäischen Union; Projektbericht im Auftrag des Umweltbundesamtes, FKZ 109 05 006, Karlsruhe 1998.

RWI (1999) Klimaschutzzerklärung der deutschen Industrie unter neuen Rahmenbedingungen. Monitoring-Bericht 1999: Fortschrittsberichte der Verbände. RWI Essen

Scheurer, W. (2000) Untersuchungen zum Stand der Mitverbrennung von Klärschlamm, Hausmüll und Biomasse in Kohlekraftwerken (Schlussbericht). Institut für Verfahrenstechnik und Dampfesselwesen (IVD) der Universität Stuttgart, März 2000

Smith, A., K. Brown, S. Ogilvie, K. Rushton and J. Bates (2001) Waste Management Options and Climate Change, Final Report to the European Commission, DG Environment, July 2001

UBA (1999) Umweltbundesamt. Bewertung in Ökobilanzen. *Methode des Umweltbundesamtes zur Normierung von Wirkungsindikatoren, Ordnung (Rangbildung) von Wirkungskategorien und zur Auswertung nach ISO 14042 und 14043.* Version '99; UBA Texte 92/99

UBA (2001) Umweltbundesamt Anlagendatenbank: Umweltbundesamt GmbH, Wien, 2001.  
[http://www2.ubavie.gv.at/0972/bawp/anlagen\\_suche.pl](http://www2.ubavie.gv.at/0972/bawp/anlagen_suche.pl)

UBA (2000) Umweltbundesamt Berlin.  
[http://www.umweltbundesamt.org/dzu/4/5/2/0040\\_0.xls](http://www.umweltbundesamt.org/dzu/4/5/2/0040_0.xls)

van Ree, R., Korbee, R., de Lange, T.(2000) Biomass Cofiring Potential and Experiences in The Netherlands. Netherlands Energy Research Foundation ECN / Unit Biomass RX-00-035. November 2000.

van Ree, R., Korbee, R., Meijer, R. et al. (2001) Operational Experiences of (in)direct co-combustion in coal and gas fired power plants in Europe. RX-01-08, February 2001.

VITO (2000) Inventaristie van hoogcalorisch en selectief ingezameld afval voor thermische valorisatie

VDZ Umweltbericht (2001) Verein Deutscher Zementwerke E. V. Düsseldorf, September 2000

VKS, ASA (2000) Mechanisch-biologische Abfallbehandlung in Europa/ Verband der Kommunalen Abfallwirtschaft und Stadtreinigung (VKS) in Verbindung mit der Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung (ASA) (Hg). B. Zeschmar-Lahl et al. Blackwell Wissenschafts-Verlag, ISBN 3-8263-3261 Berlin 2000

Whitehouse, P., G. Moran, A. Gowers (2002) Development of Environmental Impact Methodology for IPPC: Setting Environmental Assessment Levels; interim report: Principles

involved in deriving criteria for the protection of the environment and human health; study by WRC commissioned by Environment Agency, Bristol, 2002.

## APPENDIX A      EC REGULATORY FRAMEWORK

### Framework Waste Directive

The Framework Waste Directive 75/442/EEC as amended by Directive 91/156/EEC aims to harmonise waste management practices across the Community by using a common definition and emphasising priorities such as waste reduction, recovery and use of clean technologies.

The Directive required the publication of a list of waste periodically reviewed. The EC Waste Catalogue (2000/532/EC) of 3 May 2000 (CD 2000) as amended has entered into force on 1 January 2002.

The Waste Framework Directive defines waste (under Article 1) in the following way:

*(a) 'waste' shall mean any substance or object in the categories set out in Annex I which the holder discards or intends or is required to discard.*

Article 2 allows some exclusions from the terms of the Directive:

*1. The following shall be excluded from the scope of this Directive:*

*(a) gaseous effluents emitted into the atmosphere;*

*(b) where they are already covered by other legislation:*

*(i) radioactive waste;*

*(ii) waste resulting from prospecting, extraction, treatment and storage of mineral resources and the working of quarries;*

*(iii) animal carcasses and the following agricultural waste: faecal matter and other natural, non-dangerous substances used in farming;*

*(iv) waste waters, with the exception of waste in liquid form;*

*(v) decommissioned explosives.*

*2. Specific rules for particular instances or supplementing those of this Directive on the management of particular categories of waste may be laid down by means of individual Directives.*

It is clear from this that the scope of the definition of waste for the purposes of the Directive is broad and includes the materials of interest to this study. Therefore, it seems fair to state that those materials of interest to this study are wastes, and do not cease to be such by virtue of their being used to generate energy.

The implications of this are that those waste materials which are to be used as fuel are subject to relevant licensing controls regarding their movement and utilization. Permitting (licensing) controls are established by Member States through their implementation of the Waste Framework Directive (WFD). Materials which are used as fuel, however, are not wastes since, being the consequences of exploration specifically for the purpose of acquiring them, they have the status of a product.

Article 9 of the WFD states that:

*1. For the purposes of implementing Articles 4, 5 and 7, any establishment or undertaking which carries out the operations specified in Annex II A must obtain a permit from the competent authority referred to in Article 6.*

*Such permit shall cover:*

- the types and quantities of waste,*
- the technical requirements,*
- the security precautions to be taken,*
- the disposal site,*
- the treatment method.*

Annex IIA includes the following, defined as disposal operations:

*D 8 Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12*

*D 9 Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)*

*D 10 Incineration on land*

*D 11 Incineration at sea*

From this, it appears that incineration is an undertaking which requires a permit. However, Article 11 states that:

*the following may be exempted from the permit requirement imposed in Article 9 or Article 10:*

- (a) establishments or undertakings carrying out their own waste disposal at the place of production; and*
- (b) establishments or undertakings **that carry out waste recovery.***

*This exemption may apply only:*

*— if the competent authorities have adopted general rules for each type of activity laying down the types and quantities of waste and the conditions under which the activity in question may be exempted from the permit requirements, and*

*— if the types or quantities of waste and methods of disposal or recovery are such that the conditions imposed in Article 4 are complied with.*

*2. The establishments or undertakings referred to in paragraph 1 shall be registered with the competent authorities.*

*3. Member States shall inform the Commission of the general rules adopted pursuant to paragraph 1.*

Recovery Activities are defined in Annex IIB, reproduced in full below. R1 implies that where waste is used 'principally as a fuel or other means to generate energy', Member States can exempt such processes from licensing. Hence, though the material being combusted may be a waste, such processes can be exempt from licensing.

## **RECOVERY OPERATIONS AS DEFINED UNDER ANNEX IIB**

*NB:* This Annex is intended to list recovery operations as they occur in practice. In accordance with Article 4 waste must be recovered without endangering human health and without the use of processes or methods likely to harm the environment.

R 1 Use principally as a fuel or other means to generate energy

R 2 Solvent reclamation/regeneration

R 3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)

R 4 Recycling/reclamation of metals and metal compounds

R 5 Recycling/reclamation of other inorganic materials

R 6 Regeneration of acids or bases

R 7 Recovery of components used for pollution abatement

R 8 Recovery of components from catalysts

R 9 Oil re-refining or other reuses of oil

R 10 Land treatment resulting in benefit to agriculture or ecological improvement

R 11 Use of wastes obtained from any of the operations numbered R 1 to R 10

R 12 Exchange of wastes for submission to any of the operations numbered R 1 to R 11

R 13 Storage of wastes pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where it is produced)

## **Incineration Directives**

Waste incineration is one of the most tightly regulated and controlled processes in the European Union. A new Directive on Incineration of Waste (2000/76/EC) has been published which will replace the existing Directives on municipal waste incineration plants (89/369/EEC and 89/429/EEC) and Directive on the incineration of hazardous waste (94/67/EC). More detailed information is given below for the earlier Hazardous Waste Incineration Directive 94/67/EC and the New Waste Incineration Directive (2000/76/EC).

### **Hazardous Waste Incineration Directive**

Directive 94/67/EC of 16 December 1994 on the incineration of hazardous waste established a permitting regime and provides for certain controls over releases on air pollutants, wastewater and residues from these processes. It includes air emission limits and a commitment to bring forward water discharge limits. New plants must comply from 31 December 1996 and existing plants from 30 June 2000. It will be replaced by the new Incineration Directive (2000/76/EC).

It excludes from its scope:

1. Combustible liquid waste including waste oils provided that:
  - The mass content of poly-aromatics hydrocarbons (PAHs) are not higher than set out in the relevant legislation;

- These wastes are not rendered hazardous by contaminants as listed in Annex II of Directive 91/689/EEC; and
  - The waste oil has a minimum calorific value of 30 MJ/kg.
2. Any combustible liquid waste which cannot cause, in the flue gas directly resulting from their combustion, emissions other than those from gas oil or higher concentrations of emissions than those resulting from the combustion of gas oil;
  3. Hazardous waste resulting from the exploitation of oil and gas resources from off-shore installations and incinerated on board;
  4. Sewage sludge from municipal waste waters which are not rendered hazardous by containing any contaminants listed in Annex I of the Hazardous Waste Directive 91/689/EC.

It does not cover:

- Incinerators of animal carcasses or remains;
- Incinerators for infectious clinical waste provided that such waste is not rendered hazardous
- Municipal waste incinerators also burning infectious clinical waste which is not mixed with other wastes which are rendered hazardous.

The air emission limits values are presented in Table A.1 below.

**Table A.1 Air emission limit values as specified in Hazardous Waste Incineration Directive**

	Daily average values (mg/m <sup>3</sup> )	Half-hourly average values	30 min – 8 hours
Total dust	10	30/10	
TOC	10	20/10	
HCl	10	60/10	
HF	1	4/2	
SO <sub>2</sub>	50	200/50	
Cd +Tl			0.05/0.1
Hg			0.05/0.1
Sb +As +Pb +Cr +Co +Cu +Mn +Ni +V			0.5/0.1
Dioxins and furans			0.1

### **New Waste Incineration Directive**

The new Directive on Incineration of Waste (2000/76/EC) covers incineration and co-incineration of waste. It aims is to prevent and/or reduce pollution caused by emissions to air, soil, surface water and groundwater from incineration and co-incineration of waste.

It introduces more stringent operational conditions and technical requirements and requires operators to install more sophisticated monitoring equipment. It introduces tighter emission limits (i.e. nitrogen oxides) and new controls on solid and liquid residues. It makes clear distinction between incineration and co-incineration plants (Table A.2).

It will apply to all incineration plants two years after adoption (i.e. 28 December 2002) and to existing plants five years after adoption (i.e. 28 December 2005).

As specified in Annex II of the Directive, the emission limit values for co-incineration are calculated using the mixing rules (see formula below) except for cement and combustion plants which have specific standards to bring these facilities in line with modern waste incinerators, although these facilities have been granted later deadlines of 2007, 2008 or 2010 depending on the pollutant. This harmonisation of standards will address concerns of waste incinerator operators over competitive advantage albeit on a slightly prolonged time-scale.

It covers a wider scope but it excludes from its scope plants that incinerate only the following types of waste which fall under other EU regulations (i.e. the large combustion plant Directives):

1. Vegetable waste from agriculture and forestry;
2. Vegetable waste from the food processing industry, if the heat generated is recovered;
3. Fibrous vegetable waste from virgin pulp production and from paper production from pulp if it is co-incinerated at the place of production and the heat generated is recovered;
4. Wood wastes with the exception of wood waste which may contain halogenated organic compounds or heavy metals as a result of treatment with wood-preservatives or coating and includes in particular such wood waste originating from construction and demolition waste
5. Cork waste;
6. Radioactive waste;
7. Animal carcasses as regulated by Directive 90/667/EEC without prejudice to its future;
8. Waste resulting from the exploration for, and the exploitation of, oil and gas resources from off-shore installations and incinerated on board the installation.

It also excludes from its scope experimental plants used for research, development and testing which treat less than 50 tonnes of waste per year.

The pre-amble to the Directive clearly recognises both of these as desirable. There, it is stated that:

*'The distinction between hazardous and non-hazardous waste is based principally on the properties of waste prior to incineration or co-incineration but not on differences in emissions. The same emission limit values should apply to the incineration or co-incineration of hazardous and non-hazardous waste but different techniques and conditions of incineration or co-incineration and different monitoring measures upon reception of waste should be retained.[...]*

*The co-incineration of waste in plants not primarily intended to incinerate waste should not be allowed to cause higher emissions of polluting substances in that part of the exhaust gas volume resulting from such co-incineration than those permitted for dedicated incineration plants and should therefore be subject to appropriate limitations'.*

In this context, co-incineration is defined as:

*'co-incineration plant' means any stationary or mobile plant whose main purpose is the generation of energy or production of material products and:*

*—which uses wastes as a regular or additional fuel; or*

*—in which waste is thermally treated for the purpose of disposal.*

*If co-incineration takes place in such a way that the main purpose of the plant is not the generation of energy or production of material products but rather the thermal treatment of waste, the plant shall be regarded as an incineration plant within the meaning of point 4'.*

Annex II – determination of air emission limit values for the co-incineration of waste:

$C = (V_w \times C_w + V_{proc} \times C_{proc}) / (V_w + V_{proc})$  with

C = total emission limit value for CO and the relevant pollutants

V<sub>w</sub> = exhaust gas volume resulting from the incineration of waste with lowest CV

C<sub>w</sub> = emission limit values set for incineration (see Annex V) for relevant pollutants and carbon monoxide

V<sub>proc</sub> = exhaust gas volume resulting from the combustion of authorised fuels (excluding waste)

C<sub>proc</sub> = emission limit values for industrial processes.

**Table A.2 Air emission limit values for incineration and co-incineration of waste under Directive 2000/76/EC**

	Total emission limit values			
	Incinerators	Cement Kilns	Combustion plants	Other processes
Total dust*	10	30	See C proc	
TOC*	10	10	See C proc	
HCl*	10	10	See C proc	
HF*	1*	1	See C proc	
SO <sub>2</sub> *	50	50	See C proc	
NO <sub>x</sub> for existing plants*	400	800	See C proc	
NO <sub>x</sub> for new plants *	200	500 <sup>(1)</sup>	See C proc	
Cd +Tl**	0.05	0.05	0.05	0.05
Hg **	0.05	0.05	0.05	0.05
Sb +As +Pb +Cr +Co +Cu +Mn +Ni +V **	0.5	0.5	0.5	
Dioxins and furans***	0.1	0.1	0.1	0.1

Notes:

All units are in mg/m<sup>3</sup> except dioxins and furans in ng/m<sup>3</sup>

\* daily average

\*\* average values over a sample period of a minimum of 30 min and a maximum of 8 hours

\*\*\* average values over a sample period of a minimum of 6 hours and a maximum of 8 hours

**Incinerators:**

Exemptions for NO<sub>x</sub> may be authorised by the competent authority for existing incineration plants:

—with a nominal capacity of 6 tonnes per hour, provided that the permit foresees the daily average values do not exceed 500 mg/m<sup>3</sup> and this until 1 January 2008,  
 —with a nominal capacity of >6 tonnes per hour but equal or less than 16 tonnes per hour, provided the permit foresees the daily average values do not exceed 400 mg/m<sup>3</sup> and this until 1 January 2010,  
 —with a nominal capacity of >16 tonnes per hour and which do not produce water discharges, provided that the permit foresees the daily average values do not exceed 400 mg/m<sup>3</sup> and this until 1 January 2008.  
 Until 1 January 2008, exemptions for dust may be authorised by the competent authority for existing incinerating plants, provided that the permit foresees the daily average values do not exceed 20 mg/m<sup>3</sup>.

**Cement kilns:**

(1) For the implementation of the NO<sub>x</sub> emission limit values, cement kilns which are in operation and have a permit in accordance with existing Community legislation and which start co-incinerating waste after the date mentioned in Article 20(3) are not to be regarded as new plants.

Until 1 January 2008, exemptions for NO<sub>x</sub> may be authorised by the competent authorities for existing wet process cement kilns or cement kilns which burn less than three tonnes of waste per hour, provided that the permit foresees a total emission limit value for NO<sub>x</sub> of not more than 1200 mg/m<sup>3</sup>.

Until 1 January 2008, exemptions for dust may be authorised by the competent authority for cement kilns which burn less than three tonnes of waste per hour, provided that the permit foresees a total emission limit value of not more than 50 mg/m<sup>3</sup>.

Exemption might be authorised by competent authority in cases where TOC and SO<sub>2</sub> do not result from the incineration of waste.

**Table A.3 Emission limit values (C proc.) for co-incineration of waste in combustion plants under Directive 2000/76/EC**

	Solid fuels				Biomass				Liquid fuels			
	<50 MWth	50-100 MWth	100 to 300 MWth	>300 MWth	<50 MWth	50-100 MWth	100 to 300 MWth	>300 MWth	<50 MWth	50-100 MWth	100 to 300 MWth	>300 MWth
Total dust	50	50	30	30	50	50	30	30	50	50	30	30
HCl												
HF												
NO <sub>x</sub> for existing plants		400	300	200		350	300	300		400	300	200
NO <sub>x</sub> for new plants												
Cd +Tl												
Hg												
Sb +As +Pb +Cr +Co +Cu +Mn +Ni +V												
Dioxins and furans												
SO <sub>2</sub>		850	850 to 200 (linear decrease from 100 to 300 MWth)	200		200	200	200		850	850 to 200 (linear decrease from 100 to 300 MWth)	200

**Notes:**

All units are in mg/m<sup>3</sup> except dioxins and furans in ng/m<sup>3</sup>

**Solid fuel:**

Until 1 January 2008, exemptions for NO<sub>x</sub> and SO<sub>2</sub> may be authorised by the competent authorities for existing co-incineration plants between 100 and 300 MWth using fluidised bed technology and burning solid fuels provided that the permit foresees a C proc value of not more than 350 mg/Nm<sup>3</sup> for NO<sub>x</sub> and not more than 850 to 400 mg/Nm<sup>3</sup> (linear decrease from 100 to 300 MWth) for SO<sub>2</sub>.

**Biomass:**

Until 1 January 2008, exemptions for NO<sub>x</sub> may be authorised by the competent authorities for existing co-incineration plants between 100 and 300 MWth using fluidised bed technology and burning biomass provided that the permit foresees a C proc value of not more than 350 mg/Nm<sup>3</sup>



## APPENDIX B COUNTRY OVERVIEW

The detailed overview presented below cover the fifteen Member States. Table B.1 presents the relevant national and international organisations contacted by mail, phone or e-mail and visited whenever possible to collect information on RDF and other waste derived fuels in the fifteen European Member States. The information reported below has also been gathered from previous studies carried out by the European Commission and different National organisations.

Country	Contacts/organisations
Austria	Montan - University of Leoben – Mr Tesch Technical University of Vienna Environmental Agency in Vienna – Mr Grech GUA – Gesellschaft für umfassende Analysen – Mr Frühwirth Verband Österreichischer Ziegelwerke – Mr Koch
Belgium	
Brussels Region	IBGE (Brussels Institute for the Environment)
Flemish Region	OVAM (Flemish Waste Agency) – Mrs Aneleen de Wachter BBLV (Environmental NGO organisation) – Mr Bart Martens INDAVER (Waste Incinerator plant) – Mr Guido Wauters
Walloon Region	Office Wallon des Déchets – Mr Jean-Yves Mercier SCORIBEL (Secondary fuels producer for cement industry) – Mr Baudoin Nizet
Denmark	Arhus County (Natur og Miljø) – Mrs Ulla Seerup
Finland	VTT Energy - Mr Juhani Juvonen District Heating Plants
France	ADEME (French Agency for Environment and Energy) – Mr Christian Militon, Mr Philippe Bajeat and Mr Andre Kunegel Ministry of Environment – Pollution and Risk Prevention Department, Waste and Products Division – Mrs Francine Bertier
Germany	Bundesverband der deutschen Ziegelindustrie - Mr Müller TBU -Technisches Büro für Umweltschutz – Mr Steiner Institut für Dampfkesselwesen, Universität Stuttgart, Mr Scheurer
Greece	Ministry of Environment
Ireland	EPA
Italy	ENEA – Mr de Stephanis Federambiente – Mr Caggiano AITEC – Mr Burattini Pirelli – Mr Luca Zucchelli Scuola Agraria del Parco di Monza – Mr Enzo Favoino

<b>Country</b>	<b>Contacts/organisations</b>
Luxembourg	Ministry of Environment – Waste division (Administration de l'Environnement – Division Déchets)
Netherlands	ENCI CE-Deflt – Mr Croezen KEMA Nederland – Mr Lamers Essent – Mr Van Tubergen
Portugal	INR – Instituto Nacional dos Resíduos
Spain	CER – Club Español de los Resíduos Oficemen- Spanish Federation of Cement Industry
Sweden	RVF (Swedish Association of Waste Management ) SVEBIO (Swedish Bioenergy Association)
United Kingdom	Environment Agency – Mrs Sue Halshaw British Cement Association – Mr John Campbell Blue Circle – cement kiln operator – Mr Martin Gossage and Colin Booth IWS - Isle of Wight RDF plant operator – Mr John Hammond Contract Heat and Power – Mr Andrew Shire and Alan Tweedale Slough Heat and Power – Dr Andrew Ellis Reprotech – Mr David Watts
EEA-W	European Environment Agency Topic Centre on Waste
ASSURE	Association for the sustainable use and recovery of resources in Europe – Mrs Silvia Vaghi
FEAD	European Federation for Waste Activities (Fédération Européenne des Activités des Déchets)
EURITS	European Association of Waste Thermal Treatment Companies for Specialised Waste - Mr Guido Wauters
CEN-Bureau	European Association of cement industry – Mr Lars Hyorth

## AUSTRIA

### Policy and legislation framework

The fundamental piece of waste legislation is the 1990 “*Abfallwirtschaftsgesetz- AWG*” , the Waste Management Act. There are separate regulations for mechanical biological treatment plant and for co-incineration of waste and waste derived fuels.

The planning, construction and operation of a mechanical biological treatment plant is regulated by the Austrian Waste Management Act and its executive orders, the environmental impact assessment Law (*UVP-Gesetz*) and the landfill Law (*Deponieverordnung*). The output quality of MBT is standardised under ÖNORM S2202 ‘*Gütekriterien für Müllkompost*’ (1984) and ÖNORM S2024 ‘*Anwendungsrichtlinien für Müllkompost*’. Technical guidance for MBT operation is in preparation.

The co-incineration of waste and RDF is regulated under two decrees from two different ministries:

- Decree by the Ministry of Environment, Youth and Family on Incineration of Hazardous Waste “*Verordnung über die Verbrennung von gefährlichen Abfällen*”(1999); and
- Decree by the Ministry of Economics on Incineration of Hazardous Waste “*Verordnung über die Verbrennung von gefährlichen Abfällen in gewerblichen Betriebsanlagen*”.

Emissions are regulated under “*Immissionsschutzgesetz-Luft, IG-L*” and “*Luftreinhaltegesetz für Kesselanlagen – LRG-K*”. Emission limits for co-incineration plants other than cement kilns is determined by the ‘mixing rule’. For cement kilns, the mixing rule does not apply and stringent limit values have been specified. The cement industry is the largest sector relying on co-incineration and therefore it was considered appropriate to set stringent limits (EA 2001a). The emission limits (Table B.1) and monitoring requirements stipulated in the Incineration Decree have to be met by new plants from February 1999 and by existing plants from 1 July 2000.

**Table B.1 Emission limit value for cement plant co-incinerating waste in Austria (Incineration Decree 1999, as reported by EA 2001a)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	34	Daily and half hourly average	C
TOC	50 (10 by 2002)	Hourly average	C
HCl	10	Daily and half hourly average	C
HF	0.7	Daily and half hourly average	C
SO <sub>2</sub>	140 400 if sulphur rich raw material	Daily and half hourly average	C
NO <sub>2</sub>	500 new plant	Daily and half	C

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
	800 (500 by 2007) existing plant	hourly average	
Cd, Tl	0.05	30 min to 8 hour average	S
Hg	0.05	30 min to 8 hour average	S
Other metals <sup>3</sup>	0.5	30 min to 8 hour average	S
Dioxins (ng/m <sup>3</sup> TEQ)	0.1	6 to 8 hour average	S
CO			C

Notes:

- 1 reference conditions – 10 % oxygen, 0°C, 1013 mbar, dry, with subtraction of effluent gas volume not related to process
- 2 C – continuous, S - spot
- 3 Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Zn

### Production of waste derived fuels

In Austria, MSW arisings total 3.1 million tonnes per annum (tpa) (Abfallbericht 2001). Around 45% of MSW is recycled, 40% is landfilled, and 15% is incinerated in 3 incinerators with energy recovery (UBA Abfalldatenbank 2001). MSW is processed/treated in 526 composting plants with a total capacity of 1.1 million tpa (Abfallbericht 2001) and in 10 mechanical-biological treatment plants. In 2000, the capacity of the existing MBT plants was about 340,000 tpa of input waste. Two additional plants are in construction which will bring the total capacity of MBT in Austria to 400,000 tpa

Some of the 10 mechanical-biological treatment plants (MBT) are producing a high calorific waste fraction. The production of a high CV fraction is not necessarily the main objective of these plants, nevertheless, in 2000 more than 70,000 tpa of RDF were produced from these plants (Abfallbericht 2001), representing 23% of recovery. These plants process mainly MSW but also sewage sludge, bulky waste and commercial waste (Table B.2).

**Table B.2 Mechanical Biological Treatment plants in Austria, 2000 (Grech 2001a)**

<b>Location</b>	<b>Input</b>	<b>Capacity (tpa)</b>
Aisch-Assach	Biowaste, sewage sludge, commercial waste	7,000
Allerheiligen	MSW, sewage sludge	17,100
Fischamend	MSW, sewage sludge	30,000
Frojach-Katsch	MSW, sewage sludge, waste wood	15,000
Herzogsdorf	MSW, commercial biowaste	15,000
Inzersdorf	MSW, sewage sludge	9,000
Kufstein	MSW, bulky waste, waste wood	10,000
Oberpullendorf	MSW, sewage sludge, commercial waste	45,000
Ort im Innkreis	MSW	20,000
Siggerwiesen	MSW, sewage sludge, commercial waste	150,000
Zell am See	MSW, sewage sludge, bulky waste	23,000
<b>Total</b>		<b>341,000</b>

### **Utilisation of waste derived fuels**

In Austria there are around 180 industrial facilities which co-incinerate more than 1.8 million tpa of secondary fuels and/or RDF (Table B.3). A wide range of waste is used in Austria as secondary fuel in non-waste specific plants. The practice of co-combustion of RDF and similar waste streams in Austria is well documented apart for the quantities of waste co-incinerated in-house by industries (which are referred to as 'not publicly available' in Table B3 below) and for which there is no statutory requirement to report on quantities.

The most important industries for co-incineration of wastes are the pulp and paper industry and the wood industry, followed by the saw-mill industry. However, these industries mainly co-incinerate their own production residues such as waste wood, paper sludge, bark or spent liquor.

The cement industry is another important user of secondary fuels such as oil, solvents, paper rejects, tyres, plastics, petrol-coke. The brick, power, metallurgy and chemical industries as well as some smaller plants such as sewage sludge dryers and battery treatment plants also co-incinerate what is believed to be small quantities of secondary fuels. There is no use of secondary fuels in blast furnaces in Austria (Frühwirth pers comm. 2001, Grech 2000).

**Table B.3 Co-incineration of secondary fuels in Austria**

<b>Installations</b>	<b>Number of plants<sup>1</sup></b>	<b>Quantity# (x10<sup>3</sup> tpa)<sup>2</sup></b>
Pulp and paper mill	7	906
Wood and saw industry	4	750
Cement kiln	10	122
Power plant	7	NI
Used oil combustion	3	NI
Metallurgy and chemical industry	s3	NI
Sewage sludge dryer	3	NI
Brick industry	2	NI
Battery treatment plant	1	NI
Steel furnace	0	0
Other	5	33
Not publicly available*	135	NI
<b>Total</b>	<b>177</b>	<b>&gt;1,811</b>

References:

- 1 UBA 2001
- 2 Grech 2000

Notes:

- # Data reported for 1998
- \* Industrial plants co-incinerating their own production residues
- NI No information available

Paper industry

The pulp and paper industry is reported to substitute up to 99% of its energy demand by secondary fuels. There are seven plants in Austria reported to co-incinerate secondary fuels (Table B.4). In 1998, around 900,000 t of secondary fuels were co-incinerated by the paper industry. However, the majority of wastes co-incinerated by the paper industry are in-house residues from pulp and paper process such as bark, paper sludge, waste wood and spent liquor (Table B.5) which fall outside the scope of this study (i.e. not traded).

**Table B.4 Co-combustion capacity in the pulp and paper industry in Austria (UBA 2001)**

Name of the plant	Location	Capacity of co-combustion (tpa)
Wirbelschichtfeuerung Hamburger AG	Pitten	not specified
Wirbelschichtfeuerung EEVG	Laakirchen	280,000
Wirbelschichtfeuerung RVL (Reststoffverwertung Lenzing)	Lenzing	150,000
Wirbelschichtanlage Norske Skog	Bruck an der Mur	76,000
Wirbelschichtfeuerung Patria AG -- Frantschach	Frantschach-Sankt Gertraud	10,000
Sappi Austria AG	Gratkorn	not specified
Papierfabrik Kematen	Kematen	not specified
<b>Total</b>		<b>&gt;500,000</b>

**Table B.5 In-house secondary fuels co-incinerated in Austrian pulp and paper industry, 1998 (Grech 2000)**

Secondary fuel	Quantity on fresh matter basis (x10 <sup>3</sup> tpa)	Quantity on a dry matter basis (x10 <sup>3</sup> tpa)
Bark	438	200
Paper sludge	199	103
Sewage sludge	206	70
Waste wood	30	24
Spent liquor	2,676	
<b>Total</b>		<b>397</b>

### Cement industry

There are 12 cement plants operating in Austria; nine plants (one of which has two kilns) produce and grind their own clinker and three plants only grind clinker. The use of wet kilns in Austria was discontinued in the 1980s (EA 2001). All of the nine plants currently producing clinker are authorised to use secondary fuels (Table B.6) with a total capacity of about 180,000 tpa (UBA 2001).

**Table B.6 Co-combustion capacity in the cement industry in Austria (UBA 2001)**

<b>Plant</b>	<b>Location</b>	<b>Capacity (tpa)</b>
Zementwerk Gmunden (1)	Gmunden	28,600
Zementwerk Gmunden (2)	Gmunden	25,000
Kirchdorfer Zementwerk – Zementofen II	Kirchdorf an der Krems	22,000
Zementwerk Leube GmbH	Grödig	19,800
Zementwerk Peggau	Peggau	10,000
Zementwerk Schretter & Cie	Vils	5,400
Zementwerk Wietersdorf	Klein Sankt Paul	19,500
Zementwerk Lafarge Perlmooser	Mannersdorf	10,000
Zementwerk Lafarge Perlmooser	Retznei	16,000
Zementwerk Wopfinger Baustoffindustrie GmbH	Waldegg	23,200
<b>Total</b>		<b>179,500</b>

In the cement industry “classical” secondary fuels are used like tyres, used oil, pet coke, plastics and rejects of the paper industry. Tyres have been used in Austrian cement kilns since 1980. About 50% of the 45,000 tpa of waste tyres produced in Austria are used by four cement kilns. Liquid fuels - waste oils and solvents - are used in 2 plants; Gmunden and Peggau. Plastics are used in five cement plants. At the Wietersdorf plant, plastic wastes are prepared on site whereas the other plants received pre-processed plastics (EA 2001a). Paper fibre residues are used in two cement plants; the Wopfing plant co-incinerated 25,000 tpa from Germany and the Wietersdorf kiln used 15,000 tpa of plastics and paper as secondary fuels.

More recently seven cement plants were also authorised to co-incinerate meat and bone meal (Hackl and Mauschitz 2001; Grech 2001b). There is also a tendency to co-incinerate RDF, the high calorific fraction of mechanical-biological treatment plants. The fuel consumption for the Austrian cement industry is presented in Table B.7. In 1999, the total quantities of secondary fuels co-incinerated by the cement industry in Austria amounted to 134,500 tpa compared with 110,750 tpa in 1998, representing about 41 % substitution of total energy input.

#### Brick industry

The brick industry is reported to co-incinerate wastes in two plants. The industry however argues that they are using waste as pore agents not as fuel substitutes and thus that it should not be considered as energy recovery but as material recycling. The type of wastes used as pore agents are mainly sawdust (>50%), straw, fibres from paper production (<10%) and recycled Polystyrol. There are no reported data on quantities but use is estimated to be limited.

**Table B.7 Fuel consumption in the cement industry in Austria**

Fuel	Fuel consumption in 1998 <sup>1</sup>		Secondary fuel consumption in 1999 <sup>2</sup>	
	Quantity (tpa)	Energy (x10 <sup>3</sup> Gjpa)	Quantity (tpa)	Energy (x10 <sup>3</sup> Gjpa)
<b>Conventional fuel:</b>				
Coal	151,716	4,573	NI	
Fuel oil	49,720	1,955	NI	
Natural gas	6,520	239	NI	
Petroleum coke	11,618	401	24,021	815
<b>Secondary fuel:</b>				
Used tyres	22,462	612	26,949	735
Plastics	21,989	630	25,128	700
Waste oil and solvent	35,126	1,265	26,607/7530	1001/200
Paper fibre residue	27,000	95	37,927	118
Other	4,171	74	10,339	124
<b>Total secondary fuel</b>	<b>110,748</b>	<b>2,676</b>	<b>134,480</b>	<b>2,877</b>
<b>Total</b>	<b>330,322</b>	<b>9,843</b>		

Ref:

1 EA 2001

2 Hackl and Mauschitz 2001

#### Power industry

The situation of co-combustion in Austrian power plants is a little different from that in other countries. In Austria, a large proportion of energy is produced by hydroelectric power plants. Only a few coal-fired plants produce electricity and some – mainly operating in wintertime – produce heat and power. The use of waste in these facilities is not very common because of a legal uncertainty and because of the changes in the energy market. Only two power plants in Austria (Voitsberg and St. Andrä) are using a wide spectrum of waste while the other plants are only using wastes like meat and bone meal, molasses or wood. No quantities for secondary fuel consumption were provided.

#### Other industries

There is no utilisation of waste derived fuels in blast furnaces in Austria (Frühwirth, perso comm 2001; Grech 2000).

## **BELGIUM**

In Belgium, RDF production and use are only practised in two of the Belgian Regions; the Flemish and Walloon Regions.

### **Regulatory framework**

#### Flemish Region

The policy of the Flemish Waste Agency, OVAM (de Wachter, OVAM, *pers. comm.* 2001) is to impose standards on emissions from plants using RDF and/or secondary fuels that are as stringent as the standards for waste incineration as specified in the new EC Directive on Waste Incineration (2000/76/EC). A new Regulation on waste incineration is planned to be published shortly in the Flemish Region which will specify RDF as waste and re-apply the waste status on thermally dried sludge used as secondary fuel.

The quality standards imposed in the permit for facilities co-incinerating RDF from MSW are the EURITS criteria for secondary fuel used in cement plant (see Section 3).

Combustion facilities using wood or charcoal burning are only allowed to co-combust untreated waste wood and waste wood comparable to untreated waste wood. In this case, the facilities just have to comply with conditions specified for coal burning facilities in Title II of Vlarem.

The other industrial facilities burning non-hazardous treated waste wood must comply with conditions specified for domestic waste incineration (Vlarem II, art 5.2.3.4.1/1). The mixing rule applies for emissions standards. For facilities burning hazardous treated wood wastes, they must comply with the conditions specified for hazardous waste incineration (Vlarem II, art 5.2.3.4.1/2) and the mixing rule applies.

There is a future obligation to produce electricity from renewable energy which will encourage the use of alternative fuels such as dried sewage sludge and other biomass waste.

OVAM is currently drafting a policy document for dealing with RDF and criteria which should be applied for the export of RDF. It has commissioned a study on the Best Available Technology to deal with RDF which should be the basis for the policy plan (Bart Martens, personal com 2001).

#### Walloon Region

Any industrial plant (cement, heating power plant) needs an authorisation to co-incinerate waste issued from the Regional Ministry for Environment (Table B.8). If a plant co-incinerates hazardous waste, it falls under the EC Directive 94/67/EC on Hazardous Waste Incineration. And if energy input from hazardous waste is less than 40%, the mixing rules applies. Reports on quantities of co-incinerated waste must be supplied weekly to the regulatory authority. Typical emission limits for cement kilns co-incinerating waste are presented in Table B.10 below.

The policy of the Walloon Region is to support the use of hazardous waste in cement kilns as there is limited capacity for hazardous waste incineration. There is no incentive for use of alternative fuel for heat or electricity generation.

**Table B.8 Typical emission limit value for cement plant co-incinerating waste in the Walloon Region (Impel 1998, as reported by EA 2001)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	34 -50	Daily average	S+C
TOC	49-75	Daily average	S+C
HCl	20-30	Daily average	S+C
HF	3-5	Daily average	S+C
SO <sub>2</sub>	600-1000	Daily average	S+C
NO <sub>2</sub>	1000-1800	Daily average	S+C
Cd	0.1-0.2	Daily average	S
Hg, Tl	0.1-0.2	Daily average	S
Other metals <sup>3</sup>	1-5	Daily average	S
Dioxins (ng/m <sup>3</sup> TEQ)	0.1	Daily average	S
Temperature			S
CO <sub>2</sub>			S
CO			S

Notes:

- 1 Reference conditions: 11% oxygen, 273K, 101.3 kPa, dry, without correction if oxygen content is below 11% in the exhaust gas except for dioxin and furan measurements
- 2 C – continuous, S-spot
- 3 As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn

### RDF production and use

The Flemish Waste Regulatory Authority, OVAM, has recently completed a survey of the separately collected high calorific wastes which are not suitable for recycling which could potentially be used as RDF (VITO 2000). The study was specifically carried out for the Flemish Region however it generally presents information for the whole of Belgium. The results of the survey are summarised in Table B.9 and presented in text below. Secondary fuels are typically sent to cement plants in Wallonia as there are no cement plants in Flanders and limited outlets prepared to take these materials.

**Table B.9 Potential production of RDF and secondary fuels in the Flemish Region, 1999 (VITO 2000)**

Waste type	Quantity (x10 <sup>3</sup> t/a)
RDF	(240-300)
Waste wood	240 + 60*
Plant waste	200-300
Animal waste	300
Plastic waste	29.3
Textile/carpet	10/5*
Solvent	-
Paper/cardboard	50
Light residues from paper recycling	14.5-24.5
De-inking sludge	26
Used oil	-
Used tyre	32
<b>Total</b>	<b>&gt;1,100</b>

Figures into bracket are future quantities from planned new installations

\* hazardous due to treatment

### Municipal solid waste

It is estimated that the recovery rate for RDF production, the high calorific fraction left from MSW treatment in MBT plants, varies between 40 to 50% of the incoming stream. The quantities of RDF produced in the Flemish Region are expected to rise to 240,000 to 300,000 tonnes with the planned construction of 4 new MBT plants with a total capacity of 600,000 tonnes per annum (tpa) (de Wachter, OVAM, personal com 2001). Currently, there is only one plant, INDAVER in Antwerpen, producing high calorific value pellets in the Flemish Region. The RDF produced in the Flemish Region is exported to cement kilns in the Walloon Region, France or Germany as there are no cement plants located in the region and no other industry prepared to accept RDF even with the strict standards imposed on this secondary fuel.

The costs of producing RDF is reported to amount to 50 – 75 euro per tonne (2-3000 BF per tonne) and for combustion in cement plant, the waste company has to pay the cement company around 100 euro per tonne (4000 BF per tonne) (de Wachter, OVAM, pers. comm 2001).

### Waste wood

Waste wood from mills, panel production (MDF) and furniture production is usually re-used in house into panel production or burned to generate process energy on site. This is not available for energy recovery.

However, waste wood from households or industrial sectors (i.e. construction/demolition, railway, others) is potentially available for energy recovery. The total quantity of waste wood from these end-users in the Flemish Region is estimated to amount to 500,000 tonnes per year (1999 basis); around 100,000 tonnes from households, 150-250,000 tonnes from construction and demolition companies, 200,000 tonnes from other industries and 10,000 tonnes from railway company.

It was estimated that in the Flemish Region, around 200,000 tonnes were recycled for materials, while 240,000 t were co-incinerated or re-used as material after some pre-treatment (i.e. chipping and surface cleaning) and 60,000 t had to be burnt in facilities complying with the Hazardous Waste Incineration Directive.

### Animal waste

The total quantities of animal waste from abattoirs and rendering industry in Belgium is estimated to amount to around 800,000 tonnes per annum including around 100,000 tonnes originating from farms. Seventy five to eighty percent arises from the Flemish Region, equivalent to 705,000 tonnes of animal waste (1998 data).

These wastes are converted into about 230,000 tonnes per annum of bone meal. A large proportion has to be destroyed while some can still be re-used in domestic pet feed. As in the whole of Belgium, there is currently insufficient treatment capacity in the region for these wastes, as there is only one company authorised to destroy specified risk materials and high risk animal wastes. The majority of bone meals and animal fat from the Flemish Region has to be sent to cement plants in Wallonia to be co-incinerated. The disposal outlets are listed below:

- 1) cement works with a total capacity of 120,000 tonnes per annum for bone meals and 100,000 tonnes per annum for animal fat
- 2) hazardous waste incineration at Antwerpen (INDAVER) with a capacity of 15,000 tonnes per annum for elimination of materials from BSE animals
- 3) hospital waste incinerators with a total capacity of 5,000 tonnes per annum.

### Tyres

In 2000, there were 76,600 tonnes of tyres sold by the certified distributors in Belgium; 67% in the Flemish Region, 28% in Wallonia and 5% in Brussels. In 2000, 97% of waste tyres were collected (74,400 tonnes). Around 6.5% were re-used as second hand tyres, 31.7% were co-incinerated in cement plants, 31.1% were shredded for fuel substitution, 14% were granulated for raw material substitution, 3% were repaired and 13% went to other outlets. The used tyres arising in the Flemish Region are usually burnt (81% of 41,000 tonnes) in cement plants.

There are 5 tyre shredding operators in Belgium:

- BUT – Belgian Used Tyres (Indaver), Willebroek (capacity: 25,000 tonnes)
- Eco-Tri (Watco), Estampuis
- Garwig, Houthulst
- Nouel Autobandenrecup, Rumst
- Recygom (Indaver and Watco), Andrimont

## Plastic waste

In Belgium, in 1997, 395,000 tonne of plastic packaging were used; 288,000 tonnes for household products and 107,000 for industrial and distribution sectors. There were 335,000 tonnes of plastic waste produced; 238,000 tonnes from households and 97,000 tonnes from industries and distribution sectors. More than 15% of plastic waste were recycled which is the statutory recycling target.

In addition, for the whole of Belgium, there are between 16 to 78,000 tonnes of plastic waste in construction waste and 9,000 tonnes of plastic waste produced by the agricultural and horticultural sectors (APME 2000 as reported in VITO 2000).

It is estimated that there are around 170,000 tonnes of plastic waste in Flanders; 28% are recycled and 17% are sent for energy recovery, the rest is not currently collected separately (Table B.10).

**Table B.10 Quantities and outlets for plastic waste in the Flemish Region (1999)**

	Quantity (x10 <sup>3</sup> tonnes)			
	Arising	Recycled	Energy recovery	Not collected separately
Household plastic waste	90	20	5	65
Industrial packaging waste	60	26.5	9	24.5
PMD residue			13.6	
Construction				6-8
Agriculture/horticulture	5.5		1.7	3.6
<b>Total</b>	<b>170</b>	<b>47</b>	<b>29</b>	<b>100</b>

## Paper and cardboard

In 1999, around 3.3 million tonnes of paper and cardboard were used in Belgium. In 1999, 1.6 million tonnes of old paper were recovered. Around 1.7 million tonnes of old paper were exported and 0.7 million tonnes were imported. Around 0.6 million tonnes of old paper were re-used by the paper industry.

During the handling of the waste paper (sorting, shredding) residues are generated which usually amount to a maximum of 10% of waste paper input. During the processing of waste paper into pulp, de-inking sludge, a light residue fraction (plastic) (3-5% of the processed quantity), heavy residue fraction (glass, sand, etc.) are generated. The recycling residues, de-inking sludge and light residue fraction can be used for energy recovery.

In the Flemish Region the quantities of waste from paper industry amount respectively to 50,000 tonnes of recycling residues, 26,000 tds of de-inking sludge, and between 14,500 to 24,500 tonnes of light residue fraction. The de-inking sludge is co-incinerated in cement works in Wallonia (11,700 tds), in coal-fired plants in the Netherlands (6,500 tds) or co-incinerated in a steam bread factory in Germany (7,800 tds).

### Used food oils

Waste oils generated from chip shops, restaurants and households must be collected separately and treated. In the Flemish Region, 30,000 tonnes are collected and are recycled. None is available for energy recovery.

### Textiles and carpets

Of the textile waste collected separately 90% is re-used while 10% is landfilled or burnt. Carpet wastes have a high calorific value and can also be co-incinerated in industrial plants. Between 20,000 and 25,000 tpa of carpet waste is generated in Belgium. Around 5,000 t are recycled. Carpet waste can be co-incinerated in non-specialised plants (10,000 t) however the parameters such as Sb, Cr and Zn must be controlled and about 5,000 t have to be burnt in special waste incineration plants.

### Waste oils

Waste oil from cars is pre-treated and then sent to other countries for further treatment and recycling. There is no co-combustion of waste oils in Flanders.

### Waste solvents

Waste solvents are usually recycled (INDAVER) or, for high content chlorinated solvents, incinerated in dedicated plants

### **RDF utilisation**

There is currently no utilisation of waste derived fuels in the Flemish industries. Large quantities of industrial hazardous wastes as well as small quantities of conventional RDF (sorted MSW) are co-incinerated in the Walloon Region as fuel alternatives in cement kilns.

### Dedicated RDF plant:

A Flemish Waste company, INDAVER has requested a permit to operate a dedicated RDF plant to incinerate 200-300,000 tonnes of RDF in an external fluidised bed incinerator together with sewage sludge.

### Power plants:

AQUAFIN, the Flemish wastewater treatment company sends a small amount of its pelletised dried sludge to the electricity company, Electrabel. Electrabel is interested in using such a secondary fuel because of the renewable energy obligation. The company is interested in burning waste, sewage sludge and olive residues to fulfil its obligation. The emission standards applied to power plant are currently less stringent than for waste incinerators but the mixing rule applies. The electricity company does not however have to invest in costly air emission control equipment and can only co-burn small quantities of sewage sludge to comply with the standards.

### Power plants:

There is utilisation of non-hazardous household waste such as paper, plastics, cardboard waste and more recently animal fats in some local district heating plants. No quantities were reported.

### Cement kilns:

There are 3 companies operating 8 cement plants; CBR, Ciment d'Oborug and CBB. Around 6 millions tonnes of clinker are produced per annum. Around 62% are produced by the dry process and 38% by the wet process. All 3 cement works utilise waste either as process material or as fuel substitute. Waste derived fuels account for around 600,000 tonne oil equivalent (toe) per annum (Febelcem 2000). The Walloon cement plants co-incinerate waste mainly from Walloon Region (64%), Flemish Region (10%) and other countries such as the Netherlands and Germany (20%).

In general pre-treatment of waste is carried out off-site by specialised suppliers. In the Walloon Region 2 companies produce secondary fuels for the cement industry; SCORIBEL (based at Feluy-Seneffe), a subsidiary of Obourg cement company and RECYFUEL (based at Engis), a subsidiary of CBR cement company.

The secondary fuels used in the cement industry are reported to be tested extensively at different stages of the production and handling of these wastes. Their properties have to be well known to the industry to ensure that they meet required specifications which ensure that they will not impair the production and quality of the clinker. In addition, it was reported that more extensive monitoring was required for plants co-incinerating secondary fuels (Nizet, Scoribel, pers. comm. 2001).

A wide range of secondary fuels have been used in Belgian cement kilns over the last 10 years, such as tyres and solvents mixed with sawdust. Recently, cement kilns have been using meat and bone meals and are trialling RDF from MSW. There was a dispute at the European Court of Justice under the 1993 Waste shipment Regulation with regard to waste oils being sent from Germany to Belgian cement kilns which was trying to prohibit this practice. A recent hearing has however recognised that this practice could be considered as a recovery activity.

The gate fee is reported to range between 0 and 446 euros (0 to 18,000 Belgian Francs) for solvents and 74 and 124 euros (3000 to 5000 BF) for bone meals.

CBR:

CBR company runs 5 plants where were the following waste derived fuels are co-incinerated (CBR 1999 as reported by EA 2001):

- RESOFUEL (Reconstituted Solid FUEL) which is a substitute liquid fuel (SLF) (i.e. solvent) mixed with sawdust or other absorbent matter (18%);
- Tyre (16%);
- Plastics (10%);
- Automotive Shredder residues (ASR) which is made of combustible parts of vehicle dismantling operations (i.e. plastic, rubber) (16%);
- Other waste such as carpet pellets, sawdust.

Other wastes have been tested but not pursued such as wood, paper and cardboard waste.

#### Cement d'Obourg:

The cement company Obourg has two plants co-incinerating up to 265,000 tonnes of waste recovered fuels in 2000; 65,000 tonnes were secondary fuels supplied by Scoribel. Wastes provided 40% of fuel requirement while 40% of energy was provided by coal residues and 20% from high quality fuel for the starting and doping of the plant. The total energy demand is equivalent to 233,000 tonnes of oil to produce around 2,500,000 tonnes of clinker.

Around 96.5% of waste fuel substitute are constituted of used organic solvent, used oils, animal meals and fats, sawdust soaked with organics residues and 3.5% are constituted of RDF (i.e. non-hazardous waste from sorting of MSW of condensed packs of plastics, textile and paper waste). Hazardous wastes are injected at the flame while RDF is inserted as bale at mid-kilns. The use of waste as a substitute fuel has risen from 4% in 1987 to 28.3% in 1994 reaching 41.2% in 2000. The future consumption of RDF (sorted condensed MSW) is expected to increase to 15,000 tonnes per year.

In addition, about 640,000 tonnes of wastes, such as fly ash and blast furnace slag, are used for material substitution amounting to 36% of mineral component in clinker.

#### CCB:

The company CCB has 2 dry kilns based at Gaurain-Ramecroix. Their production amounts to 2 million tonnes of cement per year. The solid waste fuels are shredded tyres and animal waste (i.e. bone meal and fat). Shredded tyres have been used since 1996 and account for about 8-10% of energy input and bone meal has been used since 1999 in quantities varying depending on the supply (EA 2001).

There are plans to co-incinerate non-hazardous waste at the plant such as mixed wood, plastics and fibres from industrial processes as well as RDF from MSW (EA 2001).

## DENMARK

### Regulatory framework

In Denmark, the limits for incineration of waste as specified in the Danish National Order also apply when wastes are co-incinerated as fuel substitutes (Table B.11). A plant co-incinerating waste derived fuels must be authorised by a local authority.

**Table B.11 Emission limits for co-incineration in cement kilns in Denmark (Entec 1999 as reported by EA 2001)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	40	Daily average	C
	30	Weekly	
TOC	20	Annual	S
HCl	50	Weekly	C
	65	Daily	
HF	2	Annual	S
SO <sub>2</sub>	300	Annual	S
NO <sub>2</sub>			
Cd, Hg	0.2	Annual	S
Ni, As	1	Annual	S
Pb	1	Annual	S
Pb, Cr, Cu, Mn	5	Annual	S
Dioxins (ng/m <sup>3</sup> TEQ)			
CO	100	Hourly	C
	150	90% of either daily or half hourly average per day	

Notes:

1 Reference conditions: 11% oxygen, 273K, 101.3 kPa, dry.

2 C – continuous, S-spot

### RDF production

There have been several attempts by Danish waste companies to manufacture RDF pellets from MSW but they all failed because of the high costs compared with bales or other forms of storage. The RDF pellets can only be used in waste incineration plants, and incinerator operators are not prepared to pay for such materials.

In the County of Funen, Denmark, it is reported that one company NML based in Ringe produces fuel pellets from wastes such as cherry stones and wood shavings. The company also refines waste oil and fats from waste originating from food and fodder production. A scrap

metal company Hansen Genvindingsindustri in Odense is producing combustible shredded waste (mainly plastic) which is co-incinerated in a power and district heating plant of Fynsvaerket (see below).

## **RDF utilisation**

### District heating plant:

Power and district heating plants in Denmark have facilities to co-combust waste as secondary fuels. No overall data on quantities were available for Denmark as a whole. Detailed information was only made available for the municipality of Odense in the county of Funen and for the Ahrus County.

Fynsvaerket based in Odense is a major power and heating district plant which is reported to be able to co-burn shredded plastics from metal recycling company and, on a temporary basis, up to 50,000 tpa bone meal. The plant is equipped with extensive flue gas cleaning technology to control atmospheric emissions. Eight minor district plants owned by the municipality of Odense were reported to co-combust 1,129 t of waste oil in 2000. This practice has been discontinued.

It is reported that there are four plants in the Arhus County producing electricity and district heating by burning waste (MSW and flammable industrial waste) with a total capacity of 110,000 tpa. One district heating/electricity plant utilises biogas produced from organic MSW and industrial waste (155,000 tpa).

### Manufacturing plant:

In the Arhus County, three manufacturing plants are also reported to burn their own wastes to generate process heat and central heating, namely:

- Corn and dust waste from corn processing (1,300 tpa)
- Reject chip board and dust from chip board manufacturing (25,000 tpa)
- Coated paper board (800 tpa)

### Cement kilns:

A mixture of non-hazardous waste derived fuels is used in the only cement plant located in Denmark. Aalborg cement plant began to use substitute fuels supplied by their on-site fuel preparation plant CemMiljø in 1998. In 1999, waste derived fuel input in cement plant in Denmark amounted to 32,600 tonnes representing 7% of total fuel input for the industry. The waste derived fuels include textiles (5,600 tonnes), wood chips (333 tonnes), bulky household waste (2,571 tonnes) and plastic/paper (9,861 tonnes). This was expected to rise to 42,500 tonnes in 2000 including 7,500 tonnes of sewage sludge. The quantity of sewage sludge is expected to increase up to 20,000 tpa (EA 2001).

## FINLAND

### Regulatory framework

Finish waste management is based on separation of waste at source from households, offices, commercial enterprises and industry. Material recycling is the priority but as significant volumes of waste are non-recyclable, and as these volumes do have a calorific value, significant research and development work has been initiated to utilise this energy for power and heat generation (Manninen 1997). The National Waste Plan in Finland sets a 70% recovery from municipal, construction and demolition, and from industrial waste. This ambitious target for recovery cannot be met without the exploitation of waste as a fuel. In Finland the following types of wastes may be processed to produce a fuel:

- Domestic waste
- Forestry industry waste
- Construction and demolition waste
- Used tyres

A new standard (SFS 5875) ' Solid recovered fuel. Quality control system' has been officially accepted in 2000. The standard " Solid recovered fuels. Quality control system" defines production procedures and quality classes. The standard covers the whole chain of supply from source separation to the delivery of recovered fuel (REF). Fuel quality is divided into three classes, the criteria for which are detailed in the Table B.12 below (All concentrations are on a dry matter basis). All quality requirements have to be met for a particular class and limit values are verified according to procedures identified in the standard.

The source separation, production and energy recovery of RDF is given high priority in waste strategies developed by municipal and private waste management companies. Finish policy regards efficient source separation and a controlled production process as essential to controlling impurities within the fuel. Such controls also assist in the trade of refuse derived/recovered fuel, as both the calorific value and impurity levels are recorded and made available. Impurities in municipal waste are a barrier to the exploitation of waste as a fuel. With the recovery rate standing at 40% in 2001, there are proposals to develop more alternative technologies for energy recovery from municipal waste such as gasification with advance fuel gas cleaning and new CHP plants for RDF.

Waste originating from commerce and industry, which is generally not heavily contaminated with impurities such as chlorine or heavy metals, is often classified as REF Class 1. REF 1 can be mixed with conventional solid fuels (e.g. peat and wood fuels) and burnt in existing power plants without affecting the quality of emissions (although this is dependent on ratio). The majority of RDF fuel co-combusted in Finland is REF grade 1.

Household derived fuel (RDF) generally falls into class II or III. Co-combustion of this grade of fuel in existing power plants would generally require investments for flue gas cleaning, and may result in corrosion and fouling problems. It is therefore envisaged that recovery of household derived fuel will be through new investments such as gasification with advanced fuel gas cleaning, fluidised bed boilers and new CHP boilers.

Plants co-incinerating non-hazardous waste must have an authorisation from the District Environmental Centre (EA 2001). Each application is considered on a case by case basis. Table B.13 presents typical emission limits values in a permit for a cement plant in Finland.

**Table B.12 Finish quality standards for RDF**

Characteristic	Focus of application	Unit	Reporting Precision	Quality Class		
				I	II	III
Chlorine content	1)	% (m/m) <sup>2)</sup>	0.01	<0.15	<0.50	<1.50
Sulphur content	1)	% (m/m) <sup>2)</sup>	0.01	<0.20	<0.30	<0.50
Nitrogen content	1)	% (m/m) <sup>2)</sup>	0.01	<1.00	<1.50	<2.50
Potassium and sodium content	1)	% (m/m) <sup>2)</sup>	0.01	<0.20	<0.40	<0.50
Aluminium content	1)	% (m/m) <sup>2)</sup>	0.01	4)	5)	6)
Mercury content	1)	mg kg <sup>-1</sup>	0.1	<0.1	<0.2	<0.5
Cadmium content	1)	mg kg <sup>-1</sup>	0.1	<1.0	<4.0	<5.0

Notes:

- 1) The limit value concerns a fuel amount of  $\leq 1000 \text{ m}^3$  or a fuel amount produced or delivered during one month, and it shall be verified at least for a respective frequency.
- 2) % (m/m) denotes the percentage by mass
- 3) Total content (K+Na) of water-soluble and ion-exchangeable proportion for dry matter.
- 4) Metallic aluminium is not allowed, but is accepted within the limits of reporting precision.
- 5) Metallic aluminium is removed by source separation and by the fuel production process.
- 6) Metallic aluminium content is agreed separately.

There is a governmental decision on the recovery and disposal of waste tyres (1246/1995) which includes a target of 90% recovery for tyres by 2000. The priority is for waste tyres to be re-used or recovered as material and then to be used as energy source (EA 2001).

**Table B.13 Typical emission limit for co-incineration in cement kilns in Finland (E C 2000 reported by EA 2001)**

Parameter	Limit value <sup>1)</sup>	Control period	Control method <sup>2)</sup>
Particulates	50	Nd	Nd
SO <sub>2</sub>	150-400 (existing kilns)	Monthly average	Nd
NO <sub>2</sub>	1200-1800 (existing kilns)	Monthly average	Nd

Notes:

- Nd no data
- 1) Reference conditions: 10% oxygen, dry gas
  - 2) c – continuous, s – spot

In an effort to re-direct more waste away from landfill, the National Waste Plan revision working group are considering raising the landfill tax from €15 to 28 per tonne (90 to 170 Finnish marks per tonne (FMK/t)).

As the new Waste Incineration Directive (WID) comes in to force, so the tighter emission controls placed on co-incineration plants will increase the cost of waste derived fuels. It has been estimated that the costs of the continuous emissions monitoring be approximately € 50 500 to 67 300 per annum (300 000 to 400 000 FMK/a), which will limit the use of RDF in small district heating plants with a small proportion of the main mix fuel.

## RDF production

Finland relies on landfilling for MSW disposal and has very limited mass burn incineration capacity. Domestic waste is sorted for householders at source and separate collections are provided for paper, glass, metals and biowaste. The remaining dry fraction can be processed for RDF, referred to as REF in Finland.

The wood industry produces large volumes of wastes and has for some time now been co-combusting its wood waste together with other non-recyclables in multi-fuel fluidised bed boilers. Wood is not classified as waste in Finland, unless disposed of.

It is estimated that half of the construction and demolition (C & D) waste (excluding mineral and inert waste) has an extractable calorific value. Currently it is estimated that approximately 100 000 to 120 000 tonnes of wood based C & D waste are processed at RDF stations.

In 2000 there were 12 RDF production plants (Table B.14 below) in operation, processing household, commercial and C & D waste with a total capacity for approximately 200,000 – 300,000 tpa operating between 70% and 100 % of their capacity depending on the final use and thus the required quality of RDF being produced. In addition, 8 facilities for are planned. Typical quality data for RDF produced from household, commercial and construction waste are provided in Table B.15.

**Table B.14 RDF production capacity in Finland**

RDF processing plant	Type of waste	Capacity (x10 <sup>3</sup> tpa)
5	Household, commercial and C & D waste	120,000 –130,000
7	Commercial and C & D waste	180,000
(8) <sup>a)</sup>	Household, commercial and construction and demolition waste	Planned
<b>Total</b>		<b>200 000 to 300 000</b>

Note:

a) planned

**Table B.15 Quality of RDF from various sources**

		<b>Commercial Waste</b>	<b>Construction Waste</b>	<b>Household Waste</b>
Lower heating value as received	MJ/kg	16-20	14-15	13-16
	MWh/t	4.4-5.6	3.8-4.2	3.6-4.4
Annual Energy Content	GWh/a	530	285-315	360-440
Moisture	w-%	10-20	15-25	25-35
Ash	w-%	5-7	1-5	5-10
Sulphur	w-%	<0.1	<0.1	0.1-0.2
Chlorine	w-%	<0.1-0.2	<0.1	0.3-1.0
Storage Properties		Good	Good	Good in pellets or baled

### **RDF utilisation**

There are only three cement kilns in Finland using limited quantities of RDF and used tyres. During the last few years, the pulp and paper industry has increased the use of secondary fuels. The plants have changed their boilers into fluidised bed to be able to burn even wet waste such as paper sludge. It was reported that about 500,000 tpa of REF was used as secondary fuel in Finland and produced 1% of the primary energy supply which could increase to 3 to 5% (De Vries *et al* 2000).

#### Dedicated incineration plants:

Mass burn incineration is not widely practised in Finland. There is only one mass burn incinerator which produces 15 MW of district heat for a capacity of 50,000 tpa.

#### Power plants

Combined heat and power (CHP) plants and district heating plants are more popular, many of which practice co-incineration. Flue gas clean-up is usually effected by electrostatic precipitators or a cyclone and sometimes a scrubber (De Vries *et al* 2000). The Finish energy production system is multi-fuel based, with over 72% of large combustion plants operating a co-generation system. Multi-fuel boilers fired with peat, wood fuels, coal and natural gas are widely used, with the main product being the heat/steam demand. In small towns, district heating plants produce heat. Over 50% of all households are connected to the district heating network. In many instances electrical production is secondary, and it is the demand for heating with the current provision of adaptable boilers which has made waste to energy attractive and economical.

It is a common practice in Finland for power plants to co-combust multi-fuels including high quality secondary fuels from industrial and commercial waste. As RDF from households has a higher level of impurities it requires specially adapted power stations. It is possible to use RDF from MSW in district heating plants, but it was reported that the future EU Waste Incineration Directive will limit the economical benefits of co-incinerating small volumes of RDF with the main fuel due to the possible investment cost for flue gas equipment and monitoring.

There are around 50 small and medium size (<50 MW) district heating plants in Finland using biomass, peat and waste fuels in a multi-fuel boiler. REF usually represents 10 to 30% of fuel mass flow to the boiler. It is reported that about 50,000 tonnes of REF were co-incinerated in small district heating plants in 1998.

The price paid by power plants for REF fuel is generally lower than peat or coal (FIM 0-35/MWh) REF is normally only used as a secondary fuel. Assuming minimum quality criteria are achieved REF, has a high calorific value and low moisture content, which help combustion of process sludge or other wet fuels and cut down on CO<sub>2</sub> emissions.

#### Paper plants

It is reported that about 80% of the paper industry's energy consumption is now provided by secondary fuels such as REF, paper sludge, waste wood and bark. The annual consumption of REF amounts to 200,000 tpa (usually mixed with peat, bark, sawdust and coal) and paper sludge to 300-400,000 tpa (de Vries et al 2000).

#### Cement plant:

There is only one cement company in Finland operating 3 kilns for a total cement production of 1.3 million tpa (EA 2001). Only one kiln located at Parainen uses solid waste as secondary fuel. Around 1 tph of shredded car tyres are co-incinerated amounting to about 8,000 tonne per annum (EA 2001).

#### Gasification plants

Gasification plants which convert RDF into a combustible gas, operate at Varkaus and Lahti. The Lahti gasification plant is reported to used 35,000 tpa of REF and biofuels in 1998. The Varkaus plant is gasifying about 50,000 tpa of plastics rejects from pulp and paper industry (De Vries *et al* 2000).

## FRANCE

### Regulatory framework

Industrial plants and large combustion plants are subject to the Law 76-663 of 19 July 1976 on Classified Installation Regulation, the French equivalent to IPPC. To be authorised to use waste as substitute fuels, a company will need an authorisation issued in a Departmental Order (*Arrêté départemental*) by the Departmental Prefect with technical support of the Regional Directorate for Industry, Research and Environment (DRIRE). The Prefectoral authorisation can for example specify limits on heavy metal content in hazardous waste.

The Decree 77-1133 of 21 September 1977 and Order of 3 May 1993 regulate cement plants using conventional fuels. The Order of 10 October 1996 implementing EC Directive 94/67/EC on incineration of hazardous waste applies to cement plants co-incinerating hazardous waste. As specified in the 94/67/EC Directive, when the waste fuel provides more than 40% of heat input, the emission limits specified in the Directive apply. These limits also apply in France when the waste fuel provides less than 40% heat input. The mixing rule is not applied in France. Table B.16 presents emission limits for co-incineration in cement kilns in France.

There have been recent discussions at the Ministry level to clarify regulations with regard to combustion of biomass waste in combustion plants. These concern mainly wastes which are burnt internally (i.e. on-site production waste) and in district heating plants. Two circulars have been published in 11 August 1997 and 10 April 2001. Combustion plants are authorised to use biomass waste and fall under the authorisation regime if their thermal output equals or exceeds 20 MW or under a less demanding declaration procedure if their thermal output is comprised between 2 and 20 MW. The emission controls are less stringent than for incineration. Biomass waste is defined as:

- Vegetable waste from agriculture and from forestry,
- Vegetable waste from food processing industry,
- Vegetable waste from pulp and paper industry,
- Cork waste,
- Wood waste except wood waste susceptible of containing organic halogenated compounds due to treatment or cover applied especially demolition/construction waste.

For other waste types combusted in combustion plant of thermal power above 0.1 MW, the plant is subject to authorisation. The authorisation is given on a case by case basis and the detailed authorisation is delivered by the Departmental Prefect after consultation with the Ministry of Environment. The plant must demonstrate that the waste has similar properties to conventional fuel and that emission levels are acceptable.

**Table B.16 Emission limits for co-incineration in cement kilns in France (Impel 1998 as reported by EA 2001)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	35-50	Monthly	C+S
TOC	10 20	Daily Half hourly	C+S
HCl	10 60	Daily Half hourly	C+S
HF	1 4	Daily Half hourly	C+S
SO <sub>2</sub>	320 1280	Daily Half hourly	C+S
NO <sub>2</sub>	1200 dry 1500 semi-dry 1800 wet	Daily  Monthly	S
Cd, Tl, Hg	0.05	30 min to 8 hour average	S
Other metals <sup>3)</sup>	0.5	8 hour average	S
Dioxins (ng/m <sup>3</sup> TEQ)	0.1	6 to 8 hours average	C+S
Temperature			C+S
NH <sub>3</sub>			S

Notes:

- 1 Reference conditions: 11% oxygen (most of the time although it must be fixed in the permit and may be as low as 6%), 0°C, 1013 mbar, dry.
- 2 C – continuous, S-spot
- 3 Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn

## **RDF production**

### Municipal solid waste

In the past there were several installations producing RDF after sorting, grinding MSW. These facilities were not successful in securing outlets for the fuel and ceased operating. One installation under construction will produce charcoal from MSW using a thermolysis process. MSW will be ground, sorted, dried, heated to 500°C, sorted again and washed before being used in a cement plant.

### Non hazardous industrial waste

Non-hazardous industrial waste (*Déchets Industriels Banals*) such as waste from wood processing and tyres are co-incinerated and use as substitute fuel in industrial processes. It is reported that around 1.9 million tonnes of such wastes are used as an energy source.

### Hazardous industrial waste

In 1998, there were 63 treatment centres for which handled a total of 2.85 million tonnes of hazardous industrial waste (HIW) in France (Ademe 2000). The treatments applied were incineration, co-incineration, physico-chemical treatment, landfill or evapo-incineration.

There were 11 centres of pre-treatment of waste for secondary fuel production for the cement industry. The quantities of hazardous industrial waste pre-treated before their use in cement plants amounted to 325,000 t in 1999 (246,000 t in 1998 – see Table B.17), around 9% of the total HIW production. It was reported that these quantities would increase by 3% by 2001 (Ademe 2000).

**Table B.17 Production of secondary fuels in France, 1998 (Ademe 2000)**

	<b>Authorised capacity (tonnes)</b>	<b>Quantity treated (tonnes in 1998)</b>
A.R.F.	60,000	60,000
CTRL	108,000	NI
REGESOLVE	16,000 (HW) 15,000 (NHW)	NI
RTR	72,000	61,296
RTR SUD OUEST	NI	NI
SCORI AIRVAULT	NI	NI
SCORI FRONTIGNAN	50,000	16,000
SCORI HERSIN	100,000	58,770
SCORI VEDIRA	40,000	15,875
SOVRAC	40,000	20,600
SOVALEG	18,000	13,719
<b>Total</b>		<b>246,260</b>

Notes:

NI No information

HW Hazardous waste

NHW non hazardous waste

## **RDF utilisation**

### District heating plant:

In 1998, there was only one heating plant authorised to co-incinerate hazardous industrial waste. The quantities of waste co-incinerated in this heating plant amounted to less than 20,000 t.

The share of renewable energy in generating electricity is expected to fall in France in 2010 (IFEN 2001) although green energy output is projected to increase by 12% over the next decade. This growth will be offset by the increase of consumption.

### Cement kilns:

There are 42 cement kilns in France. Ninety five percent use a dry process (SFIC 2000, reported by EA 2001). The French cement trade association, SFIC reported that, in 1998, 24% of the total energy for cement plants was substituted by secondary fuels (SFIC 2000 reported by EA 2001).

In 1998, there were 23 cement works authorised to co-incinerate hazardous and non-hazardous waste as alternative fuel, which is twice as many as in 1989 (Table B.18). In 1999 and 2000 there were additional authorisations pending, for the use of industrial wastes in cement works.

Secondary fuels co-incinerated in cement kilns include tyres, animal meal and sawdust mixed with liquid hazardous waste (i.e. solvents). Used oils is also used as secondary fuel without pre treatment in replacement of coke (60%), coal (11%) and a bitumen fuel (29%) (Ademe 2000b) in 3 cement plants.

In 1998, the quantities of secondary fuels co-incinerated in cement works amounted to 823,000 tonnes including about 100,000 tonnes of animal bone meal. This is a 200% increase from 1989 and these quantities are expected to increase by 5% in 2001. The increase is partly due to an increase in the number of cement works authorised to co-incinerate. However the inclusion of sawdust mixed with hazardous industrial waste will expand the types of wastes which can be co-combusted to include paint residues and contaminated packaging.

It was reported that the bone meal (*Farine animale*) and other wastes with high calorific value such as oils and solvents are in competition with the production of alternative fuels from hazardous industrial waste. The quantities of bone meal co-incinerated in cement works in France in 1999 amounted to 140,000 t, a 40% increase since 1998.

**Table B.18 Co-incineration of secondary fuels in cement plants in France, 1998  
(Ademe 2000)**

	Authorised capacity (x10 <sup>3</sup> tonnes)	Quantity co-incinerated (x10 <sup>3</sup> tonnes)
<b>Lime quarry and kiln Dugny:</b>	25	13
<b>Cement Calcia:</b>		
Airvault plant 1	119 (HW) 22 (NHW)	40
Airvault plant 2	137	30
Beaucaire plant	140	15
Beffes plant 1	49	11
Beffes plant 2	49	0.8
Bussac Foret plant	NI	17
Couvrot plant	208	48
<b>Cement D'Origny:</b>		
Altkirch plant1	30	15
Altkirch plant2	30	5
Dannes plant	125	44
Heming plant1	140	24
Heming plant2	140	5.5
Lumbres plant	200	79
Rocheftort plant1	NI	5.5
Rocheftort plant2	64	20
<b>Cement Lafargue:</b>		
Contes plant1	5	0
Contes plant2	5	0.9
Frangey plant	45	29
De la Malle plant1	NI	27
De la Malle plant2	13	8.5
Couronne plant	NI	0
Havre plant	100	26.5
De le Teil plant	51.7	29.5
Martres plant	55	31
Port La Nouvelle plant	35	8
Saint Pierre La Cour plant 1	70	32
Saint Pierre La Cour plant 2	70	26
Val d'Azergues	33	16
<b>Cement Vicat:</b>		
Crechy plant	NI	16
Montalieu plant	70	70
Xeuilley plant		32
<b>Total</b>		<b>727</b>

## GERMANY

### Regulatory framework

The German law regarding waste is the “*Kreislaufwirtschafts- und Abfallgesetz – KrW-/AbfG*“. The conditions concerning co-incineration are regulated in technical instructions, called “*Technische Anleitung Abfall – TA Abfall*” (technical instruction on waste) and “*Technische Anleitung Siedlungsabfall – TASI*” (technical instruction on municipal waste).

Emissions for industrial plants co-burning waste derived fuels are regulated by the law called “*17<sup>th</sup> Bundes-Immission Schutz Gesetz – 17<sup>th</sup> BImSchG*“ (Federal Immission Protection Law) and its subordinate regulations. The limit values for dust and trace elements are shown in Table B.19.

For an energy substitution of up to 25%, emission limits have to comply with limit values specified in the EC Hazardous Waste Incineration Directive 94/67/EC with one additional limit for NO<sub>2</sub> of 200 mg/Nm<sup>3</sup>. For higher substitution rates, the German regulation is more stringent than the 1994 Directive (EA 2001).

**Table B.19 Emission limits for co-incineration in cement kilns in Germany (as reported by EA 2001)**

	17 BImSchV	
Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period
Particulates	10	Daily
	30	Half hourly
TOC	10	Daily
	20	Half hourly
HCl	10	Daily
	60	Half hourly
HF	1	Daily
	4	Half hourly
SO <sub>2</sub>	50	Daily
	200	Half hourly
NO <sub>x</sub>	200	Daily
	400	Half hourly
Cd, Tl	0.05	
Hg	0.03	Daily
	0.05	Half hourly
Other metals	0.5 <sup>2)</sup>	
Dioxins (ng/m <sup>3</sup> TEQ)	0.1	

Notes:

- 1 References conditions: 11% oxygen
- 2 Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn

## RDF production

In Germany, some plants for the treatment of waste are especially designed for the production of a high calorific fraction such as some mechanical-biological treatment (MBT) plants or the “Herhof-Trockenstabilat<sup>®</sup>-Verfahren plants processing municipal solid waste (MSW). In many other cases no high calorific value fraction is extracted but waste fractions are just ground or ground and pelletised.

In Germany, the total capacity of MBT plants producing RDF is just above 1 million tpa (Table B.20), about half of the total capacity of the MBT park. The utilisation of the RDF is secured not in all cases so in some plants the high calorific fractions are just stored. Producers of secondary fuels in Germany have created a label, called “RAL Gütezeichen Sekundärbrennstoffe”. It is like a guideline for producers to guarantee specific input limits for pollutants such as heavy metals. There are hopes to get a better market position by the introduction of the RAL-seal.

**Table B.20 Mechanical-biological treatment plants with high calorific output in Germany**

Location	Capacity [x10 <sup>3</sup> t/a]
Aßlar [1]	140
Bassum [1, 2]	65
Biberach [1, 2]	40
Düren [1]	150
Erbenschwang [1, 2]	22
Hannover [1]	200
Lüneburg [1]	29
Osnabrück [1, 2]	115
Quarzbichel [1]	30
Rennerod [1]	50
Rügen [1]	15
Schwarze Pumpe [1]	120
Wetterau [1]	45
Wiewärthe [1]	85
<b>Total</b>	<b>1,106</b>

Ref:

- 1 VKS, ASA 2000
- 2 UBA 2001

One problem in describing the overall situation of waste derived fuel production in Germany is that the non-hazardous non-municipal waste fractions are no longer under control of the authorities, so it is impossible to get precise information on quantities of fuel derived from

these waste categories. However, potential for RDF and secondary fuel production has been estimated by Köster (2001) (Table B.21) to range between 18.6 and 26.4 million tpa.

**Table B.21 Potential production of secondary fuels in Germany (Köster 2001)**

Waste type	Potential of secondary fuels (x10 <sup>6</sup> t)		Cumulative energy content (PJ)	
	min	max	min	max
Sewage sludge (dry matter)	2.3		5	
Wood packaging	0.8	1.6	10	27
Furniture	0.8	3.9	10	67
Construction and demolition wood	2.4	5.9	31	101
Demolition waste	3.2	3.2	59	59
Plastics (DSD)	0.5		15	
High calorific MBT output	5.2	8.4	83	134
Used tyres	0.5	0.5	13	13
Used oil	0.3	0.2	7	7
Specific production residues	1.5	1.5	30	30
Paper rejects	0.9		4	
Meat and bone meal	1	1	15	18
Paint sludge	0.13	0.13	1	4
<b>Total</b>	<b>18.6</b>	<b>26.4</b>	<b>279</b>	<b>460</b>

Notes:

DSD Source separated collection system for plastics (Duales System Deutschland)

MBT Mechanical-Biological Treatment plant

PJ Peta Joule – 10<sup>15</sup> Joule

## RDF utilisation

There are more than 70 plants in operation that are authorised and which are co-incinerating waste derived fuels in Germany (Table B.22). This represents an available maximum capacity for co-incineration estimated to about 12 million t (Table B.22), about 65% of the minimum potentially available quantities of RDF and secondary fuels in Germany (Table B.21). In comparison, there are 61 MSW incinerators with an existing capacity of about 13.7 million tpa to be increased to 17.6 million tpa by 2005. The main user of secondary fuels in Germany is the cement industry.

**Table B.22 Co-incineration of secondary fuels in Germany<sup>1</sup>**

Co-combustion installations	Number	Potential capacity (x10 <sup>6</sup> tpa)	Quantity (x10 <sup>6</sup> tpa)
Cement kiln	31	2.7	0.92
Power plant	(31) <sup>ab</sup>	8.5 <sup>b</sup>	NI
Non-ferrous metal producer	7	NI	NI
Steel furnace	5	0.35	0.28
Wood industry	(5) <sup>a</sup>	NI	NI
Paper mill	NI <sup>b</sup>	NI <sup>b</sup>	2,9
Roast-/Sinter-plant for iron ore	0		
Lime producer	0		
Brick kiln	NI	0.3	0.3
<b>Total</b>	<b>79</b>	<b>11.85</b>	<b>4.4</b>

Ref:

1 RWI 1999, Grech 2000, Scheurer 2000, Prognos 2001, VDZ 2001

Notes:

a Information does not represent the whole of the German industry

b Including power capacity for the paper industry

#### Cement kilns:

There are 70 cement kilns in Germany. Thirty one of them use secondary fuels with a total energy substitution ratio of about 23%. The most important wastes with regard to quantities are tyres, used oil, waste wood and industrial and commercial waste (i.e. paper rejects). The quantity of secondary fuels co-incinerated in cement kilns in Germany is estimated to amount to about 1 million tpa with an estimated maximum capacity ranging between 1.4 and 2.7 million tpa (Euwid 2001) (Table B.23).

**Table B.23 Co-incineration of secondary fuels in cement kilns in Germany, 1999 (VDZ 2000)**

Type of waste	Capacity	Quantity (x10 <sup>3</sup> tpa)	Calorific value (MJ/kg)
Industrial and commercial waste	888 <sup>a</sup> )	290	22
Tyre	596	236	26
Waste oil	441	181	35
Wood	366	77	13
Solvent	96	24	27
Carpet	NI	20	21
Fullers earth		13	10
Plastics, textile	212	-	-

Type of waste	Capacity	Quantity (x10 <sup>3</sup> tpa)	Calorific value (MJ/kg)
Paper rejects, paper sludge	189	-	-
Miscellaneous	220	82	14
<b>Total</b>	<b>2,674<sup>b)</sup></b>	<b>923</b>	

Notes:

a) Including RDF from MSW

b) Maximum capacity is lower than the overall total due to multiple entries

#### Power plants:

Information about power plants using waste derived fuels for the whole of Germany is not available, due to changes in the energy market. However, estimates can be made based on the installed capacity. The capacity of German power plants is about 114 GW, of which about 50 GW is produced in coal-fired stations. The potential for co-incineration of RDF with an average calorific value of 16 MJ/kg can be estimated to range between 8.5 and 17 million tpa depending on a substitution rate for coal by RDF of 5% or 10% respectively.

Information collected for Northrhine-Westfalia, an industrial federal state with about one third of the power plants in Germany, indicates that 31 of 170 'power plants' are authorised to use secondary fuels and that 22 are currently co-incinerating secondary fuels (Prognos 2001). The term 'power plant' is used here in a broader sense and also covers on-site power generation units for industrial plants (Table B.24). Some plants are currently in the process of being granted an authorisation to use sewage sludge and RDF as secondary fuels.

**Table B.24 Co-incineration of secondary fuels in power plants in Northrhine-Westfalia (Prognos 2001)**

Industry sector	Number of plants
Electricity/heat power generation	11
Chemical industry	10
Wood and paper industry	7
Other	3
<b>Total</b>	<b>31</b>

#### Paper industry

In Germany, it is more difficult than in Austria to differentiate between RDF utilisation in "power plant" and in the "pulp and paper industry". In the literature, power plants belonging to the pulp and paper industry are not accounted for separately because they are outsourced from the paper plants and work in a type of commercial partnership. However, information on secondary fuels co-incinerated in paper industry is reported in Table B.25.

**Table B.25 Co-incineration of secondary fuels in paper industry in Germany (RWI 1999)**

Secondary fuel	Quantity (x10 <sup>3</sup> tpa)	Energy (10 <sup>3</sup> GJ pa)
Spent liquor	1,750	12,443
Bark	225	2,358
Fibre-/De-inking-sludge	870	3,975
Other residues	100	1,137
<b>Total</b>	<b>2,945</b>	<b>19,913</b>

#### Blast furnaces

Secondary fuels – mainly plastics – are used in five German blast furnaces as reducing agents. The quantities co-incinerated amount to about 280,000 tpa while the approved maximum capacity is about 350,000 tpa (Table B.26).

**Table B.26 Co-incineration of secondary fuels in blast furnaces in Germany (Prognos 2001 and Grech 2001)**

Location		Quantity	
		max tph	max tpa
Stahlwerk Bremen	Hochofen II	8.75	77,000
Stahlwerk Bremen	Hochofen III	4.38	38,000
EKO Stahl Eisenhüttenstadt	Hochofen 3	2.81	25,000
Thyssen Krupp Stahl, Dortmund	Hochofen 4	8	70,000
Thyssen Krupp stahl, Dortmund	Hochofen 9	8	70,000
<b>Total</b>			<b>280,000</b>

#### Brick industry

The situation of co-incineration in the German brick industry is as difficult to describe as the situation in Austria as quantities are not documented. Waste like sawdust, paper fibres, Polystyrol, fly ashes and Perlith are used but as pore agents. The total quantities of pore agents are estimated to be about 300,000 tpa.

## **GREECE**

No information was provided from the authorities contacted in Greece. The information reported below is extracted from the EA report (EA 2001) which was based on a 1998 Impel study.

### **Regulatory framework**

There is no specific legislation in Greece for co-incineration of waste in cement plants and emission limits are not set in individual permits. The 1994 Hazardous Waste Incineration Directive limits will apply to emissions of any facilities burning hazardous waste. Controls rely on self-monitoring (Impel 1998 as reported by EA 2001).

### **RDF production and use**

It is reported that a new MBT plant is being built for Athens. This could potentially generate RDF from MSW.

In Greece, three out of the 8 cement plants have run trials in 1998 with small volumes of secondary fuels (Impel 1998 as reported by EA 2001). No results or future decision was reported. It is unclear if any large-scale use of secondary fuels is taking place in Greece in the cement industry or any other industrial facilities.

## **IRELAND**

Ireland has very limited infrastructure for RDF production or use. There is no reported production or utilisation of RDF or other waste derived fuels to date in Ireland. Statistics on quantities of waste arising and disposal is collated in the National Waste Database and the latest figures for 1998 are reported below.

### **Regulatory framework**

Waste management strategy is developed by the Local Authorities. To date this is largely based on landfilling of municipal solid waste (MSW) with an increasing activity of recovery of recyclable materials (paper, glass, plastics, metals) and hazardous waste (waste oils, batteries, fluorescent lights). Most industries manage waste recovery on-site and any industrial wastes arising are managed with the main aim of waste recycling rather than use as a fuel.

Ireland has set itself challenging targets regarding household waste that includes:

- Diversion of 50% of overall household waste away from landfill;
- A minimum of 65% reduction in biodegradable waste going to landfill;
- Recycling of 35% of municipal waste; and
- Reduction in number of landfills.

To achieve these targets, Ireland will have to rely on alternative ways for sorting, recycling and treating MSW which will probably generate high calorific fraction which could be turned into RDF.

### **RDF production and use**

#### Municipal solid waste

Ireland produces about 1.5 million tonnes of municipal solid waste (MSW) per year of which 1.2 million tonnes is household, 0.7 million tonnes commercial waste and 0.08 million tonnes street cleaning wastes. Most of this waste is landfilled (about 92%) with the most of the remainder recycled. Currently there is no incineration of municipal wastes with or without energy recovery.

This means a big challenge for Ireland in view of meeting the proposed target to reduce landfilling of MSW and the necessity to find alternative treatments. This situation may mean a move towards more use of waste as a secondary fuel. Most Local Authorities are considering using thermal treatments of MSW including incineration and gasification as part of their local waste management plans. Therefore the situation regarding RDF from MSW may change significantly in the future. The use of composting at home and at central locations as well as anaerobic digestion of MSW are also being considered and encouraged as part of the waste management plans.

Ireland does not have as yet a sufficiently well developed infrastructure for using other wastes as secondary fuel in significant amounts. There are at present no large scale RDF manufacturing facilities using any type of feedstock. Some smaller scale waste recovery occurs that may result in the recovered product being used as fuel. For example some waste oils may be recycled as fuel oil for home or small-scale business use.

### Waste oils

Most of the waste oil and other oily wastes (oily sludges and oil filters) are classified as hazardous waste and are collected separately. There is no known significant use of waste oil as secondary fuel in Ireland. Most waste oil is recovered or re-refined either on the oil sites, at waste oil recovery centres or exported for recovery. Some small quantities of recovered oil may be burnt domestically or by small businesses as fuel oil.

<b>Waste</b>	<b>Total (tpa)</b>	<b>Recovered on-site (tpa)</b>	<b>Recovered off-site (tpa)</b>	<b>Exported (tpa)</b>	<b>Unreported (tpa)</b>
Waste oils	17346	747	14187	131	2255
Oily sludges	19063	6444	9960	230	2429
Oil filters	1327		349	13	919

### Waste tyres

The total production of all waste tyres in Ireland is about 29,033 t/a. There is no re-use of tyres as a secondary fuel but this may be considered in the future as part of Local Authority waste management strategies. The current use of waste tyres includes re-treading, silage pit cover weights, boat fenders and landfill leachate drain collection systems. Most other tyres are landfilled. That practice will be phased out under the 1999 Landfill Directive obligations.

### Solvents

Solvent recovery is well established in Ireland with a total of about 82,035 t solvent produced per year of which about 65,988 t is recovered on the production site, 148 t recovered at other Irish off-site plants and 15,875 exported for recovery. There is no use of solvent waste as secondary fuel in Ireland.

### Paper and cardboard

Ireland has established separate collection schemes for paper and cardboard waste that recovers about 42,262 t (14.4%) of the total amount of paper and cardboard waste (297,782 t) in the household and commercial waste stream. The remainder is landfilled. All the recovered paper is recycled and none at present is used as secondary fuel.

### Plastics

Ireland also has a limited plastic collection scheme which recovers 3,458 t of plastic from the total of 164,432 t of household and commercial waste collected. All the plastic is recycled and none used as a secondary fuel.

### Wood and wood wastes

The wood and wood products industry uses about 80,727 t waste wood as fuel which is thought to be an on-site activity outside the scope of this survey. This tonnage accounts for most of the waste that is reported to be used as a secondary fuel in Ireland. Some waste wood may be used as secondary fuel by other small scale users. There is no large scale commercial unit producing RDF fuel from waste wood.

Most wood waste is being considered for recycling, e.g. pilot project to recycle pallets for use in chipboard industry.

Demolition wood waste estimated at 50,188 t per year is not separately collected.

### Textiles

There are no separate collection of textiles and all is believed to be landfilled (4,568 t).

### Agricultural wastes

Virtually all the 6.5 million tpa estimated organic agricultural wastes are recycled to land. None is used for RDF production.

### Sewage sludge

In 1998, it was reported that sewage sludge quantities in Ireland amounted to around 38,290 tonnes of dry solids and that 4,174 t (11%) were recycled to land, 18,722 tonnes (49%) were landfilled and 15,000 tonnes unspecified. There was no incineration of urban sewage sludge.

## ITALY

### Regulatory framework

In Italy, waste management is regulated under the so called “Ronchi-Decree” – the Waste Management Act 22/77 (*Decreto Legislativo No. 22*), published on February 5<sup>th</sup> 1997 which was modified several times. The Waste Act 22/97 sets many provisions for promoting the production of RDF to be exploited at existing industrial facilities (i.e. cement works). The Act introduces a simplified procedure (a simple notification to the provincial authority before starting the activity instead of a full authorisation) for RDF from MSW utilisation in both dedicated and industrial plants. The activity is defined as a recovery operation R1 as specified in Waste Framework Directive 91/156/EC.

The Ministerial Decree of February 5<sup>th</sup> 1998 is the most important regulation regarding co-incineration. The Decree specifies Articles 31 (*Determinazione delle attività e delle caratteristiche dei rifiuti per l'ammissione alle procedure semplificate*) and 33 (Operazioni di recupero) of the Ronchi Decree.

The incineration of municipal waste and hazardous waste is regulated in the Ministerial Decree 503 (19<sup>th</sup> of November 1997) and 124 (25<sup>th</sup> of February 2000) respectively. The limit values for air emissions for co-incineration in Italy are presented in Table B.27.

In Italy, the definition of RDF has changed and more stringent quality requirements for RDF were introduced. Until 1998, the English term “RDF” was used. In the new Decree of February 5<sup>th</sup> 1998, the name was changed to “CDR” – *combustibili derivato dai rifiuti*. Simultaneously, the minimum requirements for secondary fuels were amended and a new list of wastes which could be used as secondary fuels was published. Many waste fractions formerly used as secondary fuels are now excluded as they do not comply with the new requirements. The requirements are for specific pollutants (i.e. chlorine and heavy metal) but also for a minimum calorific value ranging between 6,000 kJ/kg for sludge and 16,000 kJ/kg for coal (Table B.28). Under the 1998 Decree, CDR can be produced from MSW and from industrial waste up to 50% w of the total amount. Industrial wastes that can be used for RDF production are plastics, textiles, paper and cardboard and tyres under specific conditions. Other industrial wastes such as green waste from agriculture and forestry activity, waste from wood industry, waste from textile industry, dried sewage sludge (urban and industrial), coal residues can also be used as fuel substitute under the same simplified procedure.

In Italy, waste derived fuel is viewed as an important component of an integrated waste management strategy. It allows for already existing facilities (e.g. cement plant) to be used as outlets for waste rather than having to build new incineration facilities and it offers a more flexible waste management option over mass-burning incineration as it does not preclude growth in recycling in the future. It was reported that waste derived fuels were considered as renewable energies and that energy producers co-combusting these secondary fuels could be certified to be using ‘green energy’. However, these materials are still considered to be ‘waste’ and can only be burnt in facilities under certain conditions.

**Table B.27 Emission limits for co-incineration in cement kilns in Italy (E C 2000 as reported by EA 2001)**

Parameter	Limit value <sup>1)</sup> (mg/m <sup>3</sup> )
Particulates	50
TOC	Class I – 5 Class II – 20 Class III – 150 Class IV – 300 Class V – 600
HCl	30
HF	5
SO <sub>2</sub>	600
NO <sub>2</sub>	1800
Cd, Tl, Hg	0.2
Se, Te	1
As, Cr, Co, Ni	1
Sb, Sn, Pb, Pd, Pt, Cr, Cu, Mn, V, Rh	5
Cd, Tl, Hg, Se, Te, Sb, Cr, Mn, Pd, Pb, Pt, Cu, Rh, Sn, V	5
Dioxins (ng/m <sup>3</sup> TEQ)	10,000
NH <sub>3</sub>	250

Note:

1 Limits are required for specific organic compounds divided into five classes of danger

**Table B.28 Quality standards for RDF in Italy**

Parameter	Limit value
Moisture	25% max
Calorific Value	15,000 kJ/kg
Ashes	20% (w)
Chlorine	0.9% (w)
Sulphur	0.6% (w)
Lead	200 mg/kg
Copper (soluble)	300 mg/kg
Manganese	400 mg/kg
Chromium	100 mg/kg
Nickel	40 mg/kg
Arsenic	9 mg/kg
Cadmium and mercury	7 mg/kg

## RDF production

As previously mentioned, since 1998 a new Italian Decree has changed the whole RDF and co-combustion market. Consequently, information pre-1998 does not necessarily represent the situation in Italy but on the other hand more recent data are very limited.

In Italy, there are 41 mechanical biological treatment plants (MBT) with a total capacity of 4.3 million tonnes (t). In 1999, around 2.3 million t of MSW (8.2% of MSW arising) were treated in these plants. Only 16 of these MBT plants with a total capacity of 1.5 million t produce a high calorific fraction which complies with the new CDR specifications. In 1999, the quantities of MSW treated amounted to nearly 1 million t (Table B.29). Even though regulatory framework is getting stricter for the use of RDF, there is still a high interest in constructing more plants to produce RDF.

Following a study by Federambiente, it has been estimated that up to 9.4 million tonnes of waste could be treated in CDR-production plants and that a maximum 7.2 million tonnes could be co-incinerated in thermal installations.

**Table B.29 Production capacity of CDR in Mechanical-Biological Treatment plants in Italy, 1999 (ANPA 2001)**

Location	Capacity (x10 <sup>3</sup> tpa)	Quantity treated 1999 (x10 <sup>3</sup> tpa)
Albano Laziale	156	65.5
Aulla	NI	1.9
Bergamo	60	45
Catanzaro	73	42
Ceresara	55	72
Colfelice	187	178
Foligno	62	62
Giussago	40	30
Macomer*	48	35
Parona	146	12
Perugia	150	150
Pieve di Coriano*	55	50
Ravenna*	180	4
Sesto Fiorentino	91	47
Udine	65	28
Viterbo	156	150
<b>Total</b>	<b>1,524</b>	<b>971</b>

Notes:

\* only internal use of CDR

There are other processes and plants producing a high calorific waste fraction in Italy:

- ECODECO produces RDF (similar to Trockenstabilat) in three plants. The use is still not arranged.
- LADURNA/Herhof (Trockenstabilat): a new plant in Venice will start up soon.
- 'Ex-Maserati' plant in Milan: this is the largest plant with a capacity of 350,000 tpa and a recovery rate for RDF of 58%. However this RDF does not comply with the quality requirements for CDR and is currently stored (VKS 2000, de Stefanis, ENEA pers. comm. 2001).
- Pirelli Ambiente produce high calorific value RDF by mixing MSW and tyres. Pirelli is currently developing a full scale production facility outside Milan in Cueno, which will use this process to convert MSW into a clean-burning fuel. Solid waste, old tyres and unrecycled plastic can all be converted in this new process. The authorized capacity depends on the capacity of the cement kiln and will be about 25,000 tpa. Industrial testing of the process is underway now. The group hopes to provide an alternative fuel source for Italy's national coal-fired power generation facilities and private cement kilns in the near future (pers. comm. Mr. Zucchelli 2002). Production will start in September 2002.
- Fisia Italmimpianti: This company is carrying out a contract for the realisation of three RDF production plants and a waste to energy plant in the Regione Campania. They lead an international consortium comprising Impregilo and Deutsche Babcock.

### RDF utilisation

CDR produced in Italy is co-incinerated mainly in cement kilns. There are also plans to use CDR in dedicated incinerators and power plants (Table B.30). According to ENEA (2000), the production of energy from CDR has been calculated to amount to 267.000 tonnes oil equivalent (toe) in 1998.

**Table B.30 Co-combustion of CDR in Italy**

Co-combustion installations	Total	Capacity (x10 <sup>3</sup> tpa)	Quantity (x10 <sup>3</sup> tpa)
Cement kilns	5	NI	c)
Power Plants	3 <sup>a)</sup>	1,200	a)
RDF-incinerator	2 <sup>b)</sup>	NI <sup>b)</sup>	b)
Steel furnace			
Paper Mills			
Biogasifier			
Other			
<b>Total</b>	<b>10</b>		

Notes:

- a) Only tests about co-incineration no full scale operation yet
- b) Under construction
- c) 1.5% energy substitution rate

### Cement kilns:

The only industrial sector with a satisfactory database about CDR co-incineration is the cement industry. In Italy there are currently 61 cement kilns. The use of secondary fuels has changed in the last few years. Before 1998, used tyres (50,000 tpa), plastics and oils were generally co-incinerated.

Currently, there are only 5 cement kilns co-incinerating CDR as secondary fuels (Table B.31). Their total clinker production capacity amounts to 4.6 million tonnes with an overall energy substitution rate of 1.5% while theoretically the co-incineration capacity in cement industry is about 20%. A few plants use animal waste (i.e. bone meal). It is reported that the Italian cement industry has the potential to use the whole quantity of the currently produced CDR (Mr Burattini, AITEC, pers. comm. 2001). In addition, a plant in Milan, Bergamo and Greve-in-Chianti are using (or planning to use) CDR. One plant in Pavia is using CDR and a plant in Cueno is planning to use 25,000 tpa of CDR Pirelli.

**Table B.31 Co-incineration of CDR in cement plants in Italy (CER 2001)**

Location	Production capacity (10 <sup>3</sup> tpa)
Caserta	480
Merone	1,460
Morano	260
Ravenna	380
Robilante	2,000
<b>Total</b>	<b>4,580</b>

### Power plants:

The use of RDF/CDR in Italian power plants is not common. Only three plants are currently testing or considering testing CDR as secondary fuel. The co-combustion capacity of these plants is about 1.2 million tpa.

- ENEL Public company has power plants that use coal and could use some RDF.
- Fusina plant (Veneto): is still undertaking trials with CDR.
- Greve-in-Chianti: This plant was closed because of a lack of contribution from electricity producers.

### Dedicated RDF plants:

There are plans to use CDR in dedicated plants currently under construction in Campania and Calabria as the current capacity of MSW incinerators is not sufficient to deal with any CDR quantity produced (de Stefanis, ENEA pers. Comm. 2001). There are currently 41 MSW incinerators in Italy incinerating about 2.1 millions tpa of MSW (i.e. 7.2% of the MSW arising) (ANPA 2001). Scarlino (province of Grosseto): the plant was built to incinerate CDR, but the plant was not accounted for in the local waste-management planning process, so permission

was refused and the plant is therefore not operational. Energy recovery from refuse-derived fuels and industrial waste is still possible. The fluidised bed plant can convert approx. 120,000 tonnes of residual materials, including industrial waste from wood and textiles industries, biomass and RDF, into 113 million kW/y of electrical energy. It was completed in 1999 (source: ENI)

#### Paper Mills:

Cartiere Burgo Paper Mill, in Mantova, was the first fluidised bed combustor in Italy to burn paper sludge (start up date October 1999), output rating 46 Mbtu/hr, 30,500 LB/hr, 750 psi, saturated steam. (Source: EPI – Energy Products of Idaho).

## LUXEMBOURG

### Regulatory framework

Companies authorised to co-incinerate refuse derived fuels are subjected to the Law of 10 June 1999 on classified installations. The competent authority for issuing licence is the Ministry of Environment. The regulatory authority which inspects and carries out any monitoring is the Administration of the Environment. The air emission limit values for co-incineration in Luxembourg is given in Table B.32.

**Table B.32 Emission limits for co-incineration in cement kilns in Luxembourg (Impel 1998 as reported by EA 2001)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	20	Daily average	C+S
	50	Half hourly average	
TOC	30	Half hourly	S
HCl	30	Half hourly	S
HF	5	Half hourly	S
SO <sub>2</sub>	100	Half hourly	S
NO <sub>2</sub>	800	Daily	C+S
	1600	Half hourly (100%)	
	960	Half hourly (97%)	
Cd, Tl, Hg	0.2	Half hourly	S
Sb, Pb, Cr, Cu, V	5	Half hourly	S
As, Co, Ni	1	Half hourly	S
Total heavy metals <sup>3)</sup>	5	Half hourly	S
Dioxins (ng/m <sup>3</sup> TEQ)	0.1	6 hours average	S
CO			S
CO <sub>2</sub>			S
Temperature			C+S

Notes:

- 1 Reference conditions: 10% oxygen, 0°C, 1013 mbar, dry.
- 2 C – continuous, S-spot
- 3 Cd, Hg, Tl, Se, Te, Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, F

### RDF production and utilisation

There is no production of RDF from MSW in Luxembourg. There is only one cement company in Luxembourg, the company Intermoselle Sàrl which co-incinerates secondary fuels since 1998. The cement company only co-incinerates shredded tyres supplied by a specialist company based in Belgium. It was not possible to receive information on the quantities used. However, it was reported by EA (2001) that the percentage of tyres used varies between 5 and 10% due to problems with chlorine and sulphate content in tyres. It was also reported that the tyres were supplied free of charge.

## THE NETHERLANDS

### Regulatory framework

Waste co-incineration in the Netherlands is regulated under the Environmental Protection Act. The emissions of incineration plants are regulated by the '*Besluit luchtemissies afvalverbranding – Bla*', (emissions of waste incinerators), the '*Nederlandse emissie Richtlijnen – NeR*' (Dutch emission guideline) and by the '*Besluit emissie eisen stookinstallaties – Bees*' (Emission Limits (Combustion Plants) Decree- Air Pollution Act).

Landfilling of MSW is more tightly restricted than in most other Member States. Under Article 1 of the '*Besluit stortplaatsen en stortverboden afvalstoffen*' (Landfill Decree), a long list of waste (i.e. waste paper, waste packaging, waste wood, sewage sludge, green waste and household waste) cannot be landfilled. There is a landfill tax of 70 €/t waste to equalise the costs between landfill and incineration.

The competent authorities for issuing permit for co-incineration of waste are the Provinces who in the case of hazardous waste must obtain a permit from the national government (EA 2001). Typical emission values for co-incineration in cement kilns in the Netherlands are given in Table B.33 below.

The Government initiated the "EWAB – Energy from Waste and Biomass" programme in 1989. The objective of the EWAB programme is to stimulate the use of biomass and waste as energy source in order to save fossil fuels. The target is to achieve about 120 PJ energy from biomass or other sources such as waste. In 1998, more than 23 PJ/a energy was recovered in waste incinerators and the Dutch government has planned to achieve 45 PJ/a primary energy saving by means of waste incineration by 2020. The co-combustion of RDF in coal-fired power station should rise from 3 PJ in 2000 up to 18 PJ in 2007. There is a similar incentive in the '*Landelijk Afvalbeheersplan – LAP*' (rural/municipal waste management plan) to divert waste to incineration (LAP 2001).

**Table B.33 Emission limits for co-incineration in cement kilns in the Netherlands (Impel 1998 as reported by EA 2001)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	15	Daily average	C
	30	Half hourly (100%)	
	18	Half hourly (97%)	
TOC	40	Half hourly	S
HCl	10	Half hourly	S
HF	1	Half hourly	S
SO <sub>2</sub>	90kg/h	10 day average maximum	C
	375 tpa		
NO <sub>2</sub>	1300	Daily	C
	2600	Half hourly (100%)	

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
	1560	Half hourly (97%)	
Cd, Tl, Hg	0.05	Half hourly	S
Other metals <sup>3)</sup>	1	Half hourly	S
Dioxins (ng/m <sup>3</sup> TEQ)	0.1		
NH <sub>3</sub>			
CO			S
CO <sub>2</sub>			
Temperature			C+S

Notes:

- 1 Reference conditions: 11% oxygen, 273K, 101.3 kPa, dry.
- 2 C – continuous, S-spot
- 3 Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn, Se, Te

### RDF production

In the Netherlands, the total quantities of non-hazardous waste (including domestic, commercial and industrial waste and construction and demolition waste) amounted to 7.9 millions in 1998. In addition, 1.7 million tpa of sludge and 0.4 million tpa of hazardous waste were generated bringing the overall potential for combustible waste in the Netherlands to about 10 million tpa. It is believed that the total potential of high calorific waste in the Netherlands equals 23 million tpa.

RDF pellets are produced from the mechanical recovery of plastics/paper fractions (PPF) of household waste and this is widely practised on a commercial scale by the Dutch waste company VAM. There are 13 plants producing RDF from MSW in the Netherlands. Their total input capacity is about 2 million tpa (Table B.34) with a 35% production rate (700.000 tpa) of RDF. There are plans for a dozen more plants to be constructed bringing the overall input capacity up to 3.3 million tpa (Table B.35).

**Table B.34 Production of RDF in the Netherlands, 2001 (van Tubergen, TAUW, pers. Comm. 2001)**

Plant	Product	Maximum input capacity (10 <sup>3</sup> tpa)
Essent Wijster (GAVI)	Fluff	840
VAR Wilp	Pellets	235
VAGRON Groningen	Soft-Pellets	230
Essent Wijster (BAS)	Fluff	150
Baetsen Veldhoven	Fluff	100
BTC Zoetermeer	Soft-Pellets	100
Shanks (Icova) Amsterdam	Pellets	100
SITA (Watco) Helmond	Fluff	100

<b>Plant</b>	<b>Product</b>	<b>Maximum input capacity (10<sup>3</sup> tpa)</b>
Essent Born	Fluff/Ballen	70
Kappa Roermond	Pellets	30
De Jonge-Sebra Vlissingen	Pellets/Fluff	20
SITA (Watco) Rotterdam	Pellets/Fluff	15
Gebr. Hummel Leek	Fluff	10
<b>Total</b>		<b>2,000</b>

**Table B.35 Planned RDF plants in the Netherlands (van Tubergen, TAUW, pers. Comm. 2001)**

<b>Plant</b>	<b>Product</b>	<b>Maximum input capacity (10<sup>3</sup> tpa)</b>
<b>Under construction:</b>		
Watco, Rotterdam	Floc	300
Afvalsturing Friesland, De Wierde	Floc/Balls	230
Shanks, Moerdijk,	Pellets	100
GP Groot, Alkmaar	Floc	50
Sub-total		680
<b>In planning:</b>		
EPM, (Icopower, BTC) Moerdijk	Hard-Pellets	115
BTC, Emmeloord	Soft-Pellets	95
AVR Rozenburg	Soft-Pellets	65
AlBra Groenlo, Groenlo	Soft-Pellets	65
AlBra Winschoten	Soft-Pellets	65
AlBra,	Soft-Pellets	65
AlBra,	Soft-Pellets	65
Watco, Rozendaal	Floc	60
Watco Veenendaal 2e lijn	Floc	50
Sub-total		645
<b>Total</b>		<b>1,325</b>

## RDF utilisation

Waste incineration capacity in the Netherlands is insufficient for current levels of waste arisings. Several mono-streams (demolished wood, paper rejects, vegetables, fruit and garden (VFG) waste and others, are currently taken by power plants for co-firing, and waste traders/processors (increasing export of RDF pellets and waste wood).

An overview of plants co-incinerating RDF in the Netherlands is given in Table B.36 below. There are around 30 industrial facilities authorised to use secondary fuels with a total capacity of about 5 million tpa and a current utilisation of above 0.7 million tpa.

The main industrial sector relying on secondary fuels is the power industry, as the paper industry only co-incinerates their own production residues and the cement industry with a single plant plays only a secondary role. However, there are other initiatives amounting to a capacity for secondary fuels of about 2 million tpa using primarily gasification or pyrolysis for a wide range of wastes. The current available capacity for utilisation of secondary fuels is however about half the current reported quantities of high calorific wastes available.

**Table B.36 Co-incineration of secondary fuels in the Netherlands**

Co-incineration installation	Number	Capacity (x10 <sup>6</sup> tpa)	Quantity (x10 <sup>6</sup> tpa)
Power plant		3.2	0.55
- direct combustion	6		
- indirect combustion	1		
Cement kiln	1	0.13	0.13
Paper mill <sup>1</sup>	0	NA	NA
Steel furnace	0		
Biogasifier	3	NI	NI
Other	19	2	NI
<b>Total</b>	<b>30</b>	<b>5.33</b>	<b>&gt;0.7</b>

Note:

<sup>1</sup> Paper Mill Bennekom uses only own production waste in furnace

### Power plant:

The main secondary fuels co-combusted in seven coal-fired power plants in the Netherlands are petcoke, waste wood, paper sludge, sewage sludge, solvents and biomass waste (e.g. chicken manure) (Table B.37). The current capacity for co-incineration of secondary fuels in power plants is estimated to be about 3.2 million tpa with about 550,000 tpa of RDF being used equivalent to about 5% of coal energy substitution. There are plans to co-incinerate secondary fuels in several other power plants. One of the targets of the EWAB programme (see above), is to substitute about 13% of the coal energy requirement of power industry by waste.

**Table B.37 Co-incineration in power plants in the Netherlands (Croezen, CE-Delft, pers. Comm. 2001 and van Ree *et al* 2000, 2001)**

Power plant	Secondary fuel	Quantity (10 <sup>3</sup> tpa)	Substitution rate	
			(10 <sup>3</sup> tpa)	(% energy)
Amer-8	Paper sludge	75	4,5	0.3
Amer-9	Demolition wood Petcoke	150	70	5
Borssele-12	Phosphorous gases Paper sludge Sewage sludge industrial organic waste Waste wood	(50 Nm <sup>3</sup> /a)	(23)	(3)
Gelderland-13	Demolition wood (Quality A and B)	60	45	3
Hemweg-8	Sewage sludge	75	38	3
Maasvlakte- 1 & 2	Liquid industrial organic residues Petcoke Biomass pellets/ Chicken manure	150 / 40	30 / 23	5 / 4
<b>Total</b>		<b>550*</b>	<b>233,5</b>	

Note: \* Without phosphorous gases

#### Cement kilns:

In the Netherlands, there is only one cement kiln, ENCI based at Maastricht, which has a capacity of clinker production of 0.9 million tpa. There are 2 more plants which grind imported clinker. The ENCI cement kiln uses typical secondary fuels (Table B.38). After a long permitting procedure, the cement plant was authorised in 1998 to co-incinerate rubber, tyres, PPDF (paper and plastic derived fuel), all sludge except hazardous sludge and animal manures. Maximum emissions are specified and the mixing rule is not applied.

The quality of secondary fuels are carefully checked and ENCI carries out analyses once a week (EA 2001). About 15,000 tpa of shredded tyres were used until the end of 1998 but this practice has been discontinued due to lack of consistency in size of the shredded tyres supplied (EA 2001). It is reported that sewage sludge and PPDF are supplied free of charge and that a gate fee is applied to paper sludge (EA 2001). The total quantities of secondary fuels excluding pet coke and coal shale co-incinerated in cement kiln amounted to 48,000 tpa.

**Table B.38 Co-incineration of secondary fuels in cement kilns in the Netherlands (ENCI 2001)**

Type of waste	Quantity (x10 <sup>3</sup> tpa)
Coal shale	52
Petcoke	34
Dried sewage sludge	27
Solvent	10
Paper and plastic pellets	7
Paper sludge	4
Rubber chips	0.4
<b>Total</b>	<b>134.4</b>

\* operating time of 7,500 hours per annum

Other plants:

The 19 “other” plants are not multi-fuel. They are mainly gasification or pyrolysis systems for waste wood, residues from waste shredders, RDF, paper sludge, solvents, coffee residues and chicken manure, with a total capacity of about 2 million tpa (Table B.39).

**Table B.39 Gasification and pyrolysis of secondary fuels in other plants in the Netherlands (De Vries et al 2000)**

Location	Biomass / waste type	Capacity [1000 t/a]
Akzo – Rotterdam	Solvent	5-8
Texaco- Pernis	Solvent	100
Cedem – Duiven	Paper sludge	130-200
Avira/BFI – Duiven	RDF	200-300
Gibros/Vermeer – Vijfhuizen	RDF	100-125
VAR Twello	RDF	
Heijmans	Shredder waste	25
North Refinery-PEC – Groningen	Shredder waste	30
PROAV-Gibros/PEC Botlek	Shredder waste	110-165
UNA/ENW/Adin energo – Amsterdam	Shredder waste	40
Edon/Stork/	Wood	50
ENECO	Wood	8

<b>Location</b>	<b>Biomass / waste type</b>	<b>Capacity [1000 t/a]</b>
NUON-Lelystad	Wood	24
De Lange – de Lier	Wood	7
PNEM Cuijk	Wood (fresh)	250
HIS Schijndel	Wood	12
Pyrovac-UNA –Amsterdam	Wood	30-60
Sarabee/Douwe Egberts –Joure	Coffee residues	
EPZ-PMG-DEP	Chicken Manure	300

## PORTUGAL

### Regulatory framework

Most of the progress in Portuguese legislation regarding waste has been made between 1996-1998, with the national transposition of EC Directives and the set up of specific plans.

The relevant regulations dealing with co-incineration of industrial wastes are:

- **Law 20/99** of the 15<sup>th</sup> of April regarding industrial waste treatment introduces Strategic Plan for Industrial Waste Management -PESGRI and repeals any previous Law on co-incineration of hazardous wastes
- **Decree Law 120/99** of the 16<sup>th</sup> April creates a special system for the control and environmental accounting about co-incineration
- **Decree Law 516/99** of the 2<sup>nd</sup> of December approves the Strategic Plan for Industrial Waste Management -PESGRI 99
- **Resolution of the Council of Ministries 92/2000** of the 20<sup>th</sup> of July supports co-incineration in cement kilns whenever there is no possibility for regeneration or recycling.

There is currently a strong public opposition and a heated debate on co-incineration of industrial waste in cement kilns in Portugal following the adoption in 2000 of a new law on co-incineration, the **Resolution of the Council of Ministries 92/2000**. The Resolution is based on the main results and recommendations of the Independent Scientific Commission. This reports that wastes such as used oils, ashes and fly ashes from thermal-electric processes, pyrites, used tyres etc. can be profitably co-incinerated within cement kilns with an important energy recovery contribution and negligible pollution (when compared with other traditional combustion processes). The latest plan for industrial waste management -PESGRI 2001 recently approved is trying to give an answer to most of the questions raised by co-incineration, but is also provoking strong public reactions and its possibilities of application are not very clear.

The air emission limits as specified in permit for co-incineration in cement kilns in Portugal are given in Table B.40.

**Table B.40 Emission limits for co-incineration in cement kilns in Portugal (Impel 1998 as reported by EA 2001)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	77	Daily	C
TOC	50	Daily	
HCl	10	Daily	
HF	1	Daily	
SO <sub>2</sub>	315	Daily	

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
NO <sub>2</sub>	1300	Daily	C
Cd, Tl,	0.1	Daily	
Hg	0.2	Daily	
Other metals <sup>3)</sup>	2/1	Daily	
Dioxins (ng/m <sup>3</sup> TEQ)	0.1	Daily	
CO			C
CO <sub>2</sub>			

Notes:

- 1 Reference condition: 10% oxygen
- 2 C – continuous, S-spot
- 3 Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn

### RDF production and utilisation

Portugal has made great progress in recent years in quantifying industrial waste production. Inventories have been carried out by different companies (private and public), arriving at a recent figure of about 20 millions tonnes of industrial non-hazardous waste and 213,500 tonnes of hazardous industrial waste.

The official organisation INETI has been working for several years on research and development of existing technologies for RDF production and is the only reference for the sector.

The regulations introduced in the last few years are now partially operative although substantial effort is still needed to define a better strategy for industrial waste management. The result of this uncertain situation is that many industries do not yet declare their residues and that large proportions of non-hazardous industrial wastes are still disposed of at MSW landfills (in separate areas). There are 21 MSW authorised landfills in Portugal.

Regarding hazardous wastes, 32% are subjected to physical-chemical treatment, 25% are landfilled or dumped at sea and the remainder is exported for valorisation to other member states (mainly Spain and Germany).

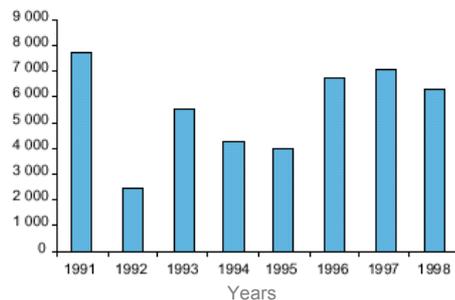
## Used oils

The only official dataset for used oils refers to a new company dedicated to the valorisation and recycling of used oils, which is located in the area of Torres Novas as an experimental project, and which is expected to enter into full operation in 2002. The company is a Portuguese-Spanish joint-venture which applies an existing technology to obtain a diesel similar to diesel oil and a second lighter fuel, to be used on-site to produce electricity.

This plant is the fourth working in Europe (the other three plants operate in Spain) and is licensed to treat around 16,000 tpa of used oils (around half of the Portuguese production). The plant will produce about 55 GW/hour of electricity, of which only 2 GW/hour will be used internally and the rest will be sold to the public grid. The plant will have two lines; each one will treat 10,000 tpa of used oils.

## Cement kilns

There are 6 cement plants in Portugal (Impel 1998 as reported by EA 2001). The Portuguese cement industry has combusted different types of residues both as material or fuel substitutes (e.g. fly ash, pyrite ashes, small metal pieces and used tyres). Only one plant, SECIL, is co-incinerating used tyres as secondary fuels. The quantities of used tyres co-incinerated in the cement plant have varied between 2,500 and 8,000 tpa (Figure B.1) (MoE 2000).



**Figure B.1 Quantities of used tyres co-incinerated in cement industry in Portugal (tpa) (MoE 2000)**

## SPAIN

### Regulatory framework

Since the creation of the Spanish Environment Ministry in 1996, there has been significant progress in the transposition of EC directives into Spanish laws. In general terms it is important to underline that Spanish Constitution recognises and transfers all environmental competence to the 17 Autonomous Regions which have legal capability to set up their own legislation.

The energy valorisation of almost all waste is contained and regulated by the following regulations;

#### Waste incineration regulations

The Spanish regulations on waste incineration are based on the Royal Decree 1217/1997 of the 18<sup>th</sup> of July and the modifications to the Royal Decree 1088/1992 of the 11<sup>th</sup> of September, relating to hazardous and municipal waste incineration respectively. The same limits for dioxin emissions have been set for incineration of both MSW and hazardous wastes.

Spain has transposed the EC requirements for hazardous waste co-incineration as defined in 1994 Hazardous Waste Incineration Directive. If the waste fuel is less than 40% of the total, no specific operational plant or conditions are required (temperature, time, and oxide concentration, additional burners and system incorporating waste, or wastewater management) as specified in the 1994 Directive.

#### The National Plan for MSW

The Ministry of Environment has set up, in collaboration with the Autonomous Regions, the First National Plan for MSW, to be applied between 2000-2006. This instrument, operative since January 2000, aims to increase waste prevention, separate collection, reuse, recycling and valorisation.

The target for the recovery of energy from wastes is 9% and 17.7% by the end of years 2001 and 2006.

The Plan has been structured with a specific programme against each objective. Those regions or local authorities to which no other possible recovery/recycling models can be applied are expected to undertake a programme of energy recovery from wastes (*PNVE – Programa Nacional de Valorización Energetica*).

#### National Plans for Special Wastes

The specific National Plan for Special Wastes regulates the treatment of a number of wastes including used oils and tyres. Subsidies are provided for the creation of companies specialising in the treatment and energy recovery from these specific wastes.

## Cement kilns

One of the most important laws in relation to waste management and waste valorisation in cement kilns is the **Royal Decree 833/1988 of the 20<sup>th</sup> July 1988** on hazardous waste which develops the basic Law 20/1986 of the 14<sup>th</sup> March 1896.

On the basis of these laws, any cement plant which wants to valorise hazardous wastes has to obtain special permissions and authorisations. Moreover the installation for the storage and treatment of hazardous wastes has to be controlled by an Environmental Assessment (Royal Decree 1302/1986 and Royal Decree 1131/1988). The authorisation is valid for a period of 5 years and can be renewed for 2 more periods of each of 5 years. Table B.41 presents air emission limit values for cement plants co-incinerating waste derived fuels in Spain.

**Table B.41 Emission limits for co-incineration in cement kilns in Spain (Impel 1998 as reported by EA 2001a)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	10	Daily	S
	30	Half hourly	
TOC	10	Daily	
	20	Half hourly	
HCl	10	Daily	
	60	Half hourly	
HF	1	Daily	
	4	Half hourly	
SO <sub>2</sub>	50	Daily	
	200	Half hourly	
NO <sub>2</sub>	300 ppm (616 mg/m <sup>3</sup> )	Daily	
Cd, Tl	0.05		
Hg	0.05		
Other metals <sup>3)</sup>	0.5		
Dioxins (ng/m <sup>3</sup> TEQ)	0.1		
CO			C
Temperature			C

Notes:

- 1 Reference conditions: 11% oxygen, 273K, 101 kPa, dry
- 2 C – continuous, S-spot
- 3 Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn

## Used oils

The management of waste oils is regulated by the **Ministry Ordinance of the 28<sup>th</sup> February 1989** (BOE n.57 of the 8.3.89) as a transposition of the EC Directive 75/439 of the Council of the 16<sup>th</sup> July modified with the 87/101/EC of the 22<sup>nd</sup> December 1996, relative to the used oil management.

## Plan for the promotion of Renewable Energies in Spain

The Plan for the promotion of renewable energies was approved on the 30<sup>th</sup> of December of 1999 and covers the period 2000-2010. The document presents the efforts of several public organisations for the creation of a strategy aiming to apply Kyoto objectives by achieving, by 2010, a minimum of the 12% of primary energy consumption supplied by renewable energy sources (RES).

All traditional sectors of renewable energy sources are covered (wind, solar PV, solar thermal and thermal-electric, hydro, biomass, biogas, biofuels and MSW valorisation) but no mention has been made of RDF utilisation and promotion, indicating that this source is not officially considered as potential renewable energy.

## **RDF production**

One of the few official sources of information concerning this issue is a report commissioned by EMGRISA (one of the biggest Spanish waste treatment companies).

The main conclusions of this report, indicate that in Spain there are as many types of waste derived fuel as pre-treatment centres, in the sense that their composition varies depending on characteristics of local production and legislation and depending on requirements from each cement plant for cement quality.

In Spain four types of RDF have been identified (see Table B.42);

- Fuel derived from liquid waste (LWDF)
- Fuel derived from sawdust and paper residues mixed with solvents (SWDF)
- Fuel derived from MSW waste (GDF)
- Fuel derived from used tyres (TDF)

**Table B.42 RDF characteristics in Spain**

LWDF	SWDF	GDF	TDF
Liquid contaminated waste, organic liquid waste (named COMBSU) containing different types of wastes in suspension	Sawdust (50%) with different paper residues in small pieces. Organic absorbers	Dry fraction of the domestic waste Residues of selection centres Residues which can be inflated into the incineration zone Small briquettes to be introduced in the extreme of the kiln	Ground tyres, of size acceptable for kiln feeding
<p><i>Medium energy value liquid:</i> between 8000 and 22000 KJ/Kg , hydrocarbons from oil industry , waste from organic synthesis and residues from distillation These are oil wastes from metallurgy</p> <p><i>High energy value liquid:</i> more than 22000 KJ/Kg residues oils and sediments from distillation</p> <p><i>Low energy value liquid:</i> between 3000 and 8000 KJ/Kg residues from perforation activities, waste water from cosmetic industry , industrial washing waste water , liquid wastes from chemical industry</p>	<p>Not sticking dust, easy to inject Size: 0-20 mm Density: 0,6 Calorific content: 12- 16 MJ/Kg Ashes content : less than 30% Humidity: 25% average Chlorine: 0.45% Sulphur: 3% Heavy metals: Hg: &lt;10 ppm Cd, Hg, Ti: &lt; 100 ppm Cu: 20000 ppm Zn: 20000 ppm As, Ni, Se, te, Cr, Pb, Sn, V: 2500 ppm</p>	<p>Thickness: 30-50 mm Density: between 0.15 and 0.3 Calorific content : 15-20 MJ/Kg Ash content: 10% Humidity: between 10% and 30% Sulphur: more than 0.10% Heavy metals: less than 500 ppm</p>	<p>Big pieces with a lateral lengths of 150 mm Size: 25 mm Density: 0.3 (if not compacted) Calorific content 30 MJ /kg Ash content 15% (iron 15%, Zinc oxide more than 2%) Humidity: negligible No chlorine Sulphur: average 1% Carbon 20%, elastomers 45% Hydrocarbons: 10%</p>
<p>Sludge: between 6000 to 33000 KJ/kg Sediments of paintings, oil sludge from the steel industry , hydrocarbons sludge from the oil</p>			

LWDF	SWDF	GDF	TDF
<p>processing industry</p> <p>Solid: 6000 to 25000 kJ/Kg: filtration soil, impregnated sawdust, residue from powder detergent</p> <p>Liquid which can be pumped at room temperature</p> <p>Size: less than 3mm</p> <p>Density:0,9 to 1</p> <p>Viscosity less than 1 poise</p> <p>Calorific content 15000 kJ/Kg</p> <p>Ash content: 5-10%</p> <p>Humidity:45%</p> <p>Chlorine max. 0,5%</p> <p>Sulphur:0,4% average</p> <p>Point of inflammation: less than 55%</p>			

## Used oils

Approximately 500,000 tpa of used oils are generated in Spain of which around 60% are reprocessed and used in the automotive industry or other industry. The remaining 200,000 tpa is collected and re-used in different ways;

- Recycling (mainly production of asphalt derived materials based on the paraffin contained in the used oils).
- Energy valorisation (as thermal energy in cement, brick and ceramic plants) or in power production.

## **RDF utilisation**

In Spain, secondary fuels have been used for a number of years by the cement and brick industry.

### Cement kilns:

In 1995 there were 37 cement plants where clinker was produced in Spain (E C 2000 as reported in EA 2001). From some additional data published by EMGRISA, at the end of year 1997 there were eleven cement plants with authorisation for using secondary fuels in their production processes located in seven different Spanish regions (Table B.43). Secondary fuels include used tyres, solvents and waste wood. The energy contribution of secondary fuels amount to 1.2% of total energy demand of the Spanish cement industry (OFICEMEN 2000). The quantities of secondary fuels used in cement industry in Spain are reported to have increased from about 9,000 tonnes in 1996 to about 40,000 tonnes in 2000 (Table B.44).

**Table B.43 Co-incineration of secondary fuels in cement kilns in Spain (1997)**

<b>Region</b>	<b>Owner</b>	<b>Localisation (Province)</b>	<b>Type of waste</b>
Andalucia	HISALBA	Gador (Almeria) Jerez (Cadiz) Carboneras (Almeria) Torredonjimeno(Jaen)	Used oils Used oils Used oils Biomass (not specified)
Asturias	Cementos Tudela Vegun	Tudela Vegun (Oviedo) Aboño (Oviedo)	Used oils Used oils
Baleares	Cia Valenciana de cemento Portland	Mallorca	Used Oils Biomass (wood)
Castilla La Mancha	Valenciana de cemento	Yepes (Toledo)	Mixture of solvents
Murcia	HISALBA	Lorca (Murcia)	Used oils and solvents
Valencia	Valenciana de Cementos	San Vicente de Raspei (Alicante)	Used Oils
Pais Vasco	Cementos Lemona	Lemona	Used tyres

**Table B.44 Trends in secondary fuel co-incineration in cement industry in Spain (OFICEMEN 2000)**

<b>Secondary fuel</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>
Waste wood	3,474	3,321	491	3,578	1,832
Tyres		2,101	3,246	12,175	12,900
Sawdust		1,921	4,235	7,831	5,367
Used oil	5,400	4,526	7,600	10,971	8,825
Other				5,266	10,415
<b>Total</b>	<b>8,874</b>	<b>11,869</b>	<b>15,572</b>	<b>39,821</b>	<b>39,339</b>

Brick industry:

The brick industry sector has a very long tradition of energy valorisation of several types of wastes in their production processes, using them in three main ways:

- Waste used directly as a fuel
- Waste incorporated in the clay body acting as a fuel
- Waste lowering the total quantity of fuel required.

Although not accurately quantified it is known that wood wastes/residues and sewage sludge have been used as supplementary fuels by the brick industry, for example:

- wood residue arising from industrial processes (wood particles) fed through a hopper and conveyed to a mill and then to fuel injectors in an Hoffmann kiln;
- tree prunings used for hot air production for the dryer, replacing about 714 toe year of energy;
- milled olive stones (1-3 mm) a residue of the olive oil production, are used to generate hot air for the dryers and as an indirect fuel and pore forming agent added to the clay mixture. 1997 data indicate approximately 10,000 t/year are used of which 6,000 t directly burned to produce hot air for the dryers and 4,000 t are added to the clay mixture;
- sewage sludge is added to the clay mixture in a project carried out in the region of Catalonia. No quantities have been reported but the only data refer to energy savings of around 7%.

## SWEDEN

### Regulatory framework

In Sweden, the main law for co-incineration is SFS 1997:692 on the Incineration of Hazardous Waste. The emission limits are the same as those specified in the 1994 Hazardous Waste Incineration Directive however limits for each plant are specified in the permit on a case by case basis by the licensing authority, the National Franchise Board (EA 2001). The air emission limits for co-incineration cement works in Sweden are given in Table B.45. These limits were reported to have been made more stringent for SO<sub>2</sub> and NO<sub>x</sub> when reported in BREF on cement industry (EA 2001).

**Table B.45 Typical emission limits for co-incineration in cement kilns in Sweden (Impel 1998 as reported by EA 2001)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	50-150	Monthly	C
TOC	20	3 hour	
HCl	2	90 minutes	
HF	0.2	3 hour	
SO <sub>2</sub>	1700 200 (sulphur rich raw materials) <sup>3)</sup>	20 monthly	C
NO <sub>2</sub>	400-1600 200 <sup>3)</sup>	Monthly	C
Cd	0.0002	3 hour	S
Tl	0.006	3 hour	S
Hg	0.001	3 hour	S
Sb	0.004	3 hour	S
As	0.01	3 hour	S
Pb	0.04	3 hour	S
Cr	0.1	3 hour	S
Co	0.004	3 hour	S
Cu	0.06	3 hour	S
Mn	0.16	3 hour	S
Ni	0.065	3 hour	S
V	0.01	3 hour	S
Sn	0.08	3 hour	S
Dioxins (ng/m <sup>3</sup> TEQ)	0.1		
NH <sub>3</sub>			S

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
CO			C
CO <sub>2</sub>			S
Temperature			C

Notes:

1 Reference conditions: 11% oxygen, 273K, 101 kPa, dry

2 C – continuous, S-spot

3 Figures given in European BREF note

## RDF production

The average household waste production in Sweden amounts to 300 kg/person/annum, of which 50% is used as secondary fuel. The most energy dense part of the MSW is sorted out and further processed to a refined waste fuel, so called RDF (Refuse Derived Fuel). The average energy content of household waste is 2.8 kWh/kg. The total amount of household waste used as fuel is approximately 1.35 million tonnes per annum (tpa).

The major part of the industrial waste is currently not used although as much as half the quantity could be used for energy production. Approximately 350,000 tpa of the industrial waste is used as fuel. The average energy content of waste is about 4.2 kWh/kg.

Of the total amount of 1.7 million tonnes industrial and household waste that is incinerated per year in Sweden, about 4.2 TWh energy is produced as heat (4.1 TWh) and electricity (140 GWh).

## RDF utilisation

Secondary fuels are used in district heating plants and in cement kilns in Sweden. No data was reported for the paper industry which combusts its own production residues.

### Power plant:

Energy recovery in district heating plants is widespread in Scandinavia. The plants are normally smaller than power plants operated for electricity generation. Their emission control is not as stringent as for waste incinerators. They are generally equipped only with dust purification. It was reported (CEN TS 118) that in 1999, that around 340,000 tonnes of RDF from MSW and waste wood have been imported in Sweden by waste incinerator companies and district heating plants. There were 8 companies handling these imports from four EU countries and Norway. There was no information on the total quantities of waste co-combusted in these plants.

### Cement plant:

In Sweden, there are three cement works, all of which are authorised to use alternative fuels (Impel 1998) but it is reported that only a small amount (about 6,000 tpa) is currently co-incinerated. The alternative fuels authorised in Sweden are tyres, used oils, solvents and synthetic material (EA 2001). The cement industry uses secondary fuels which have to comply with their own specifications (Table B.46).

**Slithe** – the plant is authorised to use tyres (28,000 tonnes in 1999 (EA 2001)) and paper/plastic waste (2000 tonnes in 1999 (EA 2001)), but only minor amounts of the latter have been used in trials. No secondary liquid fuel (SLF) is used.

**Degerhamn** – the plant, situated on the island of Öland in the Baltic Sea, is authorised to use SLF, which is delivered free of charge. In 1997, 5,891 tonnes was used representing 13.2% of the thermal requirement of the dry kiln. In 1998, the authorisation for the use of SLF was increased to 15,000 tonnes. In addition to SLF, the permit also allowed used oil/water/sediment mixtures to a maximum of 5,000 tpa. The SLF is known as “Specialbränsle A” and has specifications given in Table B.46.

**Skövde** – In November 1992, the cement plant was granted a permit under the Environmental Protection Act by the national Franchise Board to use 25,000 tonnes per year of “Lattbränsle”. During 1997, the plant used 165 tonnes of “Lattbränsle” in trials, a 0.2% thermal substitution of traditional fuels, which was delivered free of charge. The fuel specification is given in Table B.46 below.

**Table B.46 Specification for secondary fuels co-incinerated in cement plants in Sweden**

Parameter	Criteria	
	“Specialbränsle A”	“Lattbränsle”
Calorific value	23.9 – 31.4 MJ/kg	25.1 – 31.4 MJ/kg
Calorific value	5700 –7500 kcal/kg	6000 –7500 kcal/kg
Flash point	< 21°C	< 21°C
Specific density at 15°C	0.9 – 1.1 kg/dm <sup>3</sup>	0.80 – 0.95 kg/dm <sup>3</sup>
Viscosity	Pumpable	1 – 5 cst at 50 °C
Ash content	5 – 10 %	0.6 – 0.8 %
Sediment	N/A	< 5 %
Water	< 30 %	< 10 %
Pour point	N/A	< -15 %
Cl	< 1.0 %	< 1 %
S	N/A	< 0.5 %
Cr	< 300 ppm	< 30 ppm
V	N/A	< 50 ppm
Z	N/A	< 300 ppm
Zn	< 2000 ppm	N/A
Cd	< 10 ppm	< 5 ppm
Pb	< 350 ppm	< 100 ppm
Ni	N/A	< 10 ppm
Hg	N/A	< 5 ppm
PCB	N/A	< 5 ppm

## UNITED KINGDOM

The production of fuel from municipal or commercial waste for co-combustion in dedicated or adapted power plants is rare in the UK while co-incineration of high CV industrial or difficult wastes as secondary fuels is more common.

The UK currently relies on landfill for disposal of 80% of MSW. However, the introduction of recycling/recovery targets and landfill tax should encourage the diversion of landfilled waste to other outlets.

- Landfill tax has been levied on wastes deposited in landfills since October 1996. The current tax rate (March 2002) of 19 euro per tonnes (£12) will increase by 1.6 euro (£1) per tonne each year until April 2004.
- The UK government has committed itself to a policy of reducing landfilled waste to 85% of 1998 levels by 2005, and to energy recovery from wastes as specified in the Waste Strategy 2000 for England and Wales (DETR 2000). Incineration with energy recovery is not eligible for classification as a source of renewable energy, but gasification and pyrolysis are.

### Regulatory framework

Co-incineration of waste derived fuels in industrial processes is subject to authorisation under the Integrated Pollution Control (IPC) Regulations and is regulated by the Environment Agency. Operators must undergo a series of rigorous trials when submitting an application for authorisation. The results and assessment of tests are placed on public registers for public consultation.

The EC Directive 94/67/EC on Hazardous Waste Incineration was implemented in the UK during 2000. Hazardous waste incinerators are generally subject to tighter emission controls than other combustion plant. Complying with the 94/67/EC limits requires pollution abatement technology not required by cement kilns or other industrial combustion processes. For facilities relying on co-incineration of waste derived fuels, the mixing rule applies when thermal substitution of conventional fuels is less than 40%. Above 40% substitution, the emission limits apply in full. When substitute fuels fall under the definition of MSW, the requirements of the MSW Incineration Directive have to be met in full. Typical emissions limits from co-incineration in cement kilns in the UK are given in Table B.47.

**Table B.47 Typical emission limits for co-incineration in cement kilns in the UK (as reported by EA 1999b and 2001a)**

Parameter	Limit value <sup>1</sup> (mg/m <sup>3</sup> )	Control period	Control method <sup>2</sup>
Particulates	40-50	Daily	C+S
TOC	20-50	Daily	S
HCl	10-50 25-60	Daily Half- hourly	S
HF	1	Daily	S
SO <sub>2</sub>	1200-1700	Annual	C+S
NO <sub>2</sub>	1200-1500	Annual	C+S
Cd and Tl	0.1	Daily	S
Hg	0.1	Daily	S
Other metals <sup>3)</sup>	1		S
Dioxins (ng/m <sup>3</sup> TEQ)	0.1		S
CO			C
CO <sub>2</sub>			C

Notes:

- 1 Reference conditions: 11% oxygen, 273K, 101.3 kPa, dry
- 2 C – continuous, S-spot
- 3 Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn

In 1999 the Environment Agency published the "Substitute Fuels Protocol For Use In Cement and Lime Kilns" (EA 1999c). The protocol is publicly available, and has been developed to inform Agency officers, industry and the general public on the "procedures to be followed and considerations to be given on the use of substitute fuels in cement and lime manufacturing processes". The protocol requires a programme of rigorous trials to establish a scientifically sound assessment of the possible environmental impacts on the surrounding area. The protocol identifies arrangements for public consultation, and aims to demonstrate to the public that a thorough and scientific consideration of the issues is undertaken prior to authorisation.

Trials cannot be authorised without a formal application to the Agency for a variation to the plant (IPC) licence, under Section 11 of the EPA 1990. This may either be in the form of two separate applications (one for trials and one for continuous burning) or a single staged application, in which case the Agency would adopt the staged application procedure. Both applications involve public consultation stages prior to the approval of the application. In addition to the procedural and consultative stages the authorisation for a trial must include conditions containing:

- Specification for the substitute fuels;
- Requirements for on-site storage and handling of substitute fuels;

- Requirements for monitoring and sampling to ensure that out-of-specification substitute fuel is not burned in the kiln;
- Monitoring requirements during trial, and release limits.

After a trial, the operator will be required to revert to the originally authorised fuel. Results from the trials are to be compared with those from baseline testing.

Applications for continuous require supporting data to allow the Inspector to evaluate the results of trials. All information is to be contained in a single comprehensive report, therefore negating the need to reference previous documents. Amongst other information, the following are required:

- Comparative data for both baseline testing and trials (analyses of all inputs/outputs and mass balances where possible);
- Dispersion models used, assumptions made and how these were used in comparative assessments;
- Comparative environmental assessment using the Agency's BPEO methodology and dioxin trial methodology (if applicable) or other comparable methodologies;
- Proposal on how the company plans to meet the relevant emission limits;
- Non-technical summary of the application.

The authorisation, if given, will include conditions addressing:

- Specification for the substitute fuel composition and substitution rate;
- Circumstances under which the fuel may not be used;
- Handling, storage, controls for and sampling of substitute fuel;
- Release limits for the baseline and when using substitute fuel;
- Detailed compliance monitoring requirements;
- Reporting requirements

Subsequent to the Substitute Fuels Protocol, the Agency issued a "Consultation on a tyres protocol for use in cement kilns" in May 2001 (EA 2001b). The document "builds upon the experiences gained by both the Agency and other stakeholders in applying the Substitute Fuels Protocol (SFP) to tyre burning trials in cement kilns", and is a supplementary note to the SFP. This supplementary note outlines procedural changes to the SFP. The draft protocol places an emphasis on pre-application consultation by the operator. As a result of doing this, the operator should then address the concerns raised by the public within its application. Consultation on the draft protocol closed in Autumn 2001 and the final document is expected to be published in early 2002.

With the future ban on tyre disposal to landfill (by 2003 for full tyres and 2006 for shredded tyres) following the implementation of the Landfill Directive (CEC 1991), there have been

discussions in the UK between the Used Tyre Working Group (UTWG) and the relevant authorities. The group is promoting tyre combustion as a substitute fuel as a component of UK compliance with Landfill Directive requirements. The Group favours the market approach to tyre recovery, and the Government's response has been to agree. However due to the long lead time required for the drafting and implementation of statutory measures implementing the requirements of the Landfill Directive, work is to continue on drafting measures that may be rapidly implemented should developments in the scrap tyre market fail to fulfil landfill directive requirements

## RDF Production

### Municipal solid waste

In the UK the term refuse derived fuel (RDF) is generally reserved for the processed paper, card, wood and plastic fractions of municipal, commercial or industrial wastes. Typical RDF composition is: 84% paper/board, 11% plastic and 5% glass, wood, textiles and metals etc. Table B.48 summarises typical RDF composition and properties as a percentage of dry material).

In 1999/2000 UK MSW arisings totalled 29.3 million tonnes of which 8% were incinerated with energy recovery (DEFRA 2002). Over 90% of MSW is from household sources.

**Table B.48 Typical RDF properties (adapted from <sup>s</sup>2 1.05, 1995)**

Parameter	Concentration
Water content, weight %	7-28 <sup>1</sup>
Ash content, weight % DM	12.0
Volatile matter % DM	68
Fixed carbon % DM	10
Chlorine content, weight % DM	0.3-1.2
Nitrogen content, weight % DM	0.5-1.0
Phosphorus content, weight % DM	-
Sulphur content, weight % DM	0.1-0.5
Calorific energy MJ/kg DM	18.7
Fluid temperature of ash °C	1050
Bulk density kg/M <sup>3</sup>	75-600 <sup>2</sup>
Heavy metal % DM (excluding zinc)	Trace

Notes:

DM dry material

1. 7-8 for dRDF, 28 for cRDF

2. 75 for cRDF, 500-600 for dRDF

Three plants in the UK produce RDF from MSW as summarised in Table B.49.

- *Reprotech waste derived fuel plant, Hastings* (commissioned in 1988) takes 75,000 tpa of MSW under contract from the local authority. The waste is screened to remove the

<50 mm mainly putrescible fraction. The >50 mm fraction is size-reduced in a hammer mill to <300 mm and the resulting material is air classified into paper/card, dense film/plastic/miscellaneous and a heavier reject fraction (bottles/tins/textiles). Gas-fired drying reduces the initial 30% moisture content to 15%. Following shredding (<25 mm) the material is pelletised and stored or transported to a power generation plant at Slough. Approximately 20,000 tpa of fuel pellets and 2500 tpa ferrous metal are generated annually. Once moisture content is allowed for, this represents 50% diversion of MSW from landfill. Under its IPC authorisation and ISO 9002 accreditation, quarterly quality monitoring of the fuel pellets is undertaken. A typical analysis would be: CV of 17.7 Mj/kg, 0.27% S, 0.3% Cl, moisture content of 10% and ash content <12%. (Watts, *pers. comm.* 2002). The pellets can be handled in a similar manner to coal.

- *Fibre Fuel, Slough.* The current plant manufactures 34,000 tpa of dense fuel pellets. However a new 100,000 tpa plant will be commissioned shortly. Two thirds of the waste input is derived from paper manufacturing wastes and one-third is ultimately from MSW.
  - Paper manufacturing wastes. This includes reject composite paper products which cannot be reprocessed due to aluminium or laminated layers or other coating materials. Much of this is from local industry.
  - MSW. Raw MSW is not handled. Material reclamation facilities (MRFs) which process the dry source-separated recycled fractions of household waste, generate several grades of paper/card. The higher quality paper can be reprocessed by paper mills. RDF is generated from MRF paper and plastic rejects.

The CV and moisture content of the fuel are usually 18-20 Mj/kg and 10-15% wet weight respectively. Occasionally water is added to aid the cubing process. Ash content is <15% (Ellis, Slough Heat and Power, *pers. comm.* 2002)

- *Island Waste Services, Resource Recovery Facility, Isle of Wight.* The plant has a waste input capacity of 70,000 tpa and an output of 35,000 tpa (i.e. approximately 50% recovery). The compressed floc generated by high speed shredding is used in a nearby power generation plant. The floc comprises approximately 80% paper/card; 15% plastics and 5% other combustibles. It is derived from collected household waste (36,000 tpa), commercial and industrial packaging waste (19,000 tpa), wood waste from commerce and industry (10,000 tpa) and wood waste and mixed paper and card from local authorities sites (5,000 tpa). This should result in the diversion of 50% of the island's MSW from landfill.

**Table B.49 Production of RDF in the UK, 2001**

Plant Operator	Annual Plant Capacity (tonne per annum)	Annual output (tonne per annum)	Type of Waste Processed	Plant output
Reprotech, Eastbourne	75,000	17,500	MSW and commercial waste	Dense Pellets
Fibre Fuel, Slough	100,000	34,000 <sup>(a)</sup>	Source-segregated coated papers and cardboard including packaging materials.	Dense RDF (25 – 50 mm cubes)
Island Waste Services, Isle of Wight	70,000	35,000	Domestic waste, commercial/industrial packaging, wood waste, paper/card	Compressed floc
<b>Total</b>	<b>≅250,000</b>	<b>≅ 86,500</b>		

Note:

(a) Plant just commissioned, output for 2001

#### Industrial and commercial waste

Forty eight million tonnes of industrial waste and 30 million tonnes of commercial waste were produced in the UK in 1998/99 (DETR 2000).

#### *Tyres :*

In 1998, 39.5 million tyres (467,650 tonnes) were removed from cars, vans and trucks in the UK; 30% were landfilled, 18% retreating, 18% sent for energy recovery, 18% reused, 10% were recycled and 5% for landfill engineering (EA 2001a). The tyre-fuelled power station in Wolverhampton operated by Elm Energy Ltd (SITA tyre recycling) was designed to handle 90-100,000 tonnes per year and generate 25 megawatts of electricity. Since its closure, the UK are currently landfilling a larger volume of tyres than four years ago. However, with the future ban on tyre disposal to landfill, other outlets will have to be found. The Used Tyre Working Group (UTWG) is anticipating a 90% recovery rate in 2003, with co-incineration in cement kilns a major outlet. The British Cement Association has estimated that the UK cement industry can potentially recover up to 190,000 tonnes of tyres per year (BCA 2000 reported by EA 2001). Typical composition and quality requirement for a cement company is presented in Table B.50.

**Table B.50 Typical composition of fuel derived from tyres (Castle Cement 1996 reported by EA 2001a)**

Parameter	Control limit	Typical composition
CV (Gross) (kJ/kg)	>21,000	>26,000
Sulphur (% w/w)	<2.0	<1.8
Chlorine (% w/w)	<0.2	<0.07
Mercury (mg/kg)	<10	<2
Cadmium and thallium (mg/kg)	<80	<79 <sup>(a)</sup>
Antimony, arsenic, chromium, cobalt, copper, lead, manganese, nickel, tin and vanadium (mg/kg)	<1,200	<640 <sup>(a)</sup>

Note:

a) based upon 75% variability about the mean

In an effort to streamline the process for consenting tyre burning in cement kilns the Environment Agency have proposed to adopt new guidelines, providing the industry takes the initiative over public consultation. The Agency recognises the dual benefit of burning tyres, namely the replacement of fossil fuels in addition to the management option for used tyres.

#### *Secondary Liquid Fuels:*

The use of secondary liquid fuels (SLF) has increased as more cement kilns apply and are granted licences to use the fuel. This SLF is derived from organic hazardous wastes that are processed to certain performance specification, for example "Cemfuel". A debate regarding the classification of Cemfuel as a waste or fuel was resolved in March 2001. The UK High Court upheld the Environment Agency's view that Cemfuel remains a waste for the purposes of EC waste legislation (ENDS Report 315, April 2001). The Agency's main argument was that the burning of fuel was part of the recovery process and that therefore Cemfuel remained a waste until burnt.

Life-cycle analysis conducted by Environment Agency (EA 2001b) identified SLF co-incineration in cement kilns as a better environmental option than high temperature incineration. The study also supported the cement industry's claim that SLF does not undermine solvent recycling. The report concluded that the use of SLF offers distinct advantages over high temperature incineration, primarily due to the displacement of conventional fossil fuels. Whilst solvent recycling was found to be preferable to direct incineration on "almost every count", the report concluded that recycling is not "necessarily environmentally preferable to the SLF route."

A major waste disposal operator funded a critique of the life cycle analysis by independent consultants. Their report concluded that the life cycle analysis report was a "superficial attempt at evaluating the environmental impact of the use of SLF in cement kilns". The Agency admitted that SLF was the environmentally favoured option because it displaced conventional fuels. The independent review stated that the Technical Report omitted to assess the consequences of the removal of this "fuel" from hazardous waste incineration, a

process which is “dependent on SLF type waste to ensure a suitable burn menu.” By removing this waste stream from incinerators, “operators will be forced to resort to conventional fuels to maintain the overall calorific value of the menu and hence defeat the object.”

#### *Waste Oil:*

Approximately 90% of the 400 000 tonnes per annum of waste lubricating oil generated in the UK is recovered. The majority (320,000 t) is re-processed by removal of water and sediments to low grade fuel oil for cement works and other industries. Around 30,000 tonnes of untreated waste oils are burnt. The Oil Recycling Association (ORA) represents 16 small to medium size oil recycling companies, six of which operate on a country-wide scale. Oil collected by ORA’s members is re-used in power stations, cement kilns and smelters.

#### *Animal waste:*

In a number of other member states wastes (bone meal) are burned as secondary fuel in cement works. However the BSE crisis and the ensuing legislation and regulations which require the destruction of all cattle over 30 months have prevented this in the UK. Approximately 4.4 million cows have been slaughtered. A small proportion was directly incinerated using the limited incineration capacity currently available for carcasses; the rest has been rendered into meat and bone meal and tallow. The majority has been stored until sufficient destruction capacity is available.

About 1.4 million tonnes of poultry litter are produced each year in the UK (HMIP 1995). Where not used as a fertiliser in land applications the waste may be burnt in a site generating electricity from combustion of waste from several farms.

#### *Straw:*

Straw includes most plant residues gathered from crops, such as oil seed rape, rye, barley, wheat, oats, beans and peas, however, mainly cereal crop straw is used. UK annual production is around 14 million tonnes (1995) and of this around 7 million tonnes are surplus to agricultural demands. The ban on straw burning after harvest and the renewable electricity directive have led to increased interest in use for power generation.

### **RDF Utilisation**

Since the closure of the Byker plant in Newcastle, only two plants that co-combust RDF pellets or floc remain. The co-combustion of hazardous industrial wastes as substitute fuels is more common, notably in UK cement kilns since the early 1990’s (Hellberg 1998).

#### Power generation:

RDF from MSW is co-combusted at the Slough Combined Heat and Power. The power generation plant comprises two circulating fluidised bed boilers, with limestone injection and bag filters to effect flue gas clean up. The fuel input is approximately as follows:

- 85,000 tpa coal
- 54,000 tpa RDF pellets from Slough (Fibre Fuel) and Hastings (Reprotech)

- 1000 tpa wood waste (recent trials)
- small quantities of biomass (forestry residue).

A new integrated RDF production and utilisation plant is being commissioned which will burn 100,000 tpa fuel and will use gas as a backup fuel instead of coal. Output from this new plant in 2001 was 34,000 t RDF. The fuel and power plant are linked by a conveyor. The RDF pellets are relatively free-flowing and can be stored and used in the same manner as coal. (Ellis, Slough Heat and Power, pers. comm, 2002)

Co-firing biomass with other fuels (coal and natural gas) is seen as one option for electricity generators to fulfil their renewable obligations (RO) and to generate 10% of electricity from renewables by 2010. The old coal power stations would need to be retrofitted and would have efficiencies of no more than 35%. However, while biomass cofired with coal will count towards the RO, where biomass is cofired with RDF this will not be qualify for the RO. This may have the effect of stalling RDF production. There is a research project (the BAGIT project – Biomass and Gas Integrated CHP Technology) for using gasified or pyrolised biomass in a CHP unit fired initially with natural gas (ends Report 318, July 2001). The project will also look at standard steam-cycle applications for co-combustion of gasified/pyrolised biomass.

Energy Power Resources operates a plant in Ely co-combusting coal with straw. Trials have shown some problems with co-burning straw such as higher hydrochloric acid emissions and increased potassium oxide in ash preventing its use in construction applications. However, washing the straw seems to reduce chlorine and potassium emissions. The same company operates a plant in Corby, Northamptonshire for 14 MW of biomass, straw, chicken litter and miscanthus. The Corby plants had planned to co-combust biomass and waste including packaging and paper waste (Ends Report 318, July 2001), but its authorisation did not allow waste to be co-combusted.

#### Dedicated plants

The Island Waste Services are under contract to supply processed MSW to Isle of Wight CHP (Contract Heat and Power), the operators of a power plant adjacent to the RDF production plant on the Isle of Wight. With the exception of oil as a priming fuel, only waste is combusted. The power plant consumption amounts to 30,000 tpa of RDF with a net CV of 11.6 MJ/kg (Mawdsley, Isle of Wight RRF, pers. comm., 2001).

#### Cement and lime kilns:

The UK produces 15 million tonnes of cement each year and more than 90% is produced by 3 companies - Blue Circle Cement (9 works), Rugby Cement (3 plants) and Castle Cement (3 plants). About 2 million tonnes of coal are used by the UK cement industry each year and about 50% could potentially be replaced by waste derived fuels (EA 2001a). The type of secondary fuels which are co-incinerated in trial runs or under a full authorisation are presented in Table B.51 below.

**Table B.51 Co-incineration of secondary fuels in the cement industry in the UK, 2001**

Company/Plant Name	Waste type	Trial or Authorisation	Licensed Authorisation
Blue Circle			
Cauldon, Staffordshire	Tyre chips (on-site), Packaging waste, Processed sewage pellets	A	4 tonnes per hour (approx 35 000 tonnes per annum)
Weardale	SLF	A	NI
Westbury (Wilts)	Tyres	T (3 times)	
Dunbar (Scotland)	SLF Tyres	A T (for tyres)	SLF (10-20,000 tpa)
Hope (Staffordshire)	Tyre chips	T	2 tonnes per hour (approx 17 500 tonnes per annum)
Castle Cement			
Ribblesdale (3 kilns)	SLF (Cemfuel)	A	132 500 tonnes (in all three kilns)
Ketton (2 kilns)	SFL (Cemfuel) Tyres	A	SLF (73,000 tpa) Tyres (12,000 tpa)
Rugby Cement			
Barrington	SLF	A	350,000 tpa
Southam	SLF Dycal (nylon waste generated by Dupont)	A	NI
Whitewell (2 kilns Redland)	SLF	A	25% thermal substitution. Trial for 40% substitution on one kiln only approved mid 2001.
Thrislington (Lafarge)	SLF	A	Up to 40% substitution of petcoke

The main waste derived fuels are tyres and Cemfuel (SLF).

- **Tyres:** By mid-2001 there were two full authorisations for the combustion of tyres in UK cement kilns, at Castle Cement's Ketton works and Blue Circle's Caulden works. Two further plants have completed trial burns and are awaiting imminent continuous burn authorisations (Blue Circle at Westbury, Wiltshire, and Dunbar, Scotland) and a third plant, Hope (Blue Circle) is currently awaiting permission to trial tyre chips. There is currently authorised capacity to co-incinerate about 65,000 tpa of tyres. The UK cement industry co-incinerated 25,000 tonnes of used tyres in 1997 (British Cement Association). The industry has an estimated capacity for recovery of up to 190,000 tonnes which is equivalent to 50% of annual arisings.

It is the policy of the cement kiln operators to charge the prevailing market value disposal costs for receipt of used tyres. The gate fee for used tyres at cement kilns in Summer 2001 in the UK was between 50 to 65 Euros per tonne (£30-£40/tonne).

- **SLF:** cement works are authorised to co-incinerated above 600,000 tpa of SLF.
- **Oils:** There are also reports of 320,000 tonnes of re-processed used oils to be used in cement kilns and other industries (power plants and smelters) and of 30,000 tonnes of untreated waste oils to be burnt.
- **RDF:** It was reported that Blue Circle's Westbury Plant (Colin Booth *pers. comm.* 2001) was unusual in using household-sorted RDF in the 1980s as part substitution for coal. The use of RDF slowed production process and reduced output and was thus discontinued. One of the cement companies is understood to be commissioning an RDF plant similar to the 'Fibre Fuel' operation in Slough.
- **Profuel:** Trials have also been carried out with other processed fuels (Profuel) derived from a variety of sources including paper, plastics and carpet off-cuts.

### Pyrolysis

Tyre pyrolysis generates for 4 main by- products; oil, gas, steel and carbon, all of which have a market. At least three plants have been considered or are in operation.

- A mobile pyrolysis plant in the Oxfordshire operated by Bevan Recycling processes up to 90,000 tyres (1,000 tonnes) per year.
- Planning permission for a site in Sheffield was granted in 1998 with capacity for 75,000 tonnes per year.
- Bristol-based Energy Power Resources plant in South Staffordshire. However, their technology is still at development stage at present and not currently commercially viable in the UK.



## APPENDIX C CO-INCINERATION FACILITIES

### a) Cement industry

Cement kilns consists of a rotary kiln in which clinker sintering takes place. The length of the kiln varies from 70 to 200 m with one burner at the hot end of the kiln. Flue gas cleaning is via electrostatic precipitator(s).

The use of secondary fuels is an important economical option. Depending on the raw materials used and the process technology utilised (wet, dry or semi dry/wet process), the energy demand varies between 2.8 GJ and 5.5 GJ to produce one tonne of clinker. The energy conversion efficiency defined as the energy content of the clinker divided by the total energy input amounts, on average, to 44% for the European cement kilns (RDC and Kema 1999).

Fossil fuels (e.g. coal, petroleum coke, oil or natural gas) are the predominant fuels used in the cement and lime industries. However, low grade fuels such as shales, coal washings, petrol coke and waste fuels (traditionally waste oils, spent solvent, waste tyres) have been increasingly utilised in the recent years. More recently, the cement industry has co-incinerated bone meals and animal fats.

The energy content of alternative fuels can be recovered by the cement process. As for any fuel, the residual ashes from alternative fuels contribute to the mineral input to the clinker. Therefore when accepting waste products, it is necessary to accurately analyse specific components to ensure that the final product quality is not affected. Chlorine and phosphate content in waste are important as these can affect cement quality. The industry argues that the use of waste as alternative fuels has several positive impacts on sustainability, i.e. conservation of non-renewable energy sources, better energy recovery in waste, etc. A general assumption is that the cement quality is not affected by using waste as the waste composition is monitored and adjusted to comply with cement requirement. Similarly the cement industry claims that emissions are mainly determined by the raw materials and are not influenced by the type of fuel. For example, the high NO<sub>x</sub> emissions are inherent to the process because of the high temperatures of combustion. Emission of sulphur dioxide, ammonia and ammonium compounds are mainly due to raw material content. Other emissions, such as dioxins, are not affected by the type of alternative fuels.

The fuels are generally added in the main burner, or with the raw materials, or in the decarbonation zone (wet process only) or in the precalciner (dry process only).

When added into the burner, solid fuel is crushed prior to its firing into the burner. Pulverisation is necessary to assure a complete burn-out of the residual ash. The flame temperature is very high (between 1800 and 2000°C) and retention time of more than 5 sec at temperature above 1200°C ensuring the total destruction of organics (Table C.1).

**Table C.1 Main characteristics of cement production process (RDC & Kema 1999)**

Parameter	Conditions
Flame temperature	1800 –2000°C
Gas retention time	> 5sec at temperature above 1200°C
Oxygen excess	Low
Efficiency	44%
Other	Oxidizing atmosphere High thermal inertia Alkaline environment
Residue	Ash retention in clinker

To ensure additional energy transfer to the decarbonation zone, it is also possible to add solid fuel to the raw material. However this is not best practice as it results in a greatly increased emission of organics in the flue gases.

It is also possible to add solid waste in the middle of the wet kiln at the level of the decarbonation phase. The waste does not have to be pulverised. However, such a discontinuous method of supply requires special control of the quantities of fuel and oxygen to ensure complete combustion and avoid increase of organics and carbon monoxide in the flue gas. In a dry process, it is possible to inject pulverised fuels at the transition zone of the rotary kiln and pre-cyclones and oxygen supply must be properly adjusted to ensure complete burn-out.

#### **b) Power plant**

In conventional coal fired power plants, fine coal powder is burned in a furnace at about 1600°C. The retention time of the combustion gas is at least 4 seconds at >1200°C. Electrostatic precipitators and flue gas desulphurisation were reported to be commonly used in Europe together with NO<sub>x</sub> reduction by selective catalytic reduction (SCR), (RDC and Kema 1999). The residues of coal fired power plants are slag, fly ash and gypsum which can be re-used (Table 3.10).

Production of electricity from coal requires about 300 kg coal per MWh produced. It is argued that co-firing of waste with coal has the advantages of saving fossil resources and has higher efficiency than waste incineration. Co-firing with waste potentially impacts on the atmospheric emissions and residue quality. The main emissions influenced by co-incineration are linked to the heavy metal content such as mercury (Hg) and thallium (Tl). However, emissions limits will only be exceeded if the content of Hg and/or Tl in waste is high (at levels up to grams per kg). The quality of fly ash will be influenced by co-firing to a limited extent depending on the quantities of alkali elements (K and Na) in the waste (RDC & Kema 1999).

**Table C.2 Main characteristics of coal fired power plant (RDC & Kema 1999)**

<b>Parameter</b>	<b>Conditions</b>
Flame temperature	1600 –2000°C
Gas retention time	> 4sec at temperature above 1200°C
Oxygen excess	3 vol%
Efficiency	40-45%
Other	
Residue	Slag, fly ash, gypsum

**c) Lime kilns**

The production of quicklime (CaO) from burning limestone into a kiln is another high energy demanding process requiring between 900 and 1800 kcal/kg. The temperatures are as high as 1300°C with more than 5 seconds residence time for carbon dioxide to be driven off from limestone. There are 2 main types of kilns; blast shaft kilns and rotary kilns.



## APPENDIX D ALTERNATIVE RDF UTILISATION

The following definitions by Juniper (2001) describe the differences between combustion, gasification and pyrolysis, as thermal conversion process of organic materials.

The term “combustion” is used to describe the simple act of burning something under controlled conditions. It is therefore a flame initiated reaction. To ensure complete combustion, and so avoid production of tars and other pollutants, there must be an excess of combustion air. This ensures that there is sufficient oxygen for the oxidation reactions necessary to convert all the carbon and hydrogen within the waste into CO<sub>2</sub> and H<sub>2</sub>O. The process releases the energy content of the hydrocarbons in the waste into the flue gases in the form of heat and the inorganic compounds in the waste are discharged as an ash residue. The most commonly acknowledged use of combustion in the waste sector is incineration.

Gasification is a thermal upgrading process, in which the majority of the carbon is converted into the gaseous form (syngas), leaving an inert residue, by partial combustion of a portion of the fuel in the reactor with air, or with pure oxygen, or with oxygen enriched air or by countercurrent reaction with steam. Relatively high temperatures are employed, 900-1100°C with air and 1000-1400°C with oxygen. Air gasification is the most widely used technology. It is cheaper but results in relatively low energy gas, containing up to 60% nitrogen, with a heating value of 4-6 MJ/Nm<sup>3</sup>. Oxygen gasification gives a better quality gas of 10-18 MJ/Nm<sup>3</sup> [cf: natural gas = 37 MJ/Nm<sup>3</sup>] but, of course, requires an oxygen supply. The advantages and disadvantages of using oxygen from an economic and technical perspective are complex and have to be considered on a project-by-project basis. Oxygen gasification has only been considered in Continental Europe and Japan, where the plant economics are favourable to the increased costs and where much of the early development of these systems was carried out.

Via gasification, the energy content of the waste is transferred into the gas phase as chemical energy that can be re-employed as a chemical feedstock or as power via additional processing. This flexibility of usage is a significant potential advantage versus incineration.

Pyrolysis is the thermal degradation of carbonaceous materials at temperatures between 400 and 600°C either in the complete absence of oxygen, or with such a limited supply, that gasification does not occur to any appreciable extent. Such processes de-volatilise and decompose solid organic materials by heat; consequently, no combustion is possible. The products of pyrolysis always include gas, liquid and solid char with the relative proportions of each depending on the method of pyrolysis and the reaction parameters, such as temperature, heating rate, pressure and residence time. In general, lower temperatures produce more liquid product and high temperatures produce more syngas. When pyrolysis processes are operated at 800°C or greater the main product is syngas and this type of process is referred to as Thermal Gasification. These processes also produce char and tar droplets.

Pyrolysis is different from gasification and combustion, which are usually autothermic reactions, because it is endothermic requiring an input of energy, typically applied indirectly through the walls of the reactor. Table D.1 summarises the key aspects of thermal conversion processes.

**Table D.1 Main aspects of thermal conversion processes**

<b>Thermal process</b>	<b>Process type</b>	<b>Intermediate products</b>	<b>Main products</b>	<b>By-products</b>
Combustion	Flame reaction, complete oxidation	Hot flue gases, steam	Steam, electricity	Bottom ash, gas cleaning residues
Gasification	Partial oxidation	Syngas	Electricity, chemicals	Ash residues, tars, syngas cleaning residues
Pyrolysis	Externally heated, no oxygen, thermal degradation of solid organic materials	Bio-oil	Electricity, chemicals	Char, syngas
Thermal gasification	High temperature pyrolysis	Syngas	Electricity, chemicals	Char, tars, syngas cleaning residues

Various energy carrier routes can be associated with gasification and pyrolysis processes. The three main energy carrier routes are:

- *production of a “cleaned syngas” which is cooled and cleaned prior to the direct production of electricity via gas engines or gas turbines, known as a “power gasifier”;*
- *production of a “dirty syngas” which is combusted to generate hot flue gases from which steam and then electricity are produced, known as a “heat gasifier”;*
- *pyrolysis at lower temperatures to produce a “bio-oil”.*

When pyrolysis is used to treat the MSW feedstock, the products from the treatment might be a combination of char, syngas and liquids. The relative proportions are dependent on the temperature, residence time and the heating rate used. For instance, in flash pyrolysis, the combination of bed temperatures of 1000-3000°C with a high heating rate and short residence time of waste in the pyrolyser <1s, result in syngas being the largest fraction of the pyrolysis products. As the heating rates and bed temperatures become lower the fractions of solids and liquids increase.

Conventional pyrolysis processes, usually operate with bed temperatures between 400-600°C and residence times of a few hours with low heating rates. To deal with the oils and tars formed these processes use some form of secondary combustor in which the products are raised to a higher temperature (850-1200°C) in an oxygen rich environment. This treatment recovers energy from the complex organic oils and tars while simultaneously ensuring that organic emissions to air are minimised.

Because of secondary combustion of the pyrolysis products, flue gases and not syngas are produced. Energy is therefore recovered either as heat using waste heat boilers, or via power generated using a steam turbine based on conventional Rankine steam cycles.

In some pyrolysis processes operated between 400-600°C, the products are further gasified as opposed to combusted. Such processes produce an upgraded syngas, which can be used to generate power directly.

Pyrolysis carried out at temperatures higher than in conventional systems produces mostly gases. As a result, the syngas could potentially be used directly in gas engines or, if cleaned to higher standards, higher efficiency gas turbines could be used.

In processes utilising a gasification reactor, the solid feedstock is converted to syngas and ash. In such systems, with the relevant gas cleaning, it is possible to use the syngas for direct firing in internal spark combustion engines (gas engines). Nevertheless, in some processes with gasification reactors, the syngas and ash are fired at high temperatures (1300-1600°C) partly to melt the inorganic component of the ash and remove this as a slag from the process and partly to recover energy from the entrained char. In such systems, energy recovery is via waste heat boilers and the Rankine cycle.