AGGREGATES CASE STUDY

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'Aggregates case study – data gathering'

Siegmund Böhmer
Gertraud Moser
Christian Neubauer
Milla Peltoniemi
Elisabeth Schachermayer
Maria Tesar
Birgit Walter
Brigitte Winter

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Project management
Christian Neubauer

Authors
Siegmund Böhmer
Gertraud Moser
Christian Neubauer
Milla Peltoniemi
Elisabeth Schachermayer
Maria Tesar
Birgit Walter
Brigitte Winter

Layout and typesetting
Christian Neubauer

Lectorate
Brigitte Karigl
Brigitte Read
Ilse Schindler

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EXECUTIVE SUMMARY

This case study on aggregates was carried out by the Austrian Umweltbundesamt (Federal Environmental Agency) and commissioned by IPTS (Institute for Prospective Technological Studies), one of the seven scientific institutes of the European Commission's Joint Research Centre (JRC).

Covering the EU-27, the main issue of the study was to gather data on recycled and secondary aggregates, which have the potential to substitute natural aggregates. Three waste/material streams were examined: construction & demolition waste, slags from the ferrous metal production and ashes from the coal combustion.

In detail, data on the generation and on the quality of the three mentioned material streams regarding applied uses and treatment processes were assessed. In addition, the related legislations and aspects which have an influence on establishing a market for recycled and secondary aggregates and the environmental impact associated with the use of these materials were described within the study.

The Environment Ministries and Agencies of the Member States were requested to gather data on the national situation. In addition, European Associations were contacted to enable access to data already collected for the waste/material streams at European level. When interpreting and comparing the presented data it has to be taken into consideration that comparability of data is not completely ensured, e.g. due to partly different measurement methods, and some data gaps still exists.

The data on the European situation prepared in the study should provide a basis to define end-of-waste criteria for selected waste/material streams which will provide input for the definition of end-of-waste methodology.

Standardisation and legislation

Aggregates are regulated under the Construction Products Directive (89/106/EEC). The essential requirements of the Directive concern aspects like mechanical resistance and stability, safety in case of fire, hygiene and health as well as the environment.

In 1998 the European Commission gave Mandate 125 to the European Committee for Standardisation (CEN) within the context of the ‘Construction Products Directive’. According to the mandate, the Technical Committee (TC) 154 ‘Aggregates’ develops European standards for aggregates related to specific end uses. The standards specify aggregate performance requirements, sampling and methods of tests.


The Parliament’s resolution (P6_TA(2007)0029) includes a list of criteria for the distinction between by-products and wastes as well as a call for legislation to be proposed to define which secondary products are no longer deemed to be waste.
In general, the definition of waste of the Waste Framework Directive (2006/12/EC) is applied by the competent authorities on a case by case basis, e.g. when making waste shipment or permit decisions. With the Communication on waste and by-products (COM/2007/59), the Commission aims to give clear guidance on the issue of waste and by-products. The scope of the Communication is the distinction between waste and non-waste in a production process context. It does not deal with the issue of when a product may become a waste, or when a waste ceases to be a waste. The Communication interprets existing law, as set down in the Waste Framework Directive and as interpreted by the European Court of Justice (ECJ). Moreover, the Communication gives examples illustrating some cases in which materials may be classified as wastes or not, pointing out that these examples are neither definitive nor comprehensive. One example is related to slags and dusts from iron and steel production.

The European List of Waste (2000/532/EC) has a direct link with the waste definition. The List of Waste is used in the European Union for the classification of wastes. It is divided into twenty main chapters, most of which are industry-based but some of which are based on materials and processes.

The Landfill Directive (1999/31/EC) is intended to prevent or reduce the adverse effects of the landfilling of waste on the environment, in particular on surface water, groundwater, soil, air and human health. The Decision on the acceptance of waste at landfills (2003/33/EC) establishes criteria and procedures for the acceptance of waste at landfills in accordance with the principles set out in the Landfill Directive. The acceptance criteria have to be met, amongst others, for the disposal of C&D wastes, slags from iron and steel production and ashes from coal combustion, typically disposed of at landfills for inert waste.

According to the Waste Statistics Regulation (2150/2002/EC), statistics on waste generation are to be presented in tables, cross-classifying waste by economic activities and categories of waste. The Member States had to submit their first report according to the Waste Statistics Regulation to the Commission in June 2006. The reference year for the first report was 2004. Wastes, which could potentially be used as aggregates are mainly included in the categories ‘mineral wastes’ and ‘combustion wastes’.

European standardisation and legislation provides a framework for waste management for all European Member States. In addition, several Member States have already established legislative instruments at national level to promote the recycling and recovery of waste. In some cases the national approach makes it possible that waste ceases to be waste and the recycled material is traded on the market (see Chapter 7).
Construction and demolition waste

Construction and demolition waste covers a very wide range of materials. To substitute natural aggregates, the mineral fraction of construction and demolition waste is seen as a potential material for producing recycled aggregates.

With regard to the generation process, construction and demolition waste is classified as ‘construction waste’, ‘demolition waste’, ‘road construction and maintenance waste’ or ‘soil, rocks and vegetation’.

The composition of the construction and demolition waste stream varies from one Member State to another. It is affected by numerous factors, including the raw materials and construction products used, architectural techniques, and local construction and demolition practices. Construction and demolition waste usually consists of soil, concrete, bricks, tiles, ceramics as well as wood, glass, plastic, paper and metal.

Mineral construction and demolition waste as well as mixed construction wastes constitute one of the most significant waste streams in Europe. More than 200 million tons of these wastes are produced every year, excavated materials not included. Chapter 3.1.3 gives an overview of the generated volumes and the recycling of construction and demolition waste in European Countries. The United Kingdom – England (89.6 tons), Germany (73.0 tons), France (47.9 tons) and Italy (46.5 tons) are the countries with the largest volumes of construction and demolition waste. In the United Kingdom – Scotland (96%), the Netherlands (95%), Denmark (93 %), Belgium-Flanders (92 %) and Germany (91 %) the re-using and recycling rates are higher than 90 %.

Construction and demolition waste is re-used for the purpose originally intended, or it is recycled or disposed of on landfills. Approximately 30% of the total volume of C&D waste in Europe is consigned to recycling; approximately 70% of the total volume is disposed of on landfills. In many EU countries, recycling of separated fractions has become standard practice and the market recognises these products as equivalent to products manufactured from new materials. Taking into account the high recycling rates in several Member States it can be concluded that in other Member States with high arisings of C&D waste, disposal is more common as a way of treatment.

If recycled aggregates are used in production of concrete precaution should be taken with regard to the behaviour of fresh and hardened concrete (including its durability).

Depending on the nature of the construction and demolition waste and on the separation and sorting processes already carried out on this waste stream, materials can be used either directly or processed in special installations. In general, treatment processes are applied for mixed construction and demolition waste and for already separated fractions of concrete, asphalt, stones etc. and, except for the demolition itself. The processes can be carried out in mobile or fixed treatment installations on-site or off-site.
Technical equipment

Hydraulic hammers, mounted on a bulldozer or digger, have been widely used in demolition processes, especially in concrete pavement demolition. Screening separates materials into different size fractions. Crushing is the breaking or grinding by mechanical means of rock, stone or recycled materials, for direct use or further processing. Magnets are used to remove ferrous materials from the feedstock. Manual sorting may be required when unwanted material cannot be reliably or efficiently removed by other methods, such as magnetic extraction or screening. In addition, environmental equipment is used to control dust, noise and water.

Due to the wide range of materials used for construction the possibility of hazardous contaminants has to be considered for recycling processes, with special emphasis given to the leaching of dangerous substances. Chapter 3.2.2 shows potentially hazardous elements in construction and demolition waste which could have an impact on the environment. In general, these hazardous substances should be banned as much as possible from materials which are intended to be used as aggregates.

Environmental benefits

Several benefits like saving natural resources, reducing the demand for landfill capacities, reducing the harmful effects of transport can be expected from using recycled aggregates to substitute natural aggregates.

Slags from ferrous metal production

In the iron and steel industry large amounts of slags are accumulated during the production of iron and steel. A main distinction is drawn between blast furnace slag, steel slag (BOF slag, EAF slag) and secondary slag. Blast furnace slag accumulates during the production process of pig iron. Steel slag is produced from the further refining of iron in a basic oxygen furnace or from the melting of scrap in an electric arc furnace. The further processing of steel is classified as secondary steelmaking. One example is the production of stainless steel.

Quality

The chemical composition of slags as well as the generated quantity highly depends on the input materials, the produced iron or steel, the production process and the use of additives. The main components of slag are CaO, SiO₂, Al₂O₃, MgO and Fe₂O₃. The (heavy) metal content of the different slags is given in Chapter 4.1.2. Due to the input materials (scrap) the heavy metal content of EAF slags is much higher than in BOF slag.

Quantity

In 2004 the European steel industry generated about 40 million tons of slags resulting from iron and steel making. The generated blast furnace slag amounted to about 25 million tons; about 23 % was processed as air-cooled crystalline slag and 77 % as vitrified slag, whether granulated or pelletised. The total amount of steel slags in 2004 was 15 million tons; about 62 % was produced as BOF slag, 29 % as EAF slag and 9 % as secondary metallurgical slag. European countries with large slag production volumes are Germany, France, UK, Poland, Finland and Austria.

Approximately 210 – 310 kg blast furnace slag per tonne of pig iron, 85 – 110 kg BOF slag per tonne of liquid steel and 100 – 150 kg EAF slag per tonne of liquid steel are accumulated.

Uses applied

The main uses of slags in Europe are cement production and road construction. A small amount is used for hydraulic engineering, as fertilizer or recycled internally. Some slags are landfilled.
Depending on the cooling conditions, blast furnace slag crystallizes to air cooled blast furnace slag (lump slag, rock slag); foamed blast furnace slag (expanded blast furnace slag); granulated blast furnace slag (GBS, granulated cinder); blast furnace pellets (pelletized blast furnace slag) or slag wool (mineral wool).

Blast furnace slag as vitreous granulated cinder is used in the cement industry as secondary raw material or secondary constituent (‘slag cement’). Other uses are the use as concrete aggregate or the use in road construction. Crystalline air cooled blast furnace slag is used in road construction, as aggregate in concrete or in building materials with the need of high heat resistance. Blast furnace slag in the form of mineral wool is used as insulation material.

BOF slag is used in civil and hydraulic engineering or for drainage layers and mineral sealings. Approximately 25 % of European BOF slag is landfilled.

The direct use of BOF slag is only partly possible, because of the free CaO and MgO and the thus unstable volume of the slag. In contact with moisture CaO and MgO hydrate and the volume increases. Techniques for the stabilisation of the BOF slag exist, like adding silica sand combined with oxygen blowing, ageing by steam with or without pressure or ageing by spraying with water. Before using BOF slag as building aggregate a thorough characterisation has to be made. If the content of free CaO is over 7 % the slag usually cannot be used.

The reaction of water with molten slag containing sulphur compounds generates \( \text{H}_2\text{S} \) and \( \text{SO}_2 \) emissions. If the slag is not exposed to water but air-cooled, long lasting small emissions, mainly \( \text{SO}_2 \) and \( \text{H}_2\text{S} \), will occur.

Steel-industry slags contain (heavy) metals at concentrations that are higher than typical concentrations in soil (like e.g. Antimony, Cadmium, Chromium and Chromium (VI), Manganese, Molybdenum, Selenium, Silver, Thallium, Tin, Vanadium). They are alkaline, producing a water leachate with a pH of approximately 11. The environmental risks associated with the use of slags as secondary aggregates strongly depend on the type of application. If the material is bound, the risk of leachate is smaller than if the material is unbound and in contact with water. The leaching behaviour of slags is given in Chapter 4.2.2.

**Ashes from coal combustion**

The main coal combustion residues are fly ash, bottom ash and boiler slag. In addition, the flue gas desulphurisation (e.g. spray dry absorption of \( \text{SO}_2 \)) generates solid sulphur residues such as gypsum.

The composition of lignite and coal varies widely and so does the concentration of (heavy) metals. The nature and properties of fly ash are dependent on a variety of factors that include the type and fineness of coal and the conditions of combustion. The chemical composition of ashes from coal and lignite combustion is oxides, silicates and aluminium silicates of the elements contained in the coal. The (heavy) metal contents (Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc etc.) of coal as well as some fly and bottom ashes are presented in Chapter 5.1.2.
Within the EU, six countries (Germany, Greece, Spain, Poland, Romania and the UK) account for more than 75% (83.3 million tons per year; estimation for 2004) of the total generation of residues (108.65 million tons per year). Residues from coal combustion include fly ash, bottom ash, boiler slag, flue gas desulphurisation gypsum and spray dry absorption residues. In the EU-27, the total amount of fly ash is about 77.3 million tons per year and for bottom ash about 11.9 million tons per year.

Large differences exist among European Countries in the use of coal combustion residues. In some European Countries, utilisation of coal combustion residues reaches almost 100%, whereas in others almost all residues are landfilled. In the EU-15, almost all boiler slags and almost all gypsum from flue gas desulphurisation are used, mainly as construction materials. Ashes are used in the production of construction materials but also of filling materials used in open cast mines, quarries and pits.

The utilisation of fly ash across European Countries is different and is mainly based on national experience and tradition. Fly ash is the most important coal combustion residue and accounts for nearly 70% of the total amount of coal combustion residues. Approximately 33% of the total fly ash produced in the EU-15 is used as cement raw material, as a constituent in blended cement and as an addition in the production of concrete.

In 2003, about 21 million tons of fly ash were utilised in the construction industry and in underground mining. Most of the fly ash produced in 2003 was used as a concrete addition, in road construction and as a raw material in cement clinker production. Fly ash was also utilised in blended cements, in concrete blocks and for fill, i.e. for filling voids, mine shafts and subsurface mine workings. 48% of the generated bottom ash was used as fine aggregate in concrete blocks, 33% in road construction and about 14% in cement and concrete.

Critical parameters for use of fly ash in concrete are ignition loss, Cl and free CaO. Critical parameters for use in cement are ignition loss, sulphates and Cl. The physical, chemical and mechanical parameters of cement are regulated in the European Standard EN 197-1. Further requirements and standards for the use of fly and bottom ash are described in chapter 5.2.7.3.

The environmental impact caused by the handling of residues can be low if residues are utilised or disposed of in an environmentally safe way, but unsafe utilisation, storage or disposal poses risks of local water pollution. The pollutants of priority concern are the (heavy) metals. Metals which are of highest concern with respect to fossil fuel utilisation are Arsenic, Boron, Cadmium, Chromium, Copper, Mercury, Molybdenum, Nickel, Lead, Selenium, Vanadium, Thallium, Antimony, Manganese, Tin and Zinc.

One of the principles that have to be met according to the ‘Thematic Strategy on the Prevention and Recycling of Waste’ is that there has to be a market for recycled and secondary materials. End of waste criteria for defined wastes would influence the market situation for these materials and would improve the possibilities for the recycled and secondary aggregates produced to compete with primary aggregates. Above all, it has to be ensured that there is no additional negative impact on the environment by producing or using them.
Even if the technical properties of recycled or secondary aggregates are better than the ones of primary aggregates, consumers show little trust in new products especially when these products are made of waste. Awareness rising and promotion campaigns are common techniques to establish new products on the market. If end of waste criteria enhance the possibilities for trading recycled and secondary materials as a product, consumer acceptance will be influenced in a positive way. CE marking supports this positive influence without a definite guarantee of environmental safety.

Recycled and secondary aggregates are firstly generated within production or construction processes taking place near highly populated regions. This gives recycled and secondary aggregates some cost advantages over natural aggregates in terms of shorter transport distances. In some Member States recycling obligations are based on transport distance.

Imports and exports of natural aggregates indicate the need for transport and the level of resource scarcity in the Member States. With more than 20 million tons of exported natural aggregates Germany was the largest gross exporter, but it was also, with the Netherlands (more than 40 million tons) and Belgium-Luxembourg (more than 20 million tons), a major importer with more than 10 million tons.

A landfill tax has a significant effect on the amount of waste landfilled. High landfill taxes prompt the incineration of combustible waste and the recycling of non-combustible waste, or the considering of treatment alternatives. The purpose of taxation is to make the landfilling of waste more expensive than the alternatives to landfilling, with the result that the separation or post-separation of waste streams into sub-streams suitable for recovery becomes financially more attractive. Landfill taxes vary from values lower than 1 Euro per ton to values higher than 50 Euro per ton depending on the type of waste intended to be landfilled.

Takeover prices, treatment costs and sale proceeds cannot be calculated with a general method. They depend on a large number of factors, typically based on regional circumstances and varying to a high extent.

Secondary and recycled aggregates have to compete against primary aggregates (sand and gravel, and crushed rock). The availability and quality of both the natural aggregates on the one hand and the materials which compete with them on the other hand are important criteria for the establishment of a market for secondary and recycled aggregates.

One indicator that stipulates the availability of natural aggregates is the amount of natural aggregates produced, with Spain as the largest EU-31 producer of primary aggregates in 2005 (395 million tons (14%)). The overall production of natural aggregates in the EU-31 saw an increase from 2001 to 2005 to 2.742 million tons.

Prices of natural aggregates can vary considerably from one country to another, depending on the availability of hard rock, limestone and sand and gravel resources, as well as quality. For the current year 2008, the highest rises of prices for natural aggregates have been seen in Eastern Europe, particularly in Russia, Hungary, Romania and Bulgaria (about 12 Euro per ton of natural aggregates).
The construction markets in Spain, Germany, UK, Italy and France represent more than 70% of Europe's overall market and are also home to the region's largest aggregates sectors. The market prices there are at a level of about 6-7 Euro per ton.

**Taxes on natural aggregates**

Taxes on natural resources may be used as a way to encourage the substitution of virgin materials by secondary and recycled materials. E.g. in Sweden, Denmark and the UK taxes on natural resources, based on different approaches, have already been established.

**Data collection methodology**

The data presented in the study give an overview on the European situation with regard to the issues stipulated in the project. The data were gathered by carrying out two main questionnaires.

**Questionnaire**

First, a questionnaire was sent by e-mail to representatives from the national Environment Ministries or Agencies of all Member States (EU-27), without exception waste experts. If no response to the questionnaire was given until the set time limit, the questionnaire was done by telephone interview. Due to this, national legislations and data on the waste generation, applied uses and treatment processes were gathered from the national experts. This enabled the preparation of separate reports on the Member States, which were sent back to the experts for final approval (see Chapter 7).

Second, a questionnaire was sent by e-mail to representatives of National and European Associations (e.g. European Aggregates Association, German Federal Union of Recycling Building Materials, International Recycling Federation) to gather data on the waste/material streams as well as on the market situation.

**Level of detail**

Taking into consideration that there was no duty to answer the questionnaire, the given response by the Member States enabled the preparation of 17 separate reports. However, it must be assumed that the level of detail on both, data replied by the Member States and data available in the Member States varied from one Member State to another.

**Data gaps**

So data gaps still exist and comparability at the same level of detail is not ensured. For example, data on construction and demolition waste is not available at the same level of aggregation across European Countries (e.g. excavated soil included or excluded). These facts were considered for interpretations within the study and have to be taken into account when interpreting and comparing the presented data for further purposes.
1 INTRODUCTION AND SCOPE OF THE STUDY

The Institute for Prospective Technological Studies (IPTS) supports the development of European ‘end of waste’ criteria by developing a science based methodology that should be used to determine ‘end of waste’ criteria.

The assigned project ‘Aggregates Case Study – Data Gathering’ processed by Umwelbt undesamt Austria supports the ‘case study on aggregates’ with the main issue to gather data on various materials which have the potential to be used as a substitute for natural aggregates. The results should set up the basis for further discussions on the definition of ‘end of waste’ criteria according to the principles of the Thematic Strategy on the prevention and recycling of waste as well as the proposed revision of the Waste Framework Directive (WFD).

As described in the Working Document of 5th of March 2007 there are three good examples for waste/material streams which contribute to the development of an end-of-waste methodology:

- Construction and demolition waste
- Slags from ferrous metal production
- Ashes from coal combustion processes

Within this study, data on these three waste/material streams which have a significant potential to substitute natural aggregates by producing recycled or secondary aggregates from them are gathered.
1.1 Aggregates

1.1.1 Definition

According to the European Aggregates Association aggregates are “granular material used in construction. The most common natural aggregates of mineral origin are sand, gravel and crushed rock. An end-product in themselves as railway ballast or armour stones, aggregates are also a raw material used in the manufacture of other vital construction products such as ready-mixed concrete (made of 80% aggregates), pre-cast products, asphalt (made of 95% aggregates), lime and cement. Aggregates are produced from natural sources extracted from quarries and gravel pits and in some countries from sea-dredged materials (marine aggregates). Secondary aggregates are usually by-products from other industrial processes, like blast or electric furnace slags or china clay residues. Recycled aggregates derive from reprocessing materials previously used in construction, including construction and demolition residues and railway ballast”.

Based on the Working Document\(^2\) of 5\(^{th}\) of March 2007, aggregates can be classified as

- **natural aggregates**, produced from mineral sources. Sand and gravel are natural aggregates resulting from rock erosion. Natural aggregates can also be produced from crushed rock;
- **recycled aggregates**, produced from processing material previously used in construction;
- **secondary aggregates**, produced from industrial processes

according to the resource material.

1.1.2 Produced volumes

Table 1 shows the overall production of natural, recycled and secondary aggregates with a total production of more than 3.6 million tons of aggregates in 2006 covering 21 European countries, whereas in 2005 about 3 million tons were produced in 18 European countries. The average annual aggregates production represents about 7 tons per EU citizen.

---


\(^2\) INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES (2007)
Table 1: Production of aggregates 2006 (in Million tons) \(^3, 4\)

<table>
<thead>
<tr>
<th>Country</th>
<th>Companies</th>
<th>Sites</th>
<th>Employees (^5)</th>
<th>Sand &amp; Gravel (^6)</th>
<th>Crushed Rocks (^7)</th>
<th>Marine Aggregates (^8)</th>
<th>Recycled Aggregates (^9)</th>
<th>Secondary Aggregates (^10)</th>
<th>Total (^11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>1,800</td>
<td>5,396</td>
<td>92,625</td>
<td>277</td>
<td>186.5</td>
<td>0.4</td>
<td>48 (46.0)</td>
<td>30 (30.0)</td>
<td>541.9 (513.0)</td>
</tr>
<tr>
<td>Spain</td>
<td>1,600</td>
<td>1,950</td>
<td>86,000</td>
<td>170</td>
<td>314</td>
<td>0</td>
<td>1.5 (1.3)</td>
<td>0 (0.0)</td>
<td>485.5 (460.3)</td>
</tr>
<tr>
<td>France</td>
<td>1,680</td>
<td>2,700</td>
<td>17,300</td>
<td>167</td>
<td>233</td>
<td>7</td>
<td>14 (10.0)</td>
<td>9 (7.0)</td>
<td>430.0 (410.0)</td>
</tr>
<tr>
<td>Italy</td>
<td>1,700</td>
<td>2,360</td>
<td>24,000</td>
<td>210</td>
<td>135</td>
<td>0</td>
<td>5.5 (4.5)</td>
<td>3.5 (3.0)</td>
<td>354.0 (377.5)</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>350</td>
<td>1,300</td>
<td>46,000</td>
<td>68</td>
<td>123</td>
<td>13</td>
<td>58 (56.0)</td>
<td>12 (12.0)</td>
<td>274.0 (277.0)</td>
</tr>
<tr>
<td>Poland</td>
<td>2,200</td>
<td>2,550</td>
<td>53,600</td>
<td>115</td>
<td>43</td>
<td>n.a.</td>
<td>8 (7.2)</td>
<td>3 (1.6)</td>
<td>169.0 (150.8)</td>
</tr>
<tr>
<td>Ireland (^12)</td>
<td>250</td>
<td>450</td>
<td>5,100</td>
<td>54</td>
<td>79</td>
<td>n.a.</td>
<td>(1)</td>
<td>(0)</td>
<td>(134)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>60</td>
<td>185(^12)</td>
<td>400</td>
<td>44.5</td>
<td>4(^12)</td>
<td>50</td>
<td>25 (20.2)</td>
<td>n.a.</td>
<td>123.5 (48.2)</td>
</tr>
<tr>
<td>Austria</td>
<td>950</td>
<td>1,260</td>
<td>21,400</td>
<td>66</td>
<td>32</td>
<td>0</td>
<td>3.5 (3.5)</td>
<td>(3.0)</td>
<td>104.5 (104.5)</td>
</tr>
<tr>
<td>Finland</td>
<td>400</td>
<td>3,550</td>
<td>3,000</td>
<td>54</td>
<td>46</td>
<td>0</td>
<td>0.5 (0.5)</td>
<td>0 (n.a.)</td>
<td>100.5 (98.5)</td>
</tr>
<tr>
<td>Portugal</td>
<td>331(^11)</td>
<td>379</td>
<td>4,560(^12)</td>
<td>97.5</td>
<td>0</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>97.5 (88.3(^11))</td>
</tr>
<tr>
<td>Sweden</td>
<td>120</td>
<td>2,410</td>
<td>3,500</td>
<td>23</td>
<td>62</td>
<td>0</td>
<td>1.8 (7.8)</td>
<td>0.2 (0.2)</td>
<td>87.0 (80.1)</td>
</tr>
<tr>
<td>Belgium</td>
<td>184</td>
<td>253</td>
<td>15,919</td>
<td>10.07</td>
<td>55.5</td>
<td>3.5</td>
<td>13 (12.0)</td>
<td>1.3 (1.2)</td>
<td>83.4 (85.1)</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>208</td>
<td>490</td>
<td>3,368</td>
<td>27.1</td>
<td>41.5</td>
<td>0</td>
<td>3.8 (3.4)</td>
<td>0.3 (0.3)</td>
<td>72.7 (67.2)</td>
</tr>
<tr>
<td>Denmark</td>
<td>350</td>
<td>400</td>
<td>3,000</td>
<td>58.0</td>
<td>0.3</td>
<td>13.6(^13)</td>
<td>n.a.</td>
<td>n.a.</td>
<td>(72)</td>
</tr>
<tr>
<td>Croatia</td>
<td>500</td>
<td>330</td>
<td>7,000</td>
<td>6.2</td>
<td>21.8</td>
<td>0</td>
<td>3.4 (n.s.)</td>
<td>0.3 (n.s.)</td>
<td>67.2 (n.s.)</td>
</tr>
<tr>
<td>Norway</td>
<td>1,500</td>
<td>2,000</td>
<td>1,839</td>
<td>13.4</td>
<td>45.0</td>
<td>0</td>
<td>n.a. (0.2)</td>
<td>n.a. (n.a.)</td>
<td>58.4 (53.2)</td>
</tr>
<tr>
<td>Slovakia</td>
<td>175</td>
<td>213</td>
<td>3,700</td>
<td>10</td>
<td>16.5</td>
<td>0</td>
<td>0.2 (0.2)</td>
<td>0.3 (0.3)</td>
<td>27.0 (26.3)</td>
</tr>
<tr>
<td>Romania</td>
<td>440</td>
<td>11,600</td>
<td>3,368</td>
<td>15.5</td>
<td>6.5</td>
<td>0</td>
<td>0.5 (n.s.)</td>
<td>0.5 (n.s.)</td>
<td>23.0</td>
</tr>
<tr>
<td>Switzerland</td>
<td>350</td>
<td>480</td>
<td>3,200</td>
<td>50</td>
<td>5.7</td>
<td>0</td>
<td>5.7 (5.3)</td>
<td>n.a.</td>
<td>61.4 (57.1)</td>
</tr>
<tr>
<td>Turkey</td>
<td>770</td>
<td>770</td>
<td>20,240</td>
<td>24</td>
<td>260</td>
<td>0</td>
<td>0 (n.a.)</td>
<td>0 (n.a.)</td>
<td>284.0 (n.a.)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>15,478</td>
<td>29,866</td>
<td>427,351</td>
<td>1,560.27</td>
<td>1,710.3</td>
<td>87.5</td>
<td>190 (179.2)</td>
<td>63.1 (58.6)</td>
<td>3,611.2 (3,069.4)</td>
</tr>
</tbody>
</table>

\(^3\) EUROPEAN AGGREGATES ASSOCIATION UEPG (2006)

\(^4\) EUROPEAN AGGREGATES ASSOCIATION UEPG (2007)

\(^5\) Number of people directly employed (i.e. under the payroll of the companies), comprising full-time employees and part-time employees as well as people indirectly employed including all on-site contractors (e.g. truck operators, cleaners etc) unless indicated otherwise.

\(^6\) Sand and Gravel: Sold production including marine aggregates and crushed gravel.

\(^7\) Crushed rock: Sold production (excluding crushed gravel).

\(^8\) Aggregates produced from sea-dredged materials.

\(^9\) Recycled Aggregates: Materials coming from construction and demolition waste used in aggregates market.

\(^10\) Secondary aggregates include blast furnace slag, electric arc furnace slag, incinerator bottom ash (IBA), pulverised fuel ash (PFA) and other industrial and extraction by-products for construction and civil engineering.

\(^11\) Data 2003.

\(^12\) Data 2005.

\(^13\) Data 2004.
Figure 1 shows that within the countries covered a percentage of about 7% of the total aggregates produced in total are classified as recycled and secondary aggregates substituting natural aggregates.

*... No data available for secondary aggregates.
**... Data 2005.
There are established processes already applied for the production of recycled and secondary aggregates. Figure 2 show that in 2006 the UK and Germany are produced the highest amounts of recycled aggregates (both together about 106 million tons) as well as secondary aggregates (both together about 42 million tons) at European level. For 2006 there is accounted no production of recycled and secondary aggregates for Denmark, Portugal and Ireland thus these countries are not presented in Figure 2.

1.1.3 Applied uses

Aggregates are typically used for the construction of new homes and other buildings and structures (from local hospitals and schools to bridges and flood protection). Furthermore, aggregates feature at all levels of road construction up to the surface, which includes aggregates resistant to polishing, ensuring skid-resistance. Aggregates are essential as track ballast for Europe’s rail network. Table 2 shows the consumption of aggregates for typical uses.

Table 2: Consumption of aggregates for typical uses¹.

<table>
<thead>
<tr>
<th>Use</th>
<th>Average consumption of aggregates (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sport stadium</td>
<td>300,000</td>
</tr>
<tr>
<td>Motorway – 1 km</td>
<td>30,000</td>
</tr>
<tr>
<td>Railway for high speed train (TGV) – 1 km</td>
<td>9,000</td>
</tr>
<tr>
<td>School</td>
<td>3,000</td>
</tr>
<tr>
<td>New home</td>
<td>400</td>
</tr>
</tbody>
</table>
2 RELATED STANDARDS AND LEGISLATION

2.1 Standardisation according to the Construction Products Directive (89/106/EEC)


The Directive applies to construction products in so far as defined essential requirements in respect of construction works relate to them. The products must be suitable for construction works which (as a whole and in their separate parts) are fit for their intended use. The essential requirements concern aspects like e.g. mechanical resistance and stability, safety in case of fire, hygiene and health as well as the environment\textsuperscript{15}.

In 1998 the Commission gave Mandate 125\textsuperscript{16} to the European Committee for Standardisation (CEN) within the context of the ‘Construction Products Directive’. According to the mandate, the Technical Committee (TC) 154 ‘Aggregates’ develops European standards for aggregates related to the end uses of Table 3.

Table 3: End uses for aggregates defined in Mandate 125 (CEN TC/154)\textsuperscript{16}.

<table>
<thead>
<tr>
<th>End uses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor beds (including suspended ground floors), roads and other trafficked areas</td>
<td></td>
</tr>
<tr>
<td>Foundations and retaining walls</td>
<td></td>
</tr>
<tr>
<td>Pile foundations</td>
<td></td>
</tr>
<tr>
<td>External walls (including cladding), internal walls and partitions</td>
<td></td>
</tr>
<tr>
<td>Roofs</td>
<td></td>
</tr>
<tr>
<td>Floors, galleries and ceilings</td>
<td></td>
</tr>
<tr>
<td>Frame (including chimneys and shafts)</td>
<td></td>
</tr>
<tr>
<td>Disposal of solid waste (refuse)</td>
<td></td>
</tr>
<tr>
<td>Drainage (including highways) and disposal of other liquids and gaseous waste</td>
<td></td>
</tr>
<tr>
<td>Supply of gases, pressure and vacuum systems</td>
<td></td>
</tr>
<tr>
<td>Supply of electricity</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td>Circulation fixtures</td>
<td></td>
</tr>
<tr>
<td>Storage fixtures</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{14} EUROPEAN COMMITTEE FOR STANDARDIZATION (2005)

\textsuperscript{15} EUROPEAN COUNCIL (1988)

\textsuperscript{16} EUROPEAN COMMISSION (1998)
The scope of the Technical Committee (TC) 154 ‘Aggregates’ of the European Committee for Standardization (CEN) is ‘Standardization in the field of natural, recycled and manufactured aggregates, by specifying aggregate performance requirements, sampling and methods of tests’. Table 4 shows European standards for aggregates published by CEN/TC 154.

Table 4: List of published European standards for aggregates (CEN TC/154).

<table>
<thead>
<tr>
<th>Standard reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 13043:2002</td>
<td>Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas</td>
</tr>
<tr>
<td>EN 13043:2002/AC:2004</td>
<td>Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas</td>
</tr>
<tr>
<td>EN 12620:2002</td>
<td>Aggregates for concrete</td>
</tr>
<tr>
<td>EN 13139:2002</td>
<td>Aggregates for mortar</td>
</tr>
<tr>
<td>EN 13139:2002/AC:2004</td>
<td>Aggregates for mortar</td>
</tr>
<tr>
<td>EN 13450:2002</td>
<td>Aggregates for railway ballast</td>
</tr>
<tr>
<td>EN 13450:2002/AC:2004</td>
<td>Aggregates for railway ballast</td>
</tr>
<tr>
<td>EN 13242:2002</td>
<td>Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction</td>
</tr>
<tr>
<td>EN 13242:2002/AC:2004</td>
<td>Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction</td>
</tr>
<tr>
<td>EN 13383-2:2002</td>
<td>Armourstone - Part 2: Test methods</td>
</tr>
<tr>
<td>EN 13055-1:2002</td>
<td>Lightweight aggregates - Part 1: Lightweight aggregates for concrete, mortar and grout</td>
</tr>
<tr>
<td>EN 13055-2:2004</td>
<td>Lightweight aggregates - Part 2: Lightweight aggregates for bituminous mixtures and surface treatments and for unbound and bound applications</td>
</tr>
</tbody>
</table>

In addition to the list of standards presented in Table 4, standards for tests for specific properties of aggregates are published by CEN TC/154 (see Annex in Chapter 9.1).

In the standardisation process of EN 13242:2002 for ‘Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction’ a classification of the constituents of coarse recycled aggregates is used (see Table 5 and Table 6).

Reference date: October 2007.
### Table 5: Classification of the constituents of coarse recycled aggregates

<table>
<thead>
<tr>
<th>Standard reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_C</td>
<td>Concrete, concrete products, mortar, concrete masonry units</td>
</tr>
<tr>
<td>R_U</td>
<td>Unbound aggregate, natural stone, hydraulically bound aggregate</td>
</tr>
<tr>
<td>R_B</td>
<td>Clay masonry units (i.e. bricks and tiles), calcium silicate masonry units, aerated non-floating concrete</td>
</tr>
<tr>
<td>R_A</td>
<td>Bituminous materials</td>
</tr>
<tr>
<td>R_G</td>
<td>Glass</td>
</tr>
<tr>
<td>FL</td>
<td>Floating material in volume</td>
</tr>
<tr>
<td>X</td>
<td>Other: Cohesive (i.e. clay and soil); Miscellaneous: metals (ferrous and non-ferrous), non-floating wood, plastic and rubber; Gypsum plaster</td>
</tr>
</tbody>
</table>

### Table 6: Categories of constituent contents of coarse recycled aggregates

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Content</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>percentage by mass</td>
<td></td>
</tr>
<tr>
<td>R_C</td>
<td>≥ 90</td>
<td>R_C 90</td>
</tr>
<tr>
<td></td>
<td>≥ 80</td>
<td>R_C 80</td>
</tr>
<tr>
<td></td>
<td>≥ 70</td>
<td>R_C 70</td>
</tr>
<tr>
<td></td>
<td>≥ 50</td>
<td>R_C 50</td>
</tr>
<tr>
<td></td>
<td>&lt; 50</td>
<td>R_C Declared</td>
</tr>
<tr>
<td></td>
<td>no requirement</td>
<td>R_C NR</td>
</tr>
<tr>
<td>R_C + R_U + R_G</td>
<td>≥ 90</td>
<td>R_CUG 90</td>
</tr>
<tr>
<td></td>
<td>≥ 70</td>
<td>R_CUG 70</td>
</tr>
<tr>
<td></td>
<td>≥ 50</td>
<td>R_CUG 50</td>
</tr>
<tr>
<td></td>
<td>&lt; 50</td>
<td>R_CUG Declared</td>
</tr>
<tr>
<td></td>
<td>no requirement</td>
<td>R_CUG NR</td>
</tr>
<tr>
<td>R_B</td>
<td>≤ 10</td>
<td>R_B 10-</td>
</tr>
<tr>
<td></td>
<td>≤ 30</td>
<td>R_B 30-</td>
</tr>
<tr>
<td></td>
<td>≤ 50</td>
<td>R_B 50-</td>
</tr>
<tr>
<td></td>
<td>&gt; 50</td>
<td>R_B Declared</td>
</tr>
<tr>
<td></td>
<td>no requirement</td>
<td>R_B NR</td>
</tr>
<tr>
<td>R_A</td>
<td>≥ 95</td>
<td>R_A 95</td>
</tr>
<tr>
<td></td>
<td>≥ 80</td>
<td>R_A 80</td>
</tr>
<tr>
<td></td>
<td>≥ 50</td>
<td>R_A 50</td>
</tr>
<tr>
<td></td>
<td>≥ 40</td>
<td>R_A 40</td>
</tr>
<tr>
<td></td>
<td>&gt; 30</td>
<td>R_A 30</td>
</tr>
<tr>
<td></td>
<td>≤ 30</td>
<td>R_A 30-</td>
</tr>
<tr>
<td></td>
<td>≤ 20</td>
<td>R_A 20-</td>
</tr>
<tr>
<td></td>
<td>≤ 10</td>
<td>R_A 10-</td>
</tr>
<tr>
<td></td>
<td>≤ 5</td>
<td>R_A 5-</td>
</tr>
<tr>
<td></td>
<td>≤ 1</td>
<td>R_A 1-</td>
</tr>
<tr>
<td></td>
<td>no requirement</td>
<td>R_A NR</td>
</tr>
<tr>
<td>R_G</td>
<td>≤ 2</td>
<td>R_G 2-</td>
</tr>
<tr>
<td></td>
<td>≤ 5</td>
<td>R_G 5-</td>
</tr>
<tr>
<td></td>
<td>≤ 25</td>
<td>R_G 25-</td>
</tr>
<tr>
<td></td>
<td>No requirement</td>
<td>R_G NR</td>
</tr>
<tr>
<td>X</td>
<td>≤ 1</td>
<td>X_1</td>
</tr>
</tbody>
</table>

According to prEN 933-11.
2.2 Definitions according to the European Waste Framework Directive (2006/12/EC)

The Waste Framework Directive (2006/12/EC)\(^{19}\) constitutes the legal framework for Community policy on waste management. It sets the general principles and requirements for waste management across the European Union\(^{20}\).

**Important notes on the proposed revision of the Waste Framework Directive:**

The European Commission proposed, in December 2005, a revision (COM/2005/0667) of the Waste Framework Directive (2006/12/EC) as the first measure related to the Thematic Strategy on the prevention and recycling of waste (COM/2005/0666). In February 2007 the European Parliament adopted a resolution on the proposal (P6_TA(2007)0029) and made some amendments to the Commission’s text. Beyond others, two main elements of the revision of the Waste Framework Directive proposed by the Commission (COM/2005/0667) are the ‘introduction of a procedure to clarify when a waste ceases to be waste’ and ‘the clarification of the notions recovery and disposal’. Both of these elements are important for the definition process of ‘end of waste’ criteria.

In the Commission’s proposal (COM/2005/0667), the definition of waste remains unchanged but a mechanism is added to allow the possibility of clarifying when certain wastes cease to be wastes by specifying criteria via a comitology process. The Parliament’s resolution (P6_TA(2007)0029) includes a list of criteria for the distinction between by-products and wastes as well as a call for legislation to be proposed to define which secondary products are no longer deemed to be waste.

According to the Parliament’s resolution, in order to be classified as a by-product and not as waste, the following requirements shall be met by a substance or object resulting from a production process whose primary aim is not its production:

- further use of the substance or object is certain;
- the substance or object can be used directly without any further processing other than normal industrial practice;
- further use of the substance or object is an integral part of a production process or there is a market for it as a product; and
- further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for a specific application.

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\(^{19}\) EUROPEAN PARLIAMENT AND THE COUNCIL (2006)

\(^{20}\) Directive 2006/12/EC is the new codified version of the Waste Framework Directive 75/442/EEC. At present, it is the only legally valid version of the Waste Framework Directive and will remain so until the substantive proposal for a revision of the Waste Framework Directive is adopted. Codification is a process by which legal texts that have been revised several times are codified into one new text that replaces all the previous versions. No legal or political changes are made to the text during the codification process.
With the ‘Communication on the Interpretative Communication on waste and by-products (COM(2007) 59 final)’ the Commission clarifies the concepts of a product, production residue and by-product, based in part on CJEC judgments. It also sets out guidelines to help the authorities responsible determine what is to be classified as waste and what is not (see Chapter 2.3).

Further on, in the Commission’s proposal (COM/2005/0667), the revised definition of recovery confirms that the basis for this definition is the substitution of resources. In combination with the definition of disposal, it allows for the settling of difficult distinctions via the setting of efficiency criteria. It also contains procedures that allow for the clarification of the classification of certain waste operations as recovery or disposal via a comitology process.

In the resolution on the Commission’s proposal (P6_TA(2007)0029), the European Parliament proposed a new definition for recovery which specifies six criteria which an operation has to meet in order to be classified as recovery. Recovery is a waste treatment operation that meets the following criteria:

- Results in waste substituting other resources that would have been used to fulfil a particular function or in the waste being prepared for such use;
- Results in waste serving a genuine purpose by this substitution;
- Meets certain efficiency criteria, established in accordance with Article 5 (2);
- Decreases the overall negative environmental impacts by using waste as a substitute for other resources;
- Ensures that the products comply with the applicable Community safety legislation and Community standards;
- Gives a high priority to the protection of human health and the environment and minimises the formation, release, and dispersion of hazardous substances in the process.

Parliament’s amended definition of disposal is also based on these criteria:

- ‘Disposal’ means any operation that does not fulfil the conditions of recovery or re-use, and includes at least the operations listed in Annex I. All disposal operations shall give a high priority to the protection of human health and the environment.

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21 Member States shall take the necessary measures to ensure that all waste undergoes operations that result in it serving a useful purpose in replacing, whether in the plant or in the wider economy, other resources which would have been used to fulfil that function, or in it being prepared for such use, hereinafter ‘recovery operations’. They shall regard as recovery operations at least the operations listed in Annex II (Article 5).

22 Member States shall regard as disposal operations at least the operations listed in Annex I, even where the operation has as a secondary consequence the reclamation of substances or energy. (Article 6)
2.3 Interpretations according to the Communication on waste and by-products (COM (2007) 59 final)

The Communication aims to explain the definition of waste set down in Article 1 of the Waste Framework Directive, as interpreted by the European Court of Justice, in order to ensure that the Directive is properly implemented. In EU waste law, notions such as by-product or secondary raw material have no legal meaning – materials are simply waste or not. The following illustrative terms where defined without exception only for the purposes of the Communication:

- **Product** – all material that is deliberately created in a production process. In many cases it is possible to identify one (or more) "primary" products, which is the principal material produced.
- **Production residue** – a material that is processed but may or may not be a waste.
- **By-product** – a production residue that is not a waste.

In general, the definition of waste is applied by the competent authorities specified by Directive 2006/12/EC (the Waste Framework Directive), on a case by case basis, when making waste shipment or permit decisions.

The scope of the Communication is the distinction between waste and non-waste in a production process context. It is not relevant to other waste such as municipal waste or other similar waste streams, or to consumption residues. It does not deal with the issue of when a product may become a waste, or when a waste ceases to be a waste. It does not deal with waste that is excluded from the scope of the Waste Framework Directive.

The evolving jurisprudence and relative absence of legal clarity has made in some cases the application of the definition of waste difficult for competent authorities and economic operators alike. There is some evidence of differing case by case solutions to similar problems by competent authorities in different Member States – this leads to inequalities in the treatment of economic operators and obstacles in the internal market. An excessively wide interpretation of the definition of waste imposes unnecessary costs on the businesses concerned, and can reduce the attractiveness of materials that would otherwise be returned to the economy. An excessively narrow interpretation could lead to environmental damage, and undermine Community waste law and common standards for waste in the EU.

The Commission considers that guidelines are better suited to delivering legal clarity than a definition of by-products in the Waste Framework Directive. Notably, a distinction between waste and by-product that is based on whether the material is destined for recovery or disposal, or based on whether or not the material has a positive economic value, would not seem to offer the necessary guarantees for the protection of the environment. Alternatively, the direct translation in the text of the Directive of some of the language used by the ECJ, outside of its context, may simply result in creating new uncertainties. Other options, including any list type approach, appear to be impractical in operational terms and in terms of legal enforcement. Within the legally binding criteria set out by the ECJ, guidelines represent a flexible tool, adaptable to new evidence and technologies.

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23 EUROPEAN COMMISSION (2007A)
It is clear that both products and wastes can contain toxic materials and be a risk to human health and the environment if badly handled or controlled. Additionally, industrial and extraction wastes often have characteristics that mean that they may pose particular risks for the environment, when compared with products. These are linked to the fact that whereas the content of products is generally specifically designed and controlled, the composition of wastes may be less clear.

This means that from an environmental point of view, it is extremely important that materials are correctly classified as wastes or not. Waste law protects the environment from the consequences of industrial waste in a number of ways, and notably through permitting and shipment procedures, and specific standards for the incineration of waste. If a material is not a waste, this does not mean that it falls completely out of the system of environmental protection set down in Community law. Product based regulation, and other legislation such as the REACH Regulation aim at protecting human health and the environment from the potential environmental impacts of products and other materials that are not wastes.

In Annex II of the Communication includes a decision tree representing a waste versus by-product decisions (see Figure 3).

Figure 3: Decision tree representing waste versus by-product decisions.
Distinguishing between product and production residue as well as between production residue and waste seems to be important for the decision making process.

In recent jurisprudence, the ECJ has compiled a three part test that a production residue must pass in order to be considered a by-product. The court stated that where the further use of the material was not a mere possibility but a certainty, without any further processing prior to reuse and as part of a continuing process of production, the material would not be a waste. The test is cumulative test – all three parts of it must be performed. In addition to this test, the ECJ noted that the use for which the by-product is destined must also be lawful – in other words that the by-product is not something that the manufacturer is obliged to discard or for which the intended use is forbidden under EU or national law. More details on the three-part test are presented in the Communication.

The Communication also gives examples illustrating some cases in which materials may be classified as wastes or not, pointing out that these examples are neither definitive nor comprehensive. One example is related to slags and dusts from iron and steel production with the following explanation.

Blast furnace slag is produced in parallel with hot iron in a blast furnace. The production process of the iron is adapted to ensure that the slag has the requisite technical qualities. A technical choice is made at the start of the production process that determines the type of slag that is produced. Moreover, use of the slag is certain in a number of clearly defined end uses, and demand is high. Blast furnace slag can be used directly at the end of the production process, without further processing that is not an integral part of this production process (such as crushing to get the appropriate particle size). This material can therefore be considered to fall outside the definition of waste.

By contrast, desulphurisation slag is produced due to the need to remove sulphur prior to the processing of iron into steel. The resulting slag is rich in sulphur, cannot be used or recycled in the metallurgical circuit and is therefore usually disposed of in a landfill. Another example is dust extracted from the steel production process when cleaning the air inside the plant. The dust is captured in filters via an extraction process. These filters can be cleaned and the metallic content returned to the economic cycle via a recycling operation. Both of these production residues are therefore wastes from the point of view of production, with the iron content extracted from the filters ceasing to be waste once it has been recycled.

Another example mentions by-products from combustion. It is explained that flue gas desulphurisation facilities remove sulphur from the flue gases that are produced when sulphurous fossil fuels are combusted in power plants, in order to prevent these emissions contributing to air pollution and acid rain. The resulting material, flue gas desulphurisation (FGD) gypsum, is used for the range of uses that natural gypsum can be put to and notably the production of plasterboard. The process is modified and controlled to produce FGD gypsum of the required characteristics. In addition, use of the material is certain, without further processing prior to reuse and as part of an integrated production process. A number of other coal combustion products can have further uses with little or no further processing. Some, however, are in practice regularly landfilled – lignite fly ash, for example. As there is therefore no certainty of use at an EU wide level, they do not fulfil the ECJ criteria across the EU and will therefore often be wastes, although in some local situations an application and therefore certainty of use may exist.
### 2.4 Classification according to the European List of Waste (532/2000/EC)

Construction and demolition waste covers a very broad range of materials. Table 7 shows classifications for construction and demolition waste as defined in the European List of Waste (LoW)\(^{24}\), hazardous wastes excluded.

**Table 7: Non-hazardous construction and demolition waste, classified by the European List of Waste\(^{24}\).**

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>construction and demolition wastes (including excavated soil from contaminated sites)</td>
</tr>
<tr>
<td>17 01</td>
<td>concrete, bricks, tiles and ceramics</td>
</tr>
<tr>
<td>17 01 01</td>
<td>concrete</td>
</tr>
<tr>
<td>17 01 02</td>
<td>bricks</td>
</tr>
<tr>
<td>17 01 03</td>
<td>tiles and ceramics</td>
</tr>
<tr>
<td>17 01 07</td>
<td>mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06</td>
</tr>
<tr>
<td>17 02</td>
<td>wood, glass and plastic</td>
</tr>
<tr>
<td>17 02 01</td>
<td>wood</td>
</tr>
<tr>
<td>17 02 02</td>
<td>glass</td>
</tr>
<tr>
<td>17 02 03</td>
<td>plastic</td>
</tr>
<tr>
<td>17 03</td>
<td>bituminous mixtures, coal tar and tarred products</td>
</tr>
<tr>
<td>17 03 02</td>
<td>bituminous mixtures other than those mentioned in 17 03 01</td>
</tr>
<tr>
<td>17 04</td>
<td>metals (including their alloys)</td>
</tr>
<tr>
<td>17 04 01</td>
<td>copper, bronze, brass</td>
</tr>
<tr>
<td>17 04 02</td>
<td>aluminium</td>
</tr>
<tr>
<td>17 04 03</td>
<td>lead</td>
</tr>
<tr>
<td>17 04 04</td>
<td>zinc</td>
</tr>
<tr>
<td>17 04 05</td>
<td>iron and steel</td>
</tr>
<tr>
<td>17 04 06</td>
<td>tin</td>
</tr>
<tr>
<td>17 04 07</td>
<td>mixed metals</td>
</tr>
<tr>
<td>17 04 11</td>
<td>cables other than those mentioned in 17 04 10</td>
</tr>
<tr>
<td>17 05</td>
<td>soil (including excavated soil from contaminated sites), stones and dredging spoil</td>
</tr>
<tr>
<td>17 05 04</td>
<td>soil and stones other than those mentioned in 17 05 03</td>
</tr>
<tr>
<td>17 05 06</td>
<td>dredging spoil other than those mentioned in 17 05 05</td>
</tr>
<tr>
<td>17 05 08</td>
<td>track ballast other than those mentioned in 17 05 07</td>
</tr>
<tr>
<td>17 06</td>
<td>insulation materials and asbestos-containing construction materials</td>
</tr>
<tr>
<td>17 06 04</td>
<td>insulation materials other than those mentioned in 17 06 01 and 17 06 03</td>
</tr>
<tr>
<td>17 08</td>
<td>gypsum-based construction material</td>
</tr>
<tr>
<td>17 08 02</td>
<td>gypsum-based construction materials other than those mentioned in 17 08 01</td>
</tr>
<tr>
<td>17 09</td>
<td>other construction and demolition wastes</td>
</tr>
<tr>
<td>17 09 04</td>
<td>mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03</td>
</tr>
</tbody>
</table>

\(^{24}\) THE COMMISSION OF THE EUROPEAN COMMUNITIES (2000)
Table 8 shows classifications for waste from the iron and steel industry as defined in the European List of Waste, hazardous wastes excluded.

**Table 8: Non-hazardous wastes from the iron and steel industry, classified by the European List of Waste**

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>wastes from thermal processes</td>
</tr>
<tr>
<td>10 02</td>
<td>wastes from the iron and steel industry</td>
</tr>
<tr>
<td>10 02 01</td>
<td>wastes from the processing of slag</td>
</tr>
<tr>
<td>10 02 02</td>
<td>unprocessed slag</td>
</tr>
<tr>
<td>10 02 08</td>
<td>solid wastes from gas treatment other than those mentioned in 10 02 07</td>
</tr>
<tr>
<td>10 02 10</td>
<td>mill scales</td>
</tr>
<tr>
<td>10 02 12</td>
<td>wastes from cooling-water treatment other than those mentioned in 10 02 11</td>
</tr>
<tr>
<td>10 02 14</td>
<td>sludges and filter cakes from gas treatment other than those mentioned in 10 02 13</td>
</tr>
<tr>
<td>10 02 15</td>
<td>other sludges and filter cakes</td>
</tr>
<tr>
<td>10 02 99</td>
<td>wastes not otherwise specified</td>
</tr>
</tbody>
</table>

Table 9 shows classifications for wastes from power stations and other combustion plants as defined in the European List of Waste, hazardous wastes excluded.

**Table 9: Non-hazardous wastes from power stations and other combustion plants, classified by the European List of Waste**

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>wastes from thermal processes</td>
</tr>
<tr>
<td>10 01</td>
<td>wastes from power stations and other combustion plants (except 19)</td>
</tr>
<tr>
<td>10 01 01</td>
<td>bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)</td>
</tr>
<tr>
<td>10 01 02</td>
<td>coal fly ash</td>
</tr>
<tr>
<td>10 01 03</td>
<td>fly ash from peat and untreated wood</td>
</tr>
<tr>
<td>10 01 05</td>
<td>calcium-based reaction wastes from flue-gas desulphurisation in solid form</td>
</tr>
<tr>
<td>10 01 07</td>
<td>calcium-based reaction wastes from flue-gas desulphurisation in sludge form</td>
</tr>
<tr>
<td>10 01 15</td>
<td>bottom ash, slag and boiler dust from co-incineration other than those mentioned in 10 01 14</td>
</tr>
<tr>
<td>10 01 17</td>
<td>fly ash from co-incineration other than those mentioned in 10 01 16</td>
</tr>
<tr>
<td>10 01 19</td>
<td>wastes from gas cleaning other than those mentioned in 10 01 05, 10 01 07 and 10 01 18</td>
</tr>
<tr>
<td>10 01 21</td>
<td>sludges from on-site effluent treatment other than those mentioned in 10 01 20</td>
</tr>
<tr>
<td>10 01 23</td>
<td>aqueous sludges from boiler cleansing other than those mentioned in 10 01 22</td>
</tr>
<tr>
<td>10 01 24</td>
<td>sands from fluidised beds</td>
</tr>
<tr>
<td>10 01 25</td>
<td>wastes from fuel storage and preparation of coal-fired power plants</td>
</tr>
<tr>
<td>10 01 26</td>
<td>wastes from cooling-water treatment</td>
</tr>
<tr>
<td>10 01 99</td>
<td>wastes not otherwise specified</td>
</tr>
</tbody>
</table>
2.5 Disposal according to the Decision on the acceptance of waste at landfills (2003/33/EC)

This Council Decision\(^\text{25}\) of 19\(^\text{th}\) of December 2002 establishes criteria and procedures for the acceptance of waste at landfills in accordance with the principles set out in Directive 1999/31/EC\(^\text{26}\).

Landfills are divided into three classes: landfills for hazardous waste; landfills for non-hazardous waste; landfills for inert waste.

The first question to ask before acceptance could be whether or not the waste has been classified as hazardous. If the waste is not hazardous (according to the Hazardous Waste Directive (91/689/EC) and the current waste list) the next question could be whether or not the waste is inert. If the waste meets the criteria for waste to be landfilled at an inert landfill the waste may be accepted at an inert landfill.

In general, the procedure for the acceptance of waste at landfills includes basic characterisation, compliance testing and on-site verification.

The landfill for inert waste represents the landfill class where waste should have the lowest concentrations of contaminants compared to the other landfill types, and thus the set limits are very strict. Exceptions are shown in Table 10, which gives a list of wastes acceptable at landfills for inert waste without testing.

\(^{25}\) EUROPEAN COMMUNITIES (2003)

\(^{26}\) EUROPEAN COUNCIL (1999)
Table 10: Wastes acceptable at landfills for inert waste without testing.

<table>
<thead>
<tr>
<th>EWC code</th>
<th>Description</th>
<th>Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>101103</td>
<td>Waste glass-based fibrous materials</td>
<td>Only without organic binders</td>
</tr>
<tr>
<td>150107</td>
<td>Glass packaging</td>
<td></td>
</tr>
<tr>
<td>170101</td>
<td>Concrete</td>
<td>Selected C &amp; D waste only (*)</td>
</tr>
<tr>
<td>170102</td>
<td>Bricks</td>
<td>Selected C &amp; D waste only (*)</td>
</tr>
<tr>
<td>170103</td>
<td>Tiles and ceramics</td>
<td>Selected C &amp; D waste only (*)</td>
</tr>
<tr>
<td>170107</td>
<td>Mixtures of concrete, bricks, tiles and ceramics</td>
<td>Selected C &amp; D waste only (*)</td>
</tr>
<tr>
<td>170202</td>
<td>Glass</td>
<td></td>
</tr>
<tr>
<td>170504</td>
<td>Soil and stones</td>
<td>Excluding topsoil, peat; excluding soil and stones from contaminated sites</td>
</tr>
<tr>
<td>191205</td>
<td>Glass</td>
<td></td>
</tr>
<tr>
<td>200102</td>
<td>Glass</td>
<td>Separately collected glass only</td>
</tr>
<tr>
<td>200202</td>
<td>Soil and stones</td>
<td>Only from garden and parks waste; Excluding top soil, peat</td>
</tr>
</tbody>
</table>

(*) Selected construction and demolition waste (C & D waste) with low contents of other types of materials like metals, plastic, soil, organic, wood, rubber, etc. The origin of the waste must be known.

- No C & D waste from constructions polluted with inorganic or organic dangerous substances, e.g., because of production processes in the construction, soil pollution, storage and usage of pesticides or other dangerous substances, etc., unless it is made clear that the demolished construction was not significantly polluted.
- No C & D waste from constructions, treated, covered or painted with materials containing dangerous substances in significant amounts.

Table 11 and Table 12 show criteria for leaching and for the content of organic components which are defined at EU level and apply to waste acceptable at landfills for inert waste, calculated at liquid to solid ratios (L/S) of 2 l/kg and 10 l/kg for total release and directly expressed in mg/l for $C_0$ (the first eluate of percolation test at L/S = 0.1 l/kg). Criteria for the total content of inorganic components may be defined at Member State level.
Table 11: Leaching limit values for waste acceptable at landfills for inert waste.28

<table>
<thead>
<tr>
<th>Component</th>
<th>L/S = 2 l/kg</th>
<th>L/S = 10 l/kg</th>
<th>$C_a$ (percolation test)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/kg dry substance</td>
<td>mg/kg dry substance</td>
<td>mg/l</td>
</tr>
<tr>
<td>As</td>
<td>0.1</td>
<td>0.5</td>
<td>0.06</td>
</tr>
<tr>
<td>Ba</td>
<td>7</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Cd</td>
<td>0.03</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>Cr total</td>
<td>0.2</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Cu</td>
<td>0.9</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Hg</td>
<td>0.003</td>
<td>0.01</td>
<td>0.002</td>
</tr>
<tr>
<td>Mo</td>
<td>0.3</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Ni</td>
<td>0.2</td>
<td>0.4</td>
<td>0.12</td>
</tr>
<tr>
<td>Pb</td>
<td>0.2</td>
<td>0.5</td>
<td>0.15</td>
</tr>
<tr>
<td>Sb</td>
<td>0.02</td>
<td>0.06</td>
<td>0.1</td>
</tr>
<tr>
<td>Se</td>
<td>0.06</td>
<td>0.1</td>
<td>0.04</td>
</tr>
<tr>
<td>Zn</td>
<td>2</td>
<td>4</td>
<td>1.2</td>
</tr>
<tr>
<td>Chloride</td>
<td>550</td>
<td>800</td>
<td>460</td>
</tr>
<tr>
<td>Fluoride</td>
<td>4</td>
<td>10</td>
<td>2.5</td>
</tr>
<tr>
<td>Sulphate</td>
<td>560 (*)</td>
<td>1 000 (*)</td>
<td>1 500</td>
</tr>
<tr>
<td>Phenol index</td>
<td>0.5</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>DOC (***)</td>
<td>240</td>
<td>500</td>
<td>160</td>
</tr>
<tr>
<td>TDS (***)</td>
<td>2 500</td>
<td>4 000</td>
<td>—</td>
</tr>
</tbody>
</table>

(*) If the waste does not meet these values for sulphate, it may still be considered as complying with the acceptance criteria if the leaching does not exceed the following values: 1 500 mg/l at L/S = 0.1 L/kg and 6 000 mg/l/kg at L/S = 10 L/kg. It will be necessary to use a percolation test to determine the limit value at L/S = 10 L/kg under initial equilibrium conditions, whereas the value at L/S = 10 L/kg may be determined either by a batch leaching test or by a percolation test under conditions approaching local equilibrium.

(**) If the waste does not meet these values for DOC at its own pH value, it may alternatively be tested at L/S = 10 L/kg and a pH between 7.5 and 8.0. The waste may be considered as complying with the acceptance criteria for DOC, if the result of this determination does not exceed 500 mg/kg. (A draft method based on prEN 14429 is available).

(***) The values for total dissolved solids (TDS) can be used alternatively to the values for sulphate and chloride.
Table 12: Limit values for the total content of organic parameters for waste acceptable at landfills for inert waste.$^a$

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC (total organic carbon)</td>
<td>30 000 (*)</td>
</tr>
<tr>
<td>BTEX (benzene, toluene, ethylbenzene and xylenes)</td>
<td>6</td>
</tr>
<tr>
<td>PCBs (polychlorinated biphenyls, 7 congeners)</td>
<td>1</td>
</tr>
<tr>
<td>Mineral oil (C10 to C40)</td>
<td>500</td>
</tr>
<tr>
<td>PAHs (polycyclic aromatic hydrocarbons)</td>
<td>Member States to set limit value</td>
</tr>
</tbody>
</table>

(*) In the case of soils, a higher limit value may be admitted by the competent authority, provided the DOC value of 500 mg/kg is achieved at $1/S = 10$ kg, either at the soil's own pH or at a pH value between 7.5 and 8.0.
2.6 Reporting according to the Regulation on Waste Statistics (2150/2002/EC)

According to the Waste Statistics Regulation\(^{27}\) (2150/2002/EC), statistics on waste generation are to be presented in tables, cross-classifying waste by economic activities and categories of waste (covering the Sections A to Q of NACE Rev. 1.). The table on waste generation differentiates between 48 waste categories (21 of them are hazardous) and 20 source categories. In addition, the waste totals by source (hazardous waste totals, non-hazardous waste totals and waste totals) and the source totals by waste should be introduced. The data is to be presented at the national level (NUTS 0). The Member States had to submit the first report according to the Waste Statistics Regulation to the Commission in June 2006. The reference year for the first report was 2004.

From the point of view of the aggregates case study, the following waste categories (Annex I, WStatR) are relevant:

- **Category ‘Mineral wastes (non hazardous waste)’, which comprises:**
  - Concrete, bricks and gypsum waste
  - Waste hydro-carbonised road-surfacing material
  - Mixed construction wastes
  - Waste of naturally occurring minerals
  - Artificial mineral wastes
  - Waste refractory materials

- **Category ‘Combustion wastes (non hazardous waste)’, which comprises:**
  - Waste from flue gas purification
  - Slags and ashes from thermal treatment and combustion

Source sectors (Annex I, WStatR) of relevance regarding the generation of mineral wastes are especially (see Table 13):

- Mining and quarrying
- Construction

Source sectors (Annex I, WStatR) of relevance regarding the generation of combustion waste are especially (see Table 14):

- Electricity, gas and water supply
- Manufacture of basic metals and fabricated metal products

The data reported according to the Waste Statistics Regulation by the Member States can be queried from the public database available on the official Website of EUROSTAT [http://epp.eurostat.ec.europa.eu].

\(^{27}\) EUROPEAN PARLIAMENT AND THE COUNCIL (2002)
### Table 13: Mineral wastes generated in specific sectors and total in EU-27 in 2004 (in tons)\(^{28}\)

<table>
<thead>
<tr>
<th>Member State</th>
<th>Sector: Mining and quarrying</th>
<th>Sector: Construction</th>
<th>Total generated in all sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>C</td>
<td>C</td>
<td>16,057,703</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>222,201,525</td>
<td>545,738</td>
<td>232,710,827</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>131,046</td>
<td>7,079,429</td>
<td>10,954,910</td>
</tr>
<tr>
<td>Denmark</td>
<td>:</td>
<td>3,712,862</td>
<td>4,356,015</td>
</tr>
<tr>
<td>Germany</td>
<td>50,764,585</td>
<td>173,796,878</td>
<td>231,819,307</td>
</tr>
<tr>
<td>Estonia</td>
<td>5,264,257</td>
<td>383,925</td>
<td>6,082,175</td>
</tr>
<tr>
<td>Ireland</td>
<td>4,030,167</td>
<td>10,997,803</td>
<td>16,223,747</td>
</tr>
<tr>
<td>Greece</td>
<td>98,285</td>
<td>E 3,324,000</td>
<td>5,373,287</td>
</tr>
<tr>
<td>Spain</td>
<td>21,546,390</td>
<td>42,500,358</td>
<td>78,398,306</td>
</tr>
<tr>
<td>France</td>
<td>0</td>
<td>E 330,574,000</td>
<td>E 331,195,000</td>
</tr>
<tr>
<td>Italy</td>
<td>595,669</td>
<td>E 44,865,519</td>
<td>56,132,241</td>
</tr>
<tr>
<td>Cyprus</td>
<td>46,020</td>
<td>R 255,440</td>
<td>R 331,629</td>
</tr>
<tr>
<td>Latvia</td>
<td>:</td>
<td>7,066</td>
<td>56,403</td>
</tr>
<tr>
<td>Lithuania</td>
<td>0</td>
<td>340,833</td>
<td>576,784</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>665</td>
<td>6,925,367</td>
<td>7,083,043</td>
</tr>
<tr>
<td>Hungary</td>
<td>E 1,581,737</td>
<td>E 1,634,115</td>
<td>E 3,215,852</td>
</tr>
<tr>
<td>Malta</td>
<td>156</td>
<td>2,205,855</td>
<td>2,208,496</td>
</tr>
<tr>
<td>Netherlands</td>
<td>259,275</td>
<td>P 22,583,071</td>
<td>P 25,729,155</td>
</tr>
<tr>
<td>Austria</td>
<td>588,105</td>
<td>27,049,277</td>
<td>29,420,233</td>
</tr>
<tr>
<td>Poland</td>
<td>37,862,214</td>
<td>1,124,413</td>
<td>78,421,631</td>
</tr>
<tr>
<td>Romania</td>
<td>323,861,502</td>
<td>46,252</td>
<td>342,577,988</td>
</tr>
<tr>
<td>Slovenia</td>
<td>121,957</td>
<td>507,337</td>
<td>1,132,447</td>
</tr>
<tr>
<td>Slovakia</td>
<td>175,890</td>
<td>1,263,220</td>
<td>2,050,210</td>
</tr>
<tr>
<td>Finland</td>
<td>23,282,000</td>
<td>E 19,530,420</td>
<td>44,812,420</td>
</tr>
<tr>
<td>Sweden</td>
<td>58,551,252</td>
<td>6,000,000</td>
<td>65,751,252</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>E 93,882,695</td>
<td>80,113,691</td>
<td>182,524,326</td>
</tr>
<tr>
<td>Total</td>
<td>:</td>
<td>C</td>
<td>EP 1,786,181,914</td>
</tr>
</tbody>
</table>

### Table 14 Combustion wastes generated in specific sectors in EU-27 in 2004 (in tons)\(^{28}\).

<table>
<thead>
<tr>
<th>Member State</th>
<th>Sector: Electricity, gas and water supply</th>
<th>Sector: Manufacture of basic metals and fabricated metal products</th>
<th>Total generated in all sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>C</td>
<td>C</td>
<td>5,118,559</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>7,590,566</td>
<td>879,467</td>
<td>8,589,046</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>4,357,664</td>
<td>1,367,413</td>
<td>6,792,894</td>
</tr>
<tr>
<td>Denmark</td>
<td>1,234,966</td>
<td>2,478</td>
<td>1,247,120</td>
</tr>
<tr>
<td>Germany</td>
<td>8,024,999</td>
<td>7,682,727</td>
<td>25,480,764</td>
</tr>
<tr>
<td>Estonia</td>
<td>3,847</td>
<td>21,118</td>
<td>48,357</td>
</tr>
<tr>
<td>Ireland</td>
<td>226,920</td>
<td>476</td>
<td>256,015</td>
</tr>
<tr>
<td>Greece</td>
<td>12,809,290</td>
<td>380,831</td>
<td>15,014,222</td>
</tr>
<tr>
<td>Spain</td>
<td>5,509,205</td>
<td>1,761,903</td>
<td>7,343,882</td>
</tr>
<tr>
<td>France</td>
<td>E</td>
<td>0</td>
<td>E 3,924,000</td>
</tr>
<tr>
<td>Italy</td>
<td>1,949,061</td>
<td>E 5,698,105</td>
<td>8,745,761</td>
</tr>
<tr>
<td>Cyprus</td>
<td>R 425</td>
<td>:</td>
<td>R 430</td>
</tr>
<tr>
<td>Latvia</td>
<td>0,244</td>
<td>5</td>
<td>50,550</td>
</tr>
<tr>
<td>Lithuania</td>
<td>0,015</td>
<td>493</td>
<td>1,603</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>0,000</td>
<td>304,903</td>
<td>364,820</td>
</tr>
<tr>
<td>Hungary</td>
<td>E 3,149,702</td>
<td>E 128,860</td>
<td>E 3,396,870</td>
</tr>
<tr>
<td>Malta</td>
<td>0,000</td>
<td>14</td>
<td>1,953</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1,428,068</td>
<td>2,363,659</td>
<td>6,041,340</td>
</tr>
<tr>
<td>Austria</td>
<td>97,930</td>
<td>3,384,143</td>
<td>4,363,764</td>
</tr>
<tr>
<td>Poland</td>
<td>20,020,121</td>
<td>5,605,733</td>
<td>27,585,734</td>
</tr>
<tr>
<td>Romania</td>
<td>1,865</td>
<td>1,953,016</td>
<td>1,992,090</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1,141,472</td>
<td>87,275</td>
<td>1,251,723</td>
</tr>
<tr>
<td>Slovakia</td>
<td>1,145,860</td>
<td>1,769,320</td>
<td>3,022,040</td>
</tr>
<tr>
<td>Finland</td>
<td>1,518,296</td>
<td>896,361</td>
<td>2,977,843</td>
</tr>
<tr>
<td>Sweden</td>
<td>C</td>
<td>2,184,872</td>
<td>3,633,998</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>6,169,650</td>
<td>4,365,610</td>
<td>10,900,178</td>
</tr>
<tr>
<td>Total</td>
<td>EP 78,600,733</td>
<td>C</td>
<td>EP 149,182,222</td>
</tr>
</tbody>
</table>

S... Eurostat estimate, R... Revised value, P... Provisional value, E... Estimated value, Confidential value, ‘:’… Missing value
Until the reference year 2004, which was the first reference year under the Waste Statistics Regulation (2150/2002/EC), European waste statistics were collected through a questionnaire developed jointly by Eurostat and the OECD, briefly referred to as Eurostat/OECD Joint Questionnaire (JQ). The questionnaire was sent to the participating countries every second (even) year. Annual data was collected on waste generation, waste treatment and waste management infrastructure. However, until the coming into force of the Waste Statistics Regulation (2150/2002), Member States were not legally obliged to deliver waste statistics. Consequently, data gaps exist for the years before the reference year 2004, as not all countries provided the required data. The statistics resulting from these data collection can be queried on the website of EUROSTAT. Data is available for the years 1995-200329.

With the Eurostat/OECD Joint Questionnaire, data was collected on the amounts of waste generated and was broken down into the various branches of economic activities (based on NACE Rev. 1 and ISIC Rev. 3) and by households. The data on the generated waste quantities per economic sectors covers only the total amounts of non-hazardous and hazardous wastes without a more detailed breakdown into waste categories30.

From the point of view of the aggregates case study, the following source sectors are relevant (see Annex in Chapter 9.2):

- Mining and quarrying
- Construction
- Energy production
- Manufacture of basic metals

In addition, data was collected on selected waste streams, considered to be important from an environmental point of view and from the point of view of national waste management strategies. From the point of view of the aggregates case study, the following selected waste streams are relevant (see Annex in Chapter 9.2):

- Construction and demolition waste
- Excavated soils (waste from construction/demolition)

It should be noted that waste generated by sector should be clearly distinguished from the generation of a selected waste stream. Waste from the construction sector (NACE/ISIC 45) thus includes all waste generated by enterprises undertaking the economic activity of ‘construction’, whereas ‘construction and demolition waste’, covered in table ‘Generation of waste by selected waste streams’ refers to all construction and demolition waste generated in any economic activity sector30.

29 EUROPEAN COMMUNITIES (2005)
30 EUROSTAT (2004)
2.7 Identification of environmental risks considering limits defined in national legislation and guidelines

The WHO (International Programme for Chemical Safety, IPCS) and the OECD provide the following definitions:

- **Risk**: The probability of an adverse effect in an organism, system or (sub)population caused under specified circumstances by exposure to an agent.
- **Risk assessment**: A process intended to calculate or estimate the risk to a given target organism, system or (sub)population, including the identification of attendant uncertainties, following exposure to a particular agent, taking into account the inherent characteristics of the agent of concern as well as the characteristics of the specific target system.

The Risk Assessment process includes four steps:

- Hazard identification,
- Hazard characterisation (related term: dose-response assessment),
- Exposure assessment, and
- Risk characterization.

Risk Characterisation is the fourth step in the Risk Assessment process. The qualitative and, wherever possible, quantitative determination, including attendant uncertainties, of the probability of occurrence of known and potential adverse effects of an agent in a given organism, system or (sub)population, under defined exposure conditions.

The EU standards for risk assessment have been developed in the fields of chemicals safety and biocides (see Figure 4 and Technical Guidance Document on Risk Assessment for new and existing substances) which give a good overview of the principles and factors relevant for risk assessment and show ways how a structured risk management can work.
Several Member States have already established common techniques and regulations for re-using and recycling construction and demolition waste, slags from ferrous metal production as well as ashes from coal combustion processes with regard to environmental protection. To set suitable limits, different approaches are considered to minimize the transfer of contaminants into soil, water and air in the course of the treatment and use of recovered materials. Some Member States have regulations and strict bans on the input material in place whereas other Member States regulate the intended use more strictly. The limits defined in the national regulations and guidelines identify potential environmental risks.

To avoid serious or irreversible potential harm, environmental risks should be calculated by taking the precautionary principle into consideration. There are important factors which have a great influence on the potential environmental risks of a recycled material:

- Contaminants of the material (e.g. dangerous substances, leaching and total contents);
- Form of application (e.g. bound or unbound, mixed or as bulk material);
- Intended use (e.g. traffic areas, industrial areas or agricultural areas);
- Background contamination of and long-term conditions at the fitting location.
Table 15: Limits on total content defined in European Countries (Country reports, 2008).

<table>
<thead>
<tr>
<th>Covered waste/material</th>
<th>Total content (mg/kg DS)</th>
<th>General use</th>
<th>Specific use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Austria</td>
<td>Belgium</td>
<td>Denmark</td>
</tr>
<tr>
<td></td>
<td>A+</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>General unit [mg/kg DS]</td>
<td>[mg/kg DS]</td>
<td>[mg/kg DS]</td>
<td>[mg/kg DS]</td>
</tr>
<tr>
<td>Metals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>20</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Barium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.5</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Chromium total</td>
<td>40</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Chromium (VI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>30</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.2</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Molybdenum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>30</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Nickel</td>
<td>30</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Zinc</td>
<td>100</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Vanadium</td>
<td>100</td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAH</td>
<td>4*</td>
<td>12*</td>
<td>20*</td>
</tr>
<tr>
<td>PCB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOC</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>BTEX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral oil</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*) Member States to set limit value for disposal.

Table 15, Table 16 and Table 17 compare the limits on leaching and total contents in several Member States. In general, the limits are set at a similar level for related materials and intended uses. A comparison of the limits for leaching with the acceptance criteria for landfills for inert waste in Table 16 shows that several Member States are nearly in line with the limits defined in Decision 2003/33/EC.

31 Including specific limits (*) for recycled building materials and general limits for construction and demolition waste applicable for recovery processes according to different quality classifications (A+, A and B).

31 Limits and conditions for use of selected construction and demolition waste, slags and ashes as non-shaped building material.

32 Limits and conditions for use of selected construction and demolition waste, slags and ashes in or as a building material.

33 Limit values for the three quality categories (CAT1, CAT2 and CAT3) on residual products (including bottom and fly ashes from coal fired power stations).

34 C&D: Limit values for concrete chippings made of dismantled concrete structures or concrete waste; Ashes: Limits for ashes from coal combustion.

35 Limits according to the Decision on the acceptance of waste at landfills (2003/33/EC) related to landfills for inert waste.
Table 16: Leaching limits (mg/kg DS) defined in European Countries (Country reports, 2008).

<table>
<thead>
<tr>
<th>Leachability** (mg/kg DS)</th>
<th>Austria</th>
<th>Belgium</th>
<th>Finland</th>
<th>Spain</th>
<th>Sweden</th>
<th>Disposal criteria</th>
</tr>
</thead>
<tbody>
<tr>
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<td>40</td>
<td>36</td>
<td>37</td>
<td>38</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Covered waste/material</td>
<td>C&amp;D</td>
<td>C&amp;D</td>
<td>C&amp;D, Ashes, Slags</td>
<td>C&amp;D</td>
<td>C&amp;D, Ashes, Slags</td>
<td>C&amp;D, Ashes, Slags</td>
</tr>
<tr>
<td>General unit</td>
<td>L/S= 10 kg</td>
<td>L/S= 10 kg</td>
<td>L/S= 10 kg</td>
<td>L/S= 10 kg</td>
<td>L/S= 10 kg</td>
<td>EN 12457</td>
</tr>
<tr>
<td>Test method</td>
<td>L/S= 10 kg</td>
<td>L/S= 10 kg</td>
<td>L/S= 10 kg</td>
<td>L/S= 10 kg</td>
<td>L/S= 10 kg</td>
<td>EN 12457</td>
</tr>
<tr>
<td>Metals</td>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>Antimony</td>
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<td>0.06</td>
<td>0.1</td>
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<td>0.06</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Barium</td>
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<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>17</td>
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<td>Cadmium</td>
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<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
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<td>Chromium total</td>
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<td>0.5*</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
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<tr>
<td>Copper</td>
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<td>2*</td>
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<td>2.0</td>
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<td>Lead</td>
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<td>Molybdenum</td>
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<td>5</td>
<td>0.5</td>
<td>0.5</td>
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<td>Mercury</td>
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<td></td>
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<td></td>
<td>0.004</td>
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<td>Nickel</td>
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<td>0.4</td>
<td>0.6</td>
<td>0.75</td>
<td>0.4</td>
<td>0.4</td>
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<tr>
<td>Selenium</td>
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<td></td>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>Vanadium</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Zinc</td>
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<td>4</td>
<td>18</td>
<td>2.8</td>
<td>4.0</td>
<td>4.0</td>
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<td>500</td>
<td>500</td>
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<td>3*</td>
<td>5*</td>
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<td>1</td>
</tr>
<tr>
<td>Phenol index</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ammonium N</td>
<td>1*</td>
<td>4*</td>
<td>8*</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Chloride (Cl₂)</td>
<td>800</td>
<td>800</td>
<td>1,000</td>
<td>800</td>
<td>800</td>
<td>1,000</td>
</tr>
<tr>
<td>Electric conductivity</td>
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<td>150*</td>
<td>150*</td>
<td>150*</td>
<td>150*</td>
<td>150*</td>
</tr>
<tr>
<td>Fluoride (F⁻)</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>pH value [-]</td>
<td>7.5</td>
<td>12.5*</td>
<td>12.5*</td>
<td>7.5</td>
<td>12.5*</td>
<td>12.5*</td>
</tr>
<tr>
<td>Nitrite-N</td>
<td>0.5*</td>
<td>1*</td>
<td>2*</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sulphate-SO₄²⁻</td>
<td>1,500</td>
<td>2,500*</td>
<td>5,000*</td>
<td>1,000</td>
<td>3,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

36 Including specific limits (*) for recycled building materials according to different quality classifications (A+, A and B) and general limits for construction and demolition waste applicable for recovery processes.

37 Limits and conditions for use of selected construction and demolition waste, slags and ashes as non-shaped building material.

38 C&D: Limit values for concrete chippings made of dismantled concrete structures or concrete waste; Ashes: Limit values for ashes from coal combustion.

39 Leaching limit values for the use of slags in the Autonomous Communities of Cantabria (CA) and Basque Country (BC).

40 Limits according to the Decision on the acceptance of waste at landfills (2003/33/EC) related to landfills for inert waste.
Table 17: Leaching limits (µg/L) defined in European Countries (Country reports, 2008).

<table>
<thead>
<tr>
<th>Leachability** (mg/kg DS)</th>
<th>Covered waste/material</th>
<th>General unit</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&amp;D, BF, GC, ST, BA, FA, CAT1, CAT3</td>
<td>C&amp;D, Slags, Slags, Ashes, Ashes, Ashes, Ashes, C&amp;D, Ashes, Slags</td>
<td>µg/L, µg/L, µg/L, µg/L, µg/L, µg/L, [mg/L]</td>
<td>DIN 19528 (Column test), EN 12457, EN 12457, EN 12457, EN 12457, Percolation test</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metals</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>25</td>
<td>100</td>
<td>0.8</td>
</tr>
<tr>
<td>Barium</td>
<td>0-300</td>
<td>0-300</td>
<td>300-4,000</td>
</tr>
<tr>
<td>Beryllium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>35</td>
<td>0-2</td>
<td>0-2</td>
</tr>
<tr>
<td>Chromium total</td>
<td>50-100</td>
<td>1,700</td>
<td>0-10</td>
</tr>
<tr>
<td>Cobalt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>40-100</td>
<td>0-45</td>
<td>0-45</td>
</tr>
<tr>
<td>Lead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molybdenum</td>
<td>35-230</td>
<td>800</td>
<td>3,000</td>
</tr>
<tr>
<td>Manganese</td>
<td>0-150</td>
<td>0-150</td>
<td>150-1,000</td>
</tr>
<tr>
<td>Mercury</td>
<td>0-0.1</td>
<td>0-0.1</td>
<td>0.1-1</td>
</tr>
<tr>
<td>Nickel</td>
<td>0-15</td>
<td>0-15</td>
<td>5-100</td>
</tr>
<tr>
<td>Selenium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vanadium</td>
<td>30-100</td>
<td>30</td>
<td>25-800</td>
</tr>
<tr>
<td>Zinc</td>
<td>0-100</td>
<td>0-100</td>
<td>100-1,500</td>
</tr>
</tbody>
</table>

**Others**

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pH value [-]</td>
<td>7-12.5</td>
<td>9-12</td>
<td>9-12</td>
</tr>
<tr>
<td>Asbestos</td>
<td>30 [mg/L]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>30 [mg/L]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOC</td>
<td>1,600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAH</td>
<td>3-15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenol index</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>4,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric conductivity</td>
<td>2,000-10,000 [µS/cm]</td>
<td>5,000-7,000 [µS/cm]</td>
<td>1,000 [µS/cm]</td>
</tr>
<tr>
<td>Cyanides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrate-N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride (Cl-)</td>
<td>0-150,000</td>
<td>0-150,000</td>
<td>150,000-3,000,000</td>
</tr>
<tr>
<td>Fluoride (F)</td>
<td>0.75-4 [mg/L]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphate-SO₄</td>
<td>200-1,400 [mg/L]</td>
<td>900-2,500 [mg/L]</td>
<td>200 [mg/L]</td>
</tr>
</tbody>
</table>

*) The applicable test methods have to be taken into consideration if comparing leaching limits of different Member States.

41 Specific limits values for recycled construction materials (C&D), blast furnace slag (BF), granulated cinder (GC), steel slag (ST), bottom ashes (BA) and fly ashes (FA).
42 Leaching limits obtained for different recovery activities.
43 Limits according to the Decision on the acceptance of waste at landfills (2003/33/EC) related to landfills for inert waste.
3 CONSTRUCTION AND DEMOLITION WASTE

3.1 Material streams

Concerning the waste classifications of the European List of Waste, construction and demolition waste covers a very wide range of materials (see Table 7). To substitute natural aggregates, the mineral fraction of construction and demolition waste is seen as a potential material for producing recycled aggregates.

3.1.1 Generation process

With regard to the generation process, following differentiation for construction and demolition waste could be made:

- **Construction waste**: waste arising from the construction of buildings and/or civil infrastructure;
- **Demolition waste**: waste arising from the total or partial demolition of buildings and/or civil infrastructure;
- **Road construction and maintenance waste**: road construction material and associated materials arising from road maintenance activities;
- **Soil, rocks and vegetation**: waste arising from land levelling, civil works and/or general foundations.

Construction and demolition within the construction industry could be carried out in many different ways. The waste types mentioned can arise at different sites where construction, demolition, renovation and/or maintenance of buildings, civil infrastructure, roads, etc. are carried out.

To enable further recovery of waste in general and of construction and demolition waste in particular, it seems to be essential to separate and sort out defined fractions during construction and demolition processes. Selective demolition processes and on-site separation are the techniques commonly used to produce ‘high quality’ waste fractions which have the potential to be reused as construction material. In several Member States on-site separation of construction and demolition waste into specified fractions is obligatory.

---

44 According to SYMONDS GROUP (1999)
3.1.2 Quality

The composition of the construction and demolition waste stream varies from one Member State to another. The composition of this waste stream is affected by numerous factors, including the raw materials and construction products used, architectural techniques, and local construction and demolition practices. The main wastes present in this stream are soil, concrete, bricks, tiles, ceramics as well as wood, glass, plastic, paper and metal (see Table 7).66

The composition also depends on the separation already carried out on the related waste stream. Wood (often to be separated into untreated and treated wood), paper, glass, plastic, metals and other non-mineral fractions are ‘contraries’ when it comes to producing recycled aggregates from mineral construction and demolition waste. If separated, these fractions have to be recycled in an adequate way not discussed in this study. Table 18 shows a possible composition of mixed construction and demolition waste.

Table 18: Composition of mixed construction and demolition waste.

<table>
<thead>
<tr>
<th>Component</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inert material</td>
<td>30</td>
</tr>
<tr>
<td>Non-recyclables</td>
<td>25</td>
</tr>
<tr>
<td>Wood</td>
<td>15</td>
</tr>
<tr>
<td>Inflammables</td>
<td>10</td>
</tr>
<tr>
<td>Metals</td>
<td>7</td>
</tr>
<tr>
<td>Sand</td>
<td>7</td>
</tr>
<tr>
<td>Glass</td>
<td>3</td>
</tr>
<tr>
<td>Paper</td>
<td>1</td>
</tr>
</tbody>
</table>

Several Member States have published results of analyses concerning the composition of ‘construction and demolition waste’ in the past few years. Table 19 gives an overview of the typical composition within selected Member States. The data demonstrate a wide range of possible compositions. If the listed construction and demolition waste contains excavated soils this causes a considerable impact on the composition. Nevertheless some trends are evident. Approximately one third of C&D waste consists of concrete. The percentage of masonry varies from 6 to 35%. Details of the analyses can be found in country reports in Chapter 7.
Table 19: Composition of mixed construction and demolition waste in European Countries (Country reports, 2008).

<table>
<thead>
<tr>
<th>Component (in %)</th>
<th>Netherlands</th>
<th>Belgium (Flemish)</th>
<th>Denmark</th>
<th>Estonia</th>
<th>Finland</th>
<th>Czech Republic</th>
<th>Ireland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>40</td>
<td>33</td>
<td>25</td>
<td>8</td>
<td>33</td>
<td>-</td>
<td>39</td>
</tr>
<tr>
<td>Masonry</td>
<td>25</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>35</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Asphalt</td>
<td>26</td>
<td>4</td>
<td>19</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gravel</td>
<td>2</td>
<td>18</td>
<td>22</td>
<td>53</td>
<td>-</td>
<td>-</td>
<td>51*</td>
</tr>
<tr>
<td>Timber</td>
<td>1.5</td>
<td>3</td>
<td>-</td>
<td>41</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Metal</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>19</td>
<td>14</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>6.5</td>
<td>36</td>
<td>28</td>
<td>16</td>
<td>12*</td>
<td>32*</td>
<td>6</td>
</tr>
</tbody>
</table>

3.1.3 Quantity

Mineral construction and demolition waste as well as mixed construction waste constitute one of the most significant waste streams in Europe. More than 200 million tons of these wastes are produced every year, excavated materials not included.\(^{45}\)

Table 20: Arising and recycling of construction and demolition waste in European Countries, listed with regard to data availability and total amount – Part 1 (Country reports, 2008).

<table>
<thead>
<tr>
<th>Member State / Region</th>
<th>Year</th>
<th>Arising (Million tons)</th>
<th>% Re-used or recycled</th>
<th>% Incinerated or landfilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom - England(^{50})</td>
<td>2005</td>
<td>89.6</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Germany(^{51})</td>
<td>2002</td>
<td>73.0</td>
<td>91</td>
<td>9</td>
</tr>
<tr>
<td>France(^{52})</td>
<td>2004</td>
<td>47.9</td>
<td>25</td>
<td>n. s.</td>
</tr>
<tr>
<td>Italy</td>
<td>2004</td>
<td>46.5</td>
<td>n. s.</td>
<td>n. s.</td>
</tr>
<tr>
<td>Spain</td>
<td>2005</td>
<td>35.0</td>
<td>n. s.</td>
<td>n. s.</td>
</tr>
<tr>
<td>Netherlands(^{53})</td>
<td>2005</td>
<td>25.8</td>
<td>95</td>
<td>3</td>
</tr>
<tr>
<td>Sweden(^{54})</td>
<td>2006</td>
<td>11.0</td>
<td>n. s.</td>
<td>n. s.</td>
</tr>
</tbody>
</table>

---

46 Including soils.
47 Including soil and stones.
48 Including glass, plastics and other wastes.
49 Mixtures of concrete, bricks, tiles and ceramics without dangerous substances.
50 Arisings include C&D waste and excavation waste (only inert C&D waste i.e. construction, demolition and excavation waste that is suitable for reprocessing into recycled aggregates; there is no reasonable data on the non-inert fraction); landfilled as waste: 20% England (2005), 4 % Scotland (2003).
51 The total arisings include 52.1 million tons of mineral construction waste, 4.3 million tons of construction site waste and 16.6 million tons of road construction waste.
52 Arisings related to waste from construction, renovation and demolition of buildings.
53 The deposition of 2% is not specified.
54 Rough estimation of the generated amount of construction and demolition waste.
Table 21: Arising and recycling of construction and demolition waste in European Countries, listed with regard to data availability and total amount – Part 2 (Country reports, 2008).

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Arisings</th>
<th>Recycled</th>
<th>Landfill</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom-Scotland</td>
<td>2003</td>
<td>10.8</td>
<td>96</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Belgium-Flanders</td>
<td>2006</td>
<td>9.0</td>
<td>92</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>Czech Republic</td>
<td>2006</td>
<td>8.4</td>
<td>30</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>Luxembourg</td>
<td>2005</td>
<td>7.8</td>
<td>46</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Austria</td>
<td>2004</td>
<td>6.6</td>
<td>76</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>2003</td>
<td>3.8</td>
<td>93</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>1999</td>
<td>3.0</td>
<td>&lt; 5</td>
<td>&gt; 95</td>
<td></td>
</tr>
<tr>
<td>Estonia</td>
<td>2006</td>
<td>2.4</td>
<td>73</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>Ireland</td>
<td>2005</td>
<td>2.3</td>
<td>43</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>2000</td>
<td>2.2</td>
<td>75</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Belgium-Wallonia</td>
<td>1995</td>
<td>2.1</td>
<td>74</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>1999</td>
<td>2.0</td>
<td>&lt; 5</td>
<td>&gt; 95</td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>2004</td>
<td>1.6</td>
<td>54</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Belgium-Brussels</td>
<td>2000</td>
<td>1.2</td>
<td>50</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Slovenia</td>
<td>2005</td>
<td>1.1</td>
<td>53</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Lithuania</td>
<td>2006</td>
<td>0.6</td>
<td>n. s.</td>
<td>n. s.</td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td></td>
</tr>
<tr>
<td>Cyprus</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td></td>
</tr>
<tr>
<td>Latvia</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td></td>
</tr>
<tr>
<td>Malta</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td></td>
</tr>
<tr>
<td>Romania</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td></td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td></td>
</tr>
</tbody>
</table>

n. s....not specified; n. a....not available

---

55 8.25 Million tons re-used or recycled as aggregates and 0.75 Million tons residual waste with unknown deposition.

56 Arisings related to C&D waste within the sectors ‘construction and demolition’ and ‘mining and quarrying’.

57 ‘Excavated materials’ and ‘construction/demolition wood’ excluded; recycling rate related to the amounts generated by the Members of the ‘Austrian Construction Materials Recycling Association’; 16% disposed on landfills; the deposition of 8% can be related to re-use, recycling or incineration.

58 Arisings related to waste generated in the ‘building and construction sector’.

59 Mixed C&D waste (concrete and rubble, as well as wood glass, metal and plastics) excluding excavation waste like soil and stones.

60 The arisings include the waste types iron and steel, soil from excavations and deepening works, waste concrete and concrete debris coming from demolition and repair works, mixed debris and materials coming from demolition works, waste construction materials based on gypsum, soil and stones; 11% of the arisings were brought to storage.

61 Arisings excluding excavated soils; the deposition of 9% is unknown.

62 Excavated soils are excluded from the arisings.

63 The deposition of 19% is not specified.

64 Calculation for re-use and recycling rate done for about 800,000 tons of the arisings.

65 Arisings including concrete, bricks, gypsum waste, hydro-carbonised road waste (surfacing material) and mixed construction wastes.
Table 20 and Table 21 show data on the amount of construction and demolition waste generated in European Countries. For data quality see the Member States’ reports in Chapter 7.

3.2 Uses applied

3.2.1 Waste management options

Construction and demolition waste is re-used for the original intended purpose, recycled or disposed of on landfills.

3.2.1.1 Re-use, recycling and recovery

Approximately 30% of the total volume is consigned to recycling in Europe. In many EU countries, recycling of separated fractions has become a standard activity and the market recognises these products as equivalent to products manufactured from new materials.

Construction and demolition waste constitutes a highly significant proportion of all wastes having a very high recovery potential, as shown by the pilot projects carried out and the action taken in some Member States, which have achieved recycling levels of more than 80%.

New information show that several regions already have already reached a very high rate of re-use and recycling, e.g. the Netherlands with a level of 95%, Denmark with a level of 93%, Belgium-Flanders with a level of 92% and Germany with a level of 91%. In Austria, Belgium-Wallonia, Estonia and Poland approximately ¾ of the total volume is re-used or recycled. Lower recycling levels are documented in the Czech Republic with 30% and in France with 25%. In some Member States like the UK, there are high amounts of excavated waste included in the listed data, so that it seems not feasible to compare these data with the other Member States.

Inert materials from construction and demolition waste can be re-used in the following ways:

- On-site filling material to form landscape hillocks, anti-noise barriers (banks);
- Sub-grade or sub-base and base course of roadway with addition of binders;
- Wearing courses which can be regenerated in place (hot or cold procedure);
- Pavements which can be treated on the spot by a mixture with binders;
- Pavements which can be treated on the spot by crushing or screening before re-use;
- Filling material with or without treatment.

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66 EUROPEAN COMMISSION (2000)
A high proportion of conventional demolition waste and particularly the fractions derived from concrete, bricks and tiles are well suited for being crushed and recycled as a substitute for newly quarried (primary) aggregates in certain lower grade applications, most notably filling material in engineering and road sub-base. This practice has been common (though not necessarily widespread) in several Member States for many years\(^67\).

Studies show that recycled aggregates are used in several segments as filling, foundation, asphalt and concrete (the use in ready-mix concrete is in its early stages in spite of the many studies referring to it)\(^68\).

The use of aggregates derived from construction and demolition waste in new concrete is much less common, and technically much more demanding. These materials therefore have the potential to replace equivalent volumes of primary aggregates, thus preserving non-renewable resources, with minimal need for landfill space\(^67\).

Reducing the pressure on increasingly scarce landfill space is widely seen as one of the key benefits of recycling of construction and demolition waste\(^67\).

### 3.2.1.2 Disposal

Approximately \(3/4\) of the total volume is disposed of on landfills in Europe\(^66\). Regarding the high recycling rates in several Member States it can be assumed that in a few Member States with high arisings of C&D waste, disposal is more common as a way of recovery.

The disposal rates vary in widely ranges in the European Member States. Whereas the disposal rates in Member States like the Netherlands and Denmark are close to 3 and 5 %, less than 20 % of the construction and demolition waste is disposed on landfills in Austria, Belgium, Germany and Poland. Ireland, Finland and Luxembourg have higher disposal rates at about 50%.

### 3.2.2 Environmental risks

Due to the wide range of materials used for construction the possibility of hazardous contaminants has to be considered for recycling processes with special emphasis given to the leaching of dangerous substances. Table 22 shows possible potentially hazardous elements in construction and demolition waste which could have an impact on the environment. In general, these hazardous substances should be banned as much as possible from materials which are intended to be used as aggregates.

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\(^{67}\) **BRUSSELS INSTITUTE FOR THE MANAGEMENT OF THE ENVIRONMENT (2006)**

\(^{68}\) **EUROPEAN AGGREGATES ASSOCIATION (2006)**
Table 22: Potentially hazardous elements in construction and demolition waste\textsuperscript{44}.

<table>
<thead>
<tr>
<th>Product / material</th>
<th>Potentially hazardous component(s)</th>
<th>Potentially hazardous properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete additives</td>
<td>Hydrocarbon solvents</td>
<td>Flammable</td>
</tr>
<tr>
<td>Damp proof materials</td>
<td>Solvents, bitumen</td>
<td>Flammable, toxic</td>
</tr>
<tr>
<td>Adhesives</td>
<td>Solvents, isocyanides</td>
<td>Flammable, toxic, irritant</td>
</tr>
<tr>
<td>Mastics / sealants</td>
<td>Solvents, bitumen</td>
<td>Flammable, toxic</td>
</tr>
<tr>
<td>Road surfacing</td>
<td>Tar based emulsions</td>
<td>Toxic</td>
</tr>
<tr>
<td>Asbestos</td>
<td>Respirable fibre</td>
<td>Toxic, carcinogenic</td>
</tr>
<tr>
<td>Mineral fibres</td>
<td>Respirable fibre</td>
<td>Skin &amp; lung irritants</td>
</tr>
<tr>
<td>Treated timber</td>
<td>Copper, arsenic, chrome, tar, pesticides, fungicides</td>
<td>Toxic, ecotoxic, flammable</td>
</tr>
<tr>
<td>Fire resistant wasting</td>
<td>Halogenated compounds</td>
<td>Ecotoxic</td>
</tr>
<tr>
<td>Paint and coatings</td>
<td>Lead, chromium, vanadium, solvents</td>
<td>Toxic, flammable</td>
</tr>
<tr>
<td>Power transfer equipment</td>
<td>PCBs</td>
<td>Ecotoxic</td>
</tr>
<tr>
<td>Lighting</td>
<td>Sodium, Mercury, PCBs</td>
<td>Toxic, ecotoxic</td>
</tr>
<tr>
<td>Air conditioning systems</td>
<td>CFCs</td>
<td>Ozone depletes</td>
</tr>
<tr>
<td>Fire fighting systems</td>
<td>CFCs</td>
<td>Ozone depletes</td>
</tr>
<tr>
<td>Contaminated building fabric (including contamination due to previous use)</td>
<td>Radionuclides</td>
<td>Toxic</td>
</tr>
<tr>
<td></td>
<td>Heavy metals including cadmium and mercury</td>
<td>Toxic</td>
</tr>
<tr>
<td></td>
<td>Biohazards (anthrax)\textsuperscript{69}</td>
<td>Toxic</td>
</tr>
<tr>
<td>Animal product\textsuperscript{69}</td>
<td>Biohazards (anthrax)\textsuperscript{69}</td>
<td>Toxic</td>
</tr>
<tr>
<td>Gas cylinders</td>
<td>Propane, butane, acetylene</td>
<td>Flammable</td>
</tr>
<tr>
<td>Resins/ fillers, Precursors</td>
<td>Isocyanides, anhydride</td>
<td>Toxic, irritant</td>
</tr>
<tr>
<td>Oils and fuels</td>
<td>Hydrocarbons</td>
<td>Ecotoxic, flammable</td>
</tr>
<tr>
<td>Plasterboard</td>
<td>Source of hydrogen sulphides</td>
<td>Flammable, toxic</td>
</tr>
<tr>
<td>Road planings</td>
<td>Tar, asphalt, solvents</td>
<td>Flammable, toxic</td>
</tr>
<tr>
<td>Sub base (ash / clinker)</td>
<td>Heavy metals including cadmium and mercury</td>
<td>Toxic</td>
</tr>
</tbody>
</table>

The quantity of hazardous substances may seem relatively small compared with the total volume of the waste stream. Nevertheless, special precautions must be taken for their management since their presence may contaminate the entire waste stream, thus causing problems during the recovery or disposal of construction and demolition waste\textsuperscript{66}.

Quality control appears to be very important. Even in those Member States where recycled aggregates are already relatively widely used, the main barrier to greater market acceptance appears to be potential buyers’ doubts about their quality and consistency rather than a lack of formal standards for recycled materials. In some countries there is now a move among C&DW-derived aggregates producers towards introducing external quality verification procedures (typically involving cooperation with an independent materials testing laboratory), thereby allowing their products to benefit from a quality mark\textsuperscript{44}.

\textsuperscript{69} Horse hair was formerly used as a binder in plaster. Since the disease of anthrax was widespread up to the 19th century, and the spores of anthrax are very robust and long-lived as well as being hazardous to human health, walls which had been plastered in/before the 19th century must be treated with great care when being demolished.
Existing national quality systems for recycled materials show that in general, better product management tends to lead to a better final product which can be used in a wider range of applications\(^{44}\).

In order to minimise the burden of testing and to avoid that construction products have to be repeatedly tested, the European Commission’s Mandate M/366 on the ‘Development of horizontal standardised assessment methods for harmonised approaches relating to dangerous substances under the Construction Products Directive’\(^70\) was presented in 2005.

### 3.2.3 Technical limitations

#### 3.2.3.1 Use for concrete

A characterization of recycled aggregates shows that the use of these materials in concrete requires precautions with regard to the fresh and hardened behaviour of the concrete (including its durability), the pathological risks of internal reactions due to alkali-aggregates as well as sulphate reaction. Concrete fully based on recycled aggregates is characterised by a high ratio ‘total water/cement’ which leads to greater permeability on the surface and in the core, more significant water absorption and very quick carbonisation. Concrete fully based on recycled aggregates is very susceptible to frost action. Durability can be improved through the granular composition, the aggregates water pre-moistening quantity and various types of cement\(^71\).

A well formulated concrete using recycled aggregates presents the same homogenous and increasing mechanical resistances as the one which uses natural aggregates (according to the ‘water/cement ratio’ used)\(^72\).

#### 3.2.3.2 Use of reclaimed concrete pavement

The re-utilization of concrete pavement in the construction of new concrete layers is referred to as ‘reclaimed concrete pavement’, which is basically, ‘concrete pavement recycling’. Concrete pavement recycling implies a demolishing activity followed by the corresponding process in crushing plants in order to get a final product that can be used in the construction of new pavement layers. The considerations presented in the following sections also apply to the recycling of lean concrete pavement base layers, roller-compactcd concrete pavement and, to large extent, cement-bound granular material pavement\(^73\).

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\(^{70}\) EUROPEAN COMMISSION (2007b)

\(^{71}\) HADJEVA-ZAHARIEVA, R. (1998)

\(^{72}\) QUEBAUD, M. (1996)

\(^{73}\) SAMARIS (2004)
3.2.4 Environmental benefits

The following benefits can be expected from using recycled aggregates to substitute natural aggregates:

- **Saving natural resources:** In several Member States there is a policy intending to limit the exploitation of alluvium in overexploited areas and to preserve these deposits for future generations;
- **Reducing the demand for landfill capacities:** The recovery of construction and demolition waste leads to a reduction in waste disposal;
- **Reducing the harmful effects of transport:** Waste to be recovered is located in urban areas which are also the most significant consumer areas. Quarries are in theory located outside the centres of urban areas or tend to be removed further away. Therefore, the consumption of recycled aggregates leads to a significant reduction in transport and thus in the related harmful effects.

3.3 Processes applied

Depending on the nature of the construction and demolition waste and on the separation and sorting processes already carried out on this waste stream, materials can be used either directly or processed in special installations. Wood, paper, glass, plastics, metals and other non-mineral fractions separated from construction and demolition waste have to be recycled in an adequate way which will not be discussed in this study.

The mineral fraction of construction and demolition waste containing mainly concrete, bricks, tiles, ceramics, etc. can be processed:

- On-site at the construction site;
- Off-site in a recycling installation;
- As part of the manufacturing process (e.g. washed aggregates are recovered and used in the production of concrete).

The following processes are applied to enable further recovery of construction and demolition waste:

- Adequate preliminary demolition;
- Inspection and control (weighing, visual control, analysis);
- Sorting and separation processes (manual or automated sorting, screening, sieving, ferrous metal and non-ferrous metal separator);
- Crushing (mills, crusher);
- Washing (cleaning, elimination of ‘contraries’);
- Classification and quality control (in case of low quality, reprocessing is possible).

In general, the processes are applied for mixed construction and demolition waste and for already separated fractions of concrete, asphalt, stones etc. and, except the demolition itself, the processes can be carried out in mobile or fixed treatment installations on-site or off-site.
3.3.1 General technical descriptions

Nowadays, the market offers a wide variety of equipment and there is a wide range of possible technical solutions which can be applied to the recycling of construction and demolition waste, from simple mobile crushers for the inert fraction right through to fully integrated fixed recycling centres capable of dealing with the full range of construction and demolition waste streams. It should be stressed that, however sophisticated the technology and techniques available, selective demolition and avoidance of treatment at the generation site is always likely to be by far preferable to the treatment of wastes at the recycling centre.

Demolition

Hydraulic hammers, mounted on a bulldozer or digger, have been widely used in demolition processes, especially in concrete pavement demolition. This type of demolition machine has been used in the case of slabs presenting large widths as in the case of airport pavements. Further technical equipment to be used in the case of concrete pavement includes hydraulic hammers, impact breakers and hydraulic jaw crushers, jet water breakers and resonance breakers.

Screening

Screening separates materials into different size fractions. Material retained on the screen is called oversize, and material passing through the screen is called undersize. Screening equipment can be used to remove contamination and large materials unsuitable for further processing, or to produce specific aggregate types. Screens can be mounted in decks, or placed in series, so that the undersize fraction passing the first screen is further screened to remove smaller particles. This approach produces single size aggregates and graded aggregates.

Screens can be made of mesh, bars, or from holes punched in plates. Screens can become blocked and require cleaning and maintenance. There are many different types of screens like e.g. screen decks, mats, plates as well as trommel screens or vibration screens.

Crushing

Crushing is the breaking or grinding by mechanical means of rock, stone or recycled materials, for direct use or further processing. The main objective of crushing in aggregate production is to reduce the material to a specified size range. Grinding normally refers to the production of finer materials, using machines such as ball and rod mills. Crusher selection affects particle size and shape, as well as the way the plant will be configured.

74 WASTE AND RESOURCES ACTION PROGRAMME WRAP: http://www.wrap.org.uk
Several types of crushing machines are used in aggregate processing. These include: compression type crushers, such as jaw and cone crushers; impact type crushers, such as bar blow crushers or vertical shaft impactors. There are many different types of crushers like e.g. cone crushers, impact crushers or jaw crushers.

‘Impact’ crushers use a high speed rotor inside a container into which the material to be crushed is fed. There are typically four or six ‘hammer plates’ mounted on the rotor which breaks the material against ‘face plates’ set at operator-determined positions on the inner surface of the container. The ‘cutting’ action is very like that on a conventional cylinder lawnmower (for cutting grass). The throughput is greatly affected by the clearance between the rotating ‘hammer plates’ and the fixed ‘face plates’, and the rate of wear on the plates varies according to the hardness of the material being processed.

‘Jaw’ crushers are typically shaped like a wedge, in which one of the faces moves in relation to the others, producing a ‘chewing’ action which grinds the material into progressively smaller pieces as it passes towards the narrow end. Material is fed in at the wide end (the top), and falls out at the narrow end (see Annex 13 for an illustration). The narrow end can be set to a range of openings to determine the nature of the resultant material.

The choice of an ‘impact’ crusher over a ‘jaw’ crusher reflects the fact that the former produces a more consistent and predictable aggregate, with sharper edges on the individual granules. Impact crushers produce an aggregate with a smaller range of sizes, and although they are substantially cheaper to buy on a size-for-size basis, their running costs are much higher, particularly with very hard materials like some reinforced concretes. In general impact crushers tend to be designed for higher throughputs than ‘jaw’ crushers.

Magnets
Magnets are used to remove ferrous materials from the feedstock. This is done to, e.g.: avoid damage to the plant, recover valuable materials and improve the quality of the product. There are three general types of magnets that remove ferrous material from the feedstock: Suspended permanent magnets, belt magnets and drum magnets (including conveyor end roller magnets). In addition, eddy current systems can be used to remove non-ferrous metals such as aluminium.

Manual sorting
Manual sorting may be required when unwanted material cannot be reliably or efficiently removed by other methods, such as magnetic extraction or screening. The most common way for this to be undertaken is by using a picking station. Picking stations are essentially conveyor belts configured to allow operatives to remove unwanted items. This configuration includes considerations of correct ergonomics, efficiency and safety.
Conveyors

Conveyors are generally electrically driven machines which extend from a receiving point to a discharge point, and convey, transport, or transfer material between these points. The most familiar form of conveyor is the belt conveyor. The other main form used in aggregates recycling is a vibratory conveyor, which is generally used as a feeder to assist the controlled loading of material into a plant.

Environmental Equipment

Environmental equipment is used to control dust, noise and water. There is a range of equipment that can assist in the control of dust, such as hoods, screens, extraction fans, water suppression sprays, as well as sweepers, browsers and wheel washers. For noise: this equipment may include baffles, screens and belts encapsulating the noisy kit, or components within the machines that reduce the noise they make, such as elastomeric screening surfaces or linings to chutes and hoppers. For water: there may be filters, settlement tanks, pumps and storage tanks. These storage tanks can be used to process water retrieved from aggregate processing or to store water for use in aggregate processing, reducing the need for mains water on site.

3.3.2 Recycling of road waste and by-products

The two principal techniques for recycling of road waste and by-products are known as in situ and ex situ recycling.

In situ recycling of roads generally involves the remediation of worn carriageways by reprocessing the existing road construction materials and incorporating a binder material. This requires several runs of specialised machinery. The technique has been used extensively in the Scandinavian countries. A 50 km stretch of the main highway between Zaragoza and Lerida (in Spain) was renovated in this way as a trial operation. In some other Member States (such as the UK) the use of this technique has generally been restricted to minor urban and rural roads. The process of in-situ recycling normally follows the following sequence:

- The existing road construction materials (including the wearing course, base course and sub-base) are broken away and mixed during one pass of a rotary pulveriser;
- A binder is mixed into the pulverised material during a further pass of the machine (where cement-based binders are used, water is also added);
- The resultant mix is graded (levelled) as necessary and compacted using conventional equipment;
- The surface is sealed with bitumen and grit in preparation for the laying of a new wearing course.

Before the process begins, core samples are taken from the existing road pavement to be able to determine the depth of treatment and type and percentage of the binder. After the first pass of the rotary pulveriser, material often has been removed in order to allow a new wearing course to be put into place without adversely affecting the final level of the road surface. The binders used in the process are generally cement, mixes of cement and lime, fly ash or foamed bitumen.
Ex situ recycling involves the excavation and removal of existing road construction materials to a stockpile, from where it is processed by grading and mixing with appropriate binders prior to being re-compacted to form the new road\textsuperscript{44}.

Ex situ recycling has the following characteristics\textsuperscript{44}:

- The recycling installation is easily transported and can be established on the chosen site in a few hours;
- The plant itself is comparatively smokeless, odourless and quiet;
- The location for the recycling plant can be chosen to reduce environmental impacts and to enable them to be mitigated;
- Environmental impacts at the reconstruction site itself can be reduced to a minimum;
- A wide range of materials can be processed including road planings, crushed concrete and masonry;
- The materials can be crushed and screened to fit a predetermined grading ‘envelope’, before being mixed with a binder;
- All materials are processed in a controllable environment, resulting in the production of a quality controlled product;
- Graded materials can be stockpiled until they are needed;
- Bound materials, if correctly stored, can be used for up to four weeks after production;
- The excavation of the road and its replacement can be undertaken using conventional plant and equipment;

In addition to recycled aggregates secondary aggregates (such as fly ash) can be incorporated into the new road, reducing the need for primary aggregates.

The ex situ approach allows greater control over material quality than in situ recycling (see above), and more engineering control during the construction operation. It more easily provides a consistent construction material which experience has shown to be suitable for road surfaces with heavy traffic\textsuperscript{44}.
4 SLAGS FROM FERROUS METAL PRODUCTION

4.1 Material streams

In the iron and steel industry large amounts of slags are accumulated besides the production of iron and steel. According to an inquiry in 2004 the European steel industry generated about 40 million tonnes of slags resulting from iron and steel making.75

A main distinction is drawn between slag from the production of pig iron (blast furnace slag), slags from steel processing (BOF-slag (basic oxygen furnace slag), EAF-slag (electric arc furnace slag)) and secondary slags from secondary steelmaking.

The main components of slag are CaO, SiO$_2$, Al$_2$O$_3$, MgO and Fe$_2$O$_3$. The chemical composition of slags highly depends on the iron or steel production process, as well as on the use of additives. Different additives and different measures (like cooling and further treating of the slag) can influence its quality. With increasing recycling rates of internal wastes (dusts, mill scales and sludges) as well as external wastes (scraps) unwanted accumulations of elements, especially heavy metals (Pb, Zn) occur.

The physical characteristics (like vitreous or crystalline structure, particle size) can be influenced via the cooling conditions whereby different uses for the slags arise. In addition to the chemical composition, the elution of hazardous substances is important. The production of iron and steel is thus also carried out with a view to the quality of the slag.

The generated blast furnace slag amounted to about 25 million tonnes in Europe in 2004. About 23 % of this tonnage was processed as air-cooled crystalline slag, and 77 % was vitrified slag (granulated or pelletized)78.

The total amount of steel slags generated in 2004 was about 15 million tonnes. About 62 % of this tonnage was produced as basic oxygen furnace slags, 29 % as electric arc furnace slags and 9 % as secondary metallurgical slag78.

Slag treatment has a long tradition. In Figure 5 the treatment options for blast furnace slag and converter slag are given.

75 EUROSLAG (2006)
4.1.1 Generation process

4.1.1.1 Blast furnace slag

The blast furnace process remains by far the most important process for the production of pig iron. A blast furnace is a closed system into which iron bearing materials (iron ore lump, sinter and/or pellets), additives (slag formers such as limestone) and reducing agents (coke) are continuously fed from the top of the shaft furnace. A hot air blast enriched with oxygen and auxiliary reducing agents is injected; the air blast reacts with the reducing agents to produce mainly carbon monoxide, which in turn reduces iron oxides to metal iron. Finally liquid hot metal and slag are collected at the bottom. Fluxes and additives are added to lower the melting point of the gangue, improve sulphur uptake by slag, provide the required liquid pig iron quality and allow further processing of the slag. The gangue components combine with the fluxes to form slag. This slag is a complex mix of silicates of a lower density than the molten iron. For further processing it has to comply with special quality demands. Therefore in modern blast furnaces the operation mode is carried out with regard to the quality of the pig iron and the blast furnace slag.

According to the cooling conditions blast furnace slag crystallizes to:

- air cooled blast furnace slag (lump slag),
- foamed blast furnace slag (expanded blast furnace slag), or
- granulated blast furnace slag (when using quick cooling).

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76 FEHS (1992)

77 GARA, S. ET AL. (1998); FEHS (2005)
Granulated blast furnace slag (GBS) is manufactured from molten blast furnace slag, a co-product produced simultaneously with iron. Rapid chilling with water or air forms a glassy granular material with latent-hydraulic properties. It is used for cement, concrete, mortar, grout and aggregates.

Table 23: Processing methods for blast furnace slag.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Structure</th>
<th>Kind of slag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow cooling on air</td>
<td>Crystalline</td>
<td>Air cooled blast furnace slag (lump slag, rock slag)</td>
</tr>
<tr>
<td>Very fast cooling with water in granulation plants</td>
<td>vitreous, amorphous</td>
<td>granulated blast furnace slag (GBS) (granulated cinder)</td>
</tr>
<tr>
<td>Middle cooling in combination with directed induced gases</td>
<td>high porous, vitreous/crystalline</td>
<td>Expanded blast furnace slag (foamed blast furnace slag)</td>
</tr>
<tr>
<td>Jet air or water vapour</td>
<td>fibrous, vitreous</td>
<td>mineral wool, slag wool</td>
</tr>
<tr>
<td>Fluid slag flows on water-cooled rotating roll</td>
<td>fine fraction: almost vitreous; coarse fraction: vitreous/crystalline</td>
<td>blast furnace pellets (pelletized blast furnace slag)</td>
</tr>
</tbody>
</table>

4.1.1.2 Basic oxygen furnace slag

Basic oxygen furnace (BOF) slag arises when steel is produced from pig iron, direct reduced iron or scrap. The amount of slag depends on the amount of silicon in the pig iron, because this is connected with the amount of lime added.

The BOF is used to produce steel. The objective in oxygen steelmaking is to burn (oxidise) the undesirable impurities contained in the metallic feedstock. The main elements thus converted into oxides are carbon, silicon, manganese, phosphorus and sulphur. Undesirable impurities are removed with the off-gas or the liquid slag. The oxidising reactions are exothermic thus increasing the temperature of the molten iron. Scrap, iron ore or other coolants are added to cool down the reaction and maintain the temperature. The production of steel by the BOF process is a discontinuous process. During the steelmaking process, slag is formed.

Usually the slag is cooled and crushed, after which the metallic iron is recovered by magnetic separation. There are three main different kinds of the BOF-process, the LD (Linz-Donawitz) and LD/AC processes (Linz-Donawitz/Arbed-CRM), BOP processes (bottom-blown oxygen process) and combined processes. The LD process is normally used for phosphorous poor pig iron while the LD/AC process is used for phosphorous rich pig iron.

LD slag congeals to a firm, grey, stone-like material which is not as porous as blast furnace slag. Because of its structure, LD slag has a high abrasion resistance and is therefore often used for road construction. It is also used in civil and hydraulic engineering, the cement industry or disposed of in landfills.

4.1.1.3 Electric arc furnace slag

The direct smelting of iron-containing materials such as scrap is usually performed in electric arc furnaces (EAF) which play an important and increasing role in modern steel work design.
The major feed stock for EAF is ferrous scrap which may compromise scrap from inside the steelworks (e.g. off-cuts), cut-offs from steel product manufactures (e.g. vehicle builders) and capital or post consumer scrap (end of life products). Also, direct reduced iron is used as feedstock. As in the BOF, the slag is formed from lime to collect undesirable components in the steel. EAF-slag has a lower amount of free CaO than BOF-slag.

4.1.1.4 Secondary slags

After the oxidizing process the steel can be further processed, which is usually classified as secondary steelmaking. The further processing is the response to market demand for specific quality requirements. It is carried out in a ladle station. One example of secondary steelmaking is the production of stainless steel; this process leads to Argon Oxygen Decarburization slags (AOD slags).

4.1.2 Quality

4.1.2.1 Blast furnace slag

If solidified, GBS is an inorganic, glassy material. The glassy nature is responsible for its cementitious properties. The four major chemical components, calculated as oxides, are CaO, SiO$_2$, Al$_2$O$_3$, and MgO. TiO$_2$ and MnO are also present and influence the latent hydraulic properties.$^{78}$

The chemical composition of the blast furnace slag depends on the composition of the deployed iron ore and the produced pig iron. The composition of blast furnace slag for basicity below and above 1.0 is given in Table 24.$^{79}$ Table 25 and Table 26 give more data on the quality of slags.

Table 24: Composition of blast furnace slag$^{79}$

<table>
<thead>
<tr>
<th>Classification</th>
<th>Blast furnace slag</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO/SiO$_2$</td>
<td>&gt; 1.0</td>
</tr>
<tr>
<td>MgO-content</td>
<td>middle</td>
</tr>
<tr>
<td>Fe$_{\text{total}}$</td>
<td>0.2 – 0.6</td>
</tr>
<tr>
<td>Mn$_{\text{total}}$</td>
<td>0.2 – 0.7</td>
</tr>
<tr>
<td>TiO$_2$</td>
<td>0.5 – 2.7</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>9.0 – 14.0</td>
</tr>
<tr>
<td>S$_{\text{total}}$, mainly CaS</td>
<td>1.1 – 2.0</td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>33.2 – 37.0</td>
</tr>
<tr>
<td>CaO</td>
<td>38.1 – 41.7</td>
</tr>
<tr>
<td>MgO</td>
<td>7.0 – 11.0</td>
</tr>
<tr>
<td>Na$_2$O</td>
<td>0.3 – 0.6</td>
</tr>
<tr>
<td>K$_2$O</td>
<td>0.6 – 0.8</td>
</tr>
<tr>
<td>CaO/SiO$_2$</td>
<td>1.1 – 1.2</td>
</tr>
<tr>
<td>(CaO + MgO) / SiO$_2$</td>
<td>1.3 – 1.5</td>
</tr>
</tbody>
</table>


$^{79}$ EUROPEAN COMMISSION (2001)
Comparing Table 24 and Table 25, the ranges of EUROSLAG and the BREF iron and steel fit together, but the ranges are wider in the Euroslag data.

Table 25: Chemical composition of granulated blast furnace slag in comparison with ordinary Portland cement clinker (OPCC)\(^76\).

<table>
<thead>
<tr>
<th>Component</th>
<th>GBS</th>
<th>OPCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insoluble residue</td>
<td>0.03-4.06</td>
<td>0.04-0.72</td>
</tr>
<tr>
<td>SiO(_2)</td>
<td>30.5-40.8</td>
<td>19.8-23.4</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>5.9-17.6</td>
<td>4.0-6.5</td>
</tr>
<tr>
<td>FeO</td>
<td>0.12-4.72</td>
<td>-</td>
</tr>
<tr>
<td>Fe(_2)O(_3)</td>
<td>-</td>
<td>1.50-3.80</td>
</tr>
<tr>
<td>TiO(_2)</td>
<td>0.07-3.70</td>
<td>0.13-0.30</td>
</tr>
<tr>
<td>MnO</td>
<td>0.07-3.12</td>
<td>-</td>
</tr>
<tr>
<td>Mn(_2)O(_3)</td>
<td>-</td>
<td>0.01-0.28</td>
</tr>
<tr>
<td>CaO total</td>
<td>30.9-46.1</td>
<td>64.1-68.4</td>
</tr>
<tr>
<td>CaO free</td>
<td>-</td>
<td>0.30-2.37</td>
</tr>
<tr>
<td>MgO</td>
<td>1.66-17.31</td>
<td>0.72-4.66</td>
</tr>
<tr>
<td>Na(_2)O</td>
<td>0.09-1.73</td>
<td>0.03-0.38</td>
</tr>
<tr>
<td>K(_2)O</td>
<td>0.08-1.51</td>
<td>0.37-1.30</td>
</tr>
<tr>
<td>Na(_2)O-Equivalent (Na(_2)O + 0.658* K(_2)O)</td>
<td>0.19-2.61</td>
<td>0.47-1.07</td>
</tr>
<tr>
<td>SO(_3)(^2-)</td>
<td>0.00-0.86</td>
<td>0.14-1.84</td>
</tr>
<tr>
<td>S(^+)</td>
<td>0.42-2.29</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 26: Chemical composition in weight-% of two different blast furnace slags and ranges for blast furnace slag\(^80\).

<table>
<thead>
<tr>
<th>Components</th>
<th>Slag 1</th>
<th>Slag 2</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO(_2)</td>
<td>39.2</td>
<td>38.21</td>
<td>33-40</td>
</tr>
<tr>
<td>CaO</td>
<td>37.4</td>
<td>40.25</td>
<td>31-42</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>9.7</td>
<td>11.07</td>
<td>8-14</td>
</tr>
<tr>
<td>MgO</td>
<td>8.7</td>
<td>7.82</td>
<td>7-15</td>
</tr>
<tr>
<td>K(_2)O</td>
<td>1.4</td>
<td>0.55</td>
<td>0.6-1.2</td>
</tr>
<tr>
<td>TiO(_2)</td>
<td>1.3</td>
<td>0.48</td>
<td>0.1-2.7</td>
</tr>
<tr>
<td>S total</td>
<td>1.2</td>
<td>1.15</td>
<td>0.7-1.6</td>
</tr>
<tr>
<td>Mn total</td>
<td>0.8</td>
<td>0.29</td>
<td>0.2-0.8</td>
</tr>
<tr>
<td>Fe total</td>
<td>0.5 (FeO)</td>
<td>0.29</td>
<td>0.2-0.7</td>
</tr>
<tr>
<td>P(_2)O(_5)</td>
<td>0.01</td>
<td>n.s.</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Na(_2)O</td>
<td>0.5</td>
<td>n.s.</td>
<td>0.3-1.2</td>
</tr>
<tr>
<td>CaO/SiO(_2)</td>
<td>n.s.</td>
<td>n.s.</td>
<td>0.8-1.2</td>
</tr>
<tr>
<td>(CaO + MgO) / SiO(_2)</td>
<td>n.s.</td>
<td>n.s.</td>
<td>1.0-1.3</td>
</tr>
<tr>
<td>Co</td>
<td>&lt;0.001</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cu</td>
<td>&lt;0.001</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sb</td>
<td>&lt;0.001</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sn</td>
<td>&lt;0.0001</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zn</td>
<td>&lt;0.0002</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

\(^{76}\) ANONYMOUS (2003); \(^{80}\) ARLT, K.J. (2005)
4.1.2.2 BOF slag

The chemical composition of BOF-slag is strongly dependent on the steel process and the additives. Basically a distinction of the slag is drawn between its lime, phosphate, silicate and iron content\(^{81}\).

The slag from basic oxygen steelmaking makes up the largest share of residues. The chemical composition of the slag depends on the processes employed and is given in the following tables.

**Table 27: Chemical composition of BOF slag in weight-%\(^{79}\).**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>50.0</td>
<td>50.0</td>
<td>53.0</td>
</tr>
<tr>
<td>SiO(_2)</td>
<td>9.0</td>
<td>15.0</td>
<td>28.0</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>≤ 2</td>
<td>≤ 2</td>
<td>3.0</td>
</tr>
<tr>
<td>MgO</td>
<td>≤ 3</td>
<td>≤ 3</td>
<td>5.0</td>
</tr>
<tr>
<td>Total Fe</td>
<td>12.0</td>
<td>16.0</td>
<td>≤ 2</td>
</tr>
<tr>
<td>Metallic Fe</td>
<td>≤ 1</td>
<td>≤ 1</td>
<td>≤ 1</td>
</tr>
<tr>
<td>MnO</td>
<td>2.0</td>
<td>≤ 4</td>
<td>≤ 1</td>
</tr>
<tr>
<td>P(_2)O(_5)</td>
<td>15.0</td>
<td>≤ 2</td>
<td>≤ 0.5</td>
</tr>
<tr>
<td>Cr(_2)O(_3)</td>
<td>≤ 1</td>
<td>≤ 1</td>
<td>≤ 2</td>
</tr>
<tr>
<td>Free CaO</td>
<td>≤ 7</td>
<td>≤ 10</td>
<td>≤ 5</td>
</tr>
<tr>
<td>S</td>
<td>-</td>
<td>-</td>
<td>≤ 1</td>
</tr>
<tr>
<td>CaO/SiO(_2)</td>
<td>4</td>
<td>2.5</td>
<td>1.8</td>
</tr>
</tbody>
</table>

**Table 28: Chemical composition of BOF slag in weight % based on an analysis of 7389 samples taken in 2005 and 2006\(^{82}\).**

<table>
<thead>
<tr>
<th>Process</th>
<th>Mean value</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al(_2)O(_3)</td>
<td>1.98</td>
<td>0.21</td>
<td>49.69</td>
</tr>
<tr>
<td>CaO</td>
<td>49.2</td>
<td>23.29</td>
<td>61.27</td>
</tr>
<tr>
<td>FeO</td>
<td>18.2</td>
<td>0.00</td>
<td>36.70</td>
</tr>
<tr>
<td>MgO</td>
<td>6.43</td>
<td>3.20</td>
<td>32.22</td>
</tr>
<tr>
<td>MnO</td>
<td>3.6</td>
<td>0.29</td>
<td>13.55</td>
</tr>
<tr>
<td>P(_2)O(_5)</td>
<td>2.1</td>
<td>0.00</td>
<td>3.93</td>
</tr>
<tr>
<td>SiO(_2)</td>
<td>12.77</td>
<td>1.00</td>
<td>42.80</td>
</tr>
<tr>
<td>S</td>
<td>0.04</td>
<td>0.00</td>
<td>0.23</td>
</tr>
<tr>
<td>TiO(_2)</td>
<td>0.68</td>
<td>0.20</td>
<td>3.80</td>
</tr>
</tbody>
</table>

\(^{81}\) GARA, S. ET AL. (1998)

\(^{82}\) According to a presentation of EUROSLAG (2007).
Table 29: Chemical composition in mass % of two different BOF slags and ranges for BOF slags.  

<table>
<thead>
<tr>
<th>Components</th>
<th>Slag 1</th>
<th>Slag 2</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>14.7</td>
<td>10.7</td>
<td>10-15</td>
</tr>
<tr>
<td>CaO</td>
<td>45.6</td>
<td>45.3</td>
<td>36-50</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>2.5</td>
<td>2.5</td>
<td>1.0-3.5</td>
</tr>
<tr>
<td>MgO</td>
<td>5.0</td>
<td>2.6</td>
<td>4-8</td>
</tr>
<tr>
<td>K₂O</td>
<td>&lt; 0.02</td>
<td>0.03</td>
<td>n.s.</td>
</tr>
<tr>
<td>TiO₂</td>
<td>1.2</td>
<td>0.52</td>
<td>n.s.</td>
</tr>
<tr>
<td>S</td>
<td>n.s.</td>
<td>n.s.</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>Mn</td>
<td>4.5</td>
<td>2.9</td>
<td>5 (MnO)</td>
</tr>
<tr>
<td>Fe-total</td>
<td>18.9</td>
<td>20.0</td>
<td>18-24</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>n.s.</td>
<td>1.35</td>
<td>0.7-2.0</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.04</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cu</td>
<td>&lt;0.008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zn</td>
<td>&lt;0.009</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>&lt;0.003</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Co</td>
<td>&lt;0.0009</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mo</td>
<td>&lt;0.001</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cr</td>
<td>&lt;0.175</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

BOF slags may expand because of the free CaO and MgO. The slag has to be stabilised in order to avoid this reaction.  

4.1.2.3 EAF slag

The different input materials (like scrap, additives and alloy elements) determine the chemical composition of the EAF slag. The composition of slag from the production of carbon and low alloyed steel can be seen in the following tables. The tables contain, in addition, the slag composition from the production of high alloyed steel and from secondary metallurgy (AOD — argon oxygen decarburization and VOD - vacuum oxygen decarburization).

Table 30: Chemical composition of EAF slag in weight % compared to AOD slag.  

<table>
<thead>
<tr>
<th>Process</th>
<th>EAF slag (EWC 100202)</th>
<th>AOD slag (EWC 100202)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>43</td>
<td>50</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>SiO₂</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>MgO</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>FeO</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>rest</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

83 MARKUS, R. et al. (2005)  
84 ANONYMOUS (2005)
Table 31: Composition of slag from the production of carbon and low alloyed steel as well as from the production of high alloyed steel and from secondary metallurgy.

<table>
<thead>
<tr>
<th>Component (Weight-%)</th>
<th>Production of carbon/low alloyed steel</th>
<th>Production of high alloyed steel</th>
<th>Secondary metallurgy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slag from EAF</td>
<td>Slag from ladle</td>
<td>Slag from EAF</td>
</tr>
<tr>
<td>Fe total</td>
<td>10 – 32</td>
<td>≤ 2 – 5</td>
<td>≤ 2</td>
</tr>
<tr>
<td>CaO</td>
<td>25 – 45</td>
<td>30 - 50</td>
<td>45</td>
</tr>
<tr>
<td>CaO_free</td>
<td>≤ 4</td>
<td>≤ 10</td>
<td>≤ 10</td>
</tr>
<tr>
<td>SiO₂</td>
<td>10 – 18</td>
<td>10 – 20</td>
<td>30</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>3 – 8</td>
<td>3 – 12</td>
<td>5</td>
</tr>
<tr>
<td>MgO</td>
<td>4 – 13</td>
<td>7 – 18</td>
<td>7</td>
</tr>
<tr>
<td>MnO</td>
<td>4 – 12</td>
<td>≤ 1 – 5</td>
<td>2</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>1 – 2</td>
<td>≤ 0.5</td>
<td>3</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.3</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.001 – 0.6</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.46</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.11</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>V₂O₅</td>
<td>0.11 – 0.25</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>ZnO</td>
<td>0.02</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>CuO</td>
<td>0.03</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>NiO</td>
<td>0.01 – 0.4</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>S</td>
<td>0.02</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>C</td>
<td>0.33</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Table 32: Chemical composition of EAF slags in weight % for low alloyed, high alloyed steel and secondary metallurgy.

<table>
<thead>
<tr>
<th>Composition</th>
<th>EAF</th>
<th>AOD</th>
<th>Desulphurisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>35-45</td>
<td>35-50</td>
<td>50-60</td>
</tr>
<tr>
<td>SiO₂</td>
<td>10-18</td>
<td>25-35</td>
<td>15-25</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>3-8</td>
<td>1-10</td>
<td>&lt; 4</td>
</tr>
<tr>
<td>MgO</td>
<td>7-15</td>
<td>4-7</td>
<td>1-5</td>
</tr>
<tr>
<td>Fe total</td>
<td>10-30</td>
<td>&lt; 2</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>MnO</td>
<td>&lt; 1</td>
<td>k. A.</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>&lt; 1</td>
<td>&lt; 0.4</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>&lt; 2</td>
<td>1-5</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>CaO_free</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>S total</td>
<td>0.2-1</td>
<td>&lt; 0.4</td>
<td>1</td>
</tr>
</tbody>
</table>
4.1.2.4 Chemical characterisation of blast furnace slag and steel slag

Table 33: Chemical composition of blast furnace slag and steel slag in weight %.

<table>
<thead>
<tr>
<th></th>
<th>Blast furnace slag</th>
<th>BOF</th>
<th>Steel slag</th>
<th>EAF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>max.</td>
<td>average</td>
<td>max.</td>
</tr>
<tr>
<td>SiO₂</td>
<td>36.7</td>
<td>40</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>10.2</td>
<td>12</td>
<td>2.0</td>
<td>5.0</td>
</tr>
<tr>
<td>CaO</td>
<td>39.5</td>
<td>43</td>
<td>49</td>
<td>53</td>
</tr>
<tr>
<td>CaO free</td>
<td>n. d.</td>
<td>n. d.</td>
<td>6</td>
<td>9.5</td>
</tr>
<tr>
<td>MgO</td>
<td>9.4</td>
<td>16</td>
<td>2.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.4</td>
<td>0.8</td>
<td>n. d.</td>
<td>n. d.</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.5</td>
<td>0.9</td>
<td>n. d.</td>
<td>n. d.</td>
</tr>
<tr>
<td>TiO₂</td>
<td>1.1</td>
<td>2.5</td>
<td>n. d.</td>
<td>n. d.</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>n. a.</td>
<td>n. a.</td>
<td>1.5</td>
<td>2.7</td>
</tr>
<tr>
<td>MnO₂</td>
<td>0.6</td>
<td>1.3</td>
<td>4.2</td>
<td>6.0</td>
</tr>
<tr>
<td>Fe</td>
<td>0.4</td>
<td>0.7</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>S</td>
<td>1.5</td>
<td>1.9</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>n. d.</td>
<td>n. d.</td>
<td>0.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

in mg/kg:

<table>
<thead>
<tr>
<th></th>
<th>As</th>
<th>Cd</th>
<th>Cr</th>
<th>Co</th>
<th>Cu</th>
<th>Hg</th>
<th>Mo</th>
<th>Ni</th>
<th>Pb</th>
<th>Se</th>
<th>Ti</th>
<th>V</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>7</td>
<td>10</td>
<td>&lt;1</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;100</td>
</tr>
<tr>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>10</td>
<td>6</td>
<td>&lt;1</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;100</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>10</td>
<td>6</td>
<td>20</td>
<td>4</td>
<td>9</td>
<td>20</td>
<td>20</td>
<td>1</td>
<td>1</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>&lt;21</td>
<td>6</td>
<td>8</td>
<td>20</td>
<td>90</td>
<td>4</td>
<td>9</td>
<td>20</td>
<td>20</td>
<td>1</td>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>&lt;100</td>
<td>&lt;100</td>
<td>600</td>
<td>150</td>
<td>300</td>
<td>800</td>
<td>600</td>
<td>300</td>
<td>800</td>
<td>2500</td>
<td>900</td>
<td>900</td>
<td>&lt;900</td>
</tr>
</tbody>
</table>

F  600  <900  2200  3800  800  1800
CN_{total} n. d.  n. d.  <10  n. d.  <10

n.d. … not defined; n.a. … no answer

As shown in Table 33 the heavy metal-content of EAF slags is much higher than in BOF or blast furnace slags.

4.1.3 Quantity

4.1.3.1 Blast furnace slag

The amount of blast furnace slag produced is determined by the iron ore used and the amount of flux required achieving the necessary pig iron quality. Approximately 210 – 310 kg of blast furnace slag per ton of pig iron is accumulated; another source says 230 – 300 kg of blast furnace slag per ton of pig iron.

4.1.3.2 BOF slag

Approximately 85 – 110 kg\(^79\) of BOF slag per ton of liquid steel is accumulated; another source says 100 – 130 kg\(^79\) of BOF slag per ton of liquid steel.

4.1.3.3 EAF slag

Approximately 100 – 150 kg\(^79\) of EAF slag per ton of liquid steel is accumulated. The amount of slag from the production of high-grade steel is higher than the production of normal steel. When scraps with high quality and tight specifications are used for the production of steel, the amount of slag can be clearly lower (45 kg per ton of steel) than the above given value.

4.1.3.4 Generation of slags in Europe

Table 34: Generation of slags from ferrous metal production in European Countries, listed with regard to availability and total amount (Country reports, 2008).

<table>
<thead>
<tr>
<th>Member State / Region (in million tons)</th>
<th>Total</th>
<th>Blast furnace slag</th>
<th>Steel slag</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>14.490</td>
<td>7.62</td>
<td>6.87</td>
<td>2006</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5.200</td>
<td>2.0</td>
<td>3.2</td>
<td>2005</td>
</tr>
<tr>
<td>Poland</td>
<td>3.334</td>
<td>n. s.</td>
<td>n. s.</td>
<td>2000</td>
</tr>
<tr>
<td>Finland</td>
<td>3.000</td>
<td>n. s.</td>
<td>n. s.</td>
<td>2005</td>
</tr>
<tr>
<td>Austria</td>
<td>2.456</td>
<td>1.6</td>
<td>0.8</td>
<td>2004</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1.700</td>
<td>1.2</td>
<td>0.5</td>
<td>2000</td>
</tr>
<tr>
<td>Belgium Flemish Region</td>
<td>1.850</td>
<td>1.20</td>
<td>0.65</td>
<td>2006</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1.510</td>
<td>n. s.</td>
<td>n. s.</td>
<td>2006</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.996</td>
<td>0.580</td>
<td>0.416</td>
<td>2001</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>0.435</td>
<td>n. s.</td>
<td>n. s.</td>
<td>2005</td>
</tr>
<tr>
<td>Belgium Walloon Region</td>
<td>0.194</td>
<td>0.085</td>
<td>0.109</td>
<td>1995</td>
</tr>
<tr>
<td>Slovenia**</td>
<td>0.135</td>
<td>n. s.</td>
<td>n. s.</td>
<td>2006</td>
</tr>
<tr>
<td>Latvia**</td>
<td>0.047</td>
<td>n. s.</td>
<td>n. s.</td>
<td>2006</td>
</tr>
<tr>
<td>Ireland*</td>
<td>0.035</td>
<td>n. s.</td>
<td>n. s.</td>
<td>1999</td>
</tr>
<tr>
<td>Belgium Brussels Region</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Estonia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Malta</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Cyprus</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Denmark</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Greece</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Hungary</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Italy</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Lithuania</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Portugal</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Rumania</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Slovakia</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
<tr>
<td>Spain</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
<td>n. a.</td>
</tr>
</tbody>
</table>

\*: no iron and steel industry; n. s.: not specified; n. a.: not available.
*) waste from the processing of slag (EWC = 100201)
**) unprocessed slag (EWC = 100202)
4.2 Uses applied

Figure 6 shows applied uses of slags in Europe in 12 European countries: Austria, Belgium, Denmark, Germany, Finland, France, Luxembourg, Netherlands, Slovenia, Slovak Republic, Spain and the UK. They account for approximately 90% of the European total steel output. The main uses are cement production and road construction. Unfortunately, no distinction has been made between the different kinds of slags.

![Figure 6: Use of slags in Europe](image)

4.2.1 Waste management options

4.2.1.1 Blast furnace slag

Table 35 shows possible uses for blast furnace slags.

*Table 35: Possible use of blast furnace slags*

<table>
<thead>
<tr>
<th>Type of application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slag cement</td>
<td>There are two possibilities to produce slag cement. The individual components (granulated blast furnace slag and Portland cement clinker) are ground separately and subsequently blended. Or they are ground together, which means mixing and grinding in one single operation. In the European cement standard EN 197-1, nine cements containing slag are listed which have slag contents between 6 weight % and 95 weight %.</td>
</tr>
<tr>
<td>Concrete</td>
<td>In some parts of Europe slag cement is available as a separately ground material which is be used by the concrete producer as a cementitious component.</td>
</tr>
<tr>
<td>Mortar</td>
<td>Slag used as a cementitious component in mortars enhances their workability and can allow further working time for the bricklayer.</td>
</tr>
<tr>
<td>Grout</td>
<td>Grouts containing slag have been used to control temperature rise during hydration and in areas of aggressive conditions.</td>
</tr>
<tr>
<td>Aggregate</td>
<td>Unground granulated blast furnace slag is also used as a weight aggregate in concrete.</td>
</tr>
<tr>
<td>Road Making</td>
<td>Unground granulated blast furnace slag can be used as a base layer material in road construction.</td>
</tr>
</tbody>
</table>
Blast furnace slag as vitreous granulated cinder is used in the cement industry as secondary raw material or secondary constituent. Other uses are the use as concrete aggregate or the use in road construction.

The crystalline blast furnace slag (air cooled blast furnace slag, “lump slag”) has a good workability, a high load-high carrying capacity and stability. It is frost-proof and stable and can be used in road construction, as aggregate in concrete or in building materials with the need of high heat resistance.

Blast furnace slag as mineral wool is used as insulation.

In the BREF iron and steel the final use of blast furnace slag in the EU is given as followed:

- Cement industry: 26 %
- Road construction: 8 %
- Landfilled: 2 %
- Indefinite storage: 0.4 %
- Other (sold): 64 %

4.2.1.2 BOF slag

A big amount of crystalline LD slag is used in the building sector and in road construction, mostly because of its abrasive resistance. The direct use of it is only partly possible, because of the free CaO and MgO and thus the unstable volume of the slag. In contact with moisture the CaO and MgO hydrates and the volume increases. The free lime hydrates rapidly and can cause large volume changes over a relatively short period of time, while magnesia hydrates much more slowly and contributes to long-term expansion that may take years to develop.

There are several techniques used to overcome this problem:

- Adding silica sand into the liquid steel slag, combined with oxygen blowing;
- Ageing the slag by steam. The slag is covered with tent sheets and steam is injected for 48 hours;
- Ageing the slag by steam under pressure. The steel slag is placed into the autoclave where steam is injected under pressure and the slag is kept for about three hours at 0.5 Mpa of pressure;
- Ageing the slag by spraying with water, in controlled heaps.

Before using BOF slags as building aggregates a thorough classification has to be made; if the content of free CaO is over 7 % the slag cannot be used as building aggregate.

BOF slag is used in hydraulic engineering because of its high bulky density. BOF slag is also used for drainage layers and mineral sealings.

For the use of BOF slag the elution of hazardous substances is important.
BOF slag can be reused by returning it to the iron-making process. It can also be used for fertilizer manufacture or for road construction. BOF slags are normally used in civil and hydraulic engineering, road construction and the cement industry. Here the relatively high free CaO content has to be considered. The iron and steel BREF\textsuperscript{79} gives the fate of BOF slags in the EU:

- 28 % on site recycling
- 26 % external use
- 20 % sold
- 26 % landfilled

4.2.1.3 EAF slag

In the EU most of the slags from carbon and low alloyed steelmaking are landfilled, whereas the percentage of reuse of slags from the production of high alloyed steel is significantly higher. One third is still landfilled and stored\textsuperscript{79}.

4.2.2 Environmental risks

Steel-industry slags contain certain metals at concentrations that are higher than typical concentrations in soil. These include antimony, cadmium, total and hexavalent chromium, manganese, molybdenum, selenium, silver, thallium, tin and vanadium\textsuperscript{86}.

Steel-industry slags are alkaline, producing water leachate with a pH of approximately 11. The elevated pH is one of the reasons for the reduced mobility (i.e. leachability) of metals in slag, and an important consideration for slag applications in or near surface water and groundwater bodies that have limited dilution volume.

The environmental risks associated with the use of secondary aggregates strongly depend on the type of application. If the material is bound, the risk of leaching is smaller than if the material is unbound and in contact with water.

All slag cooling processes may generate hydrogen sulphide.

When using BOF slags in hydraulic engineering the rate of water amount to slag amount has to be measured so that the pH value lies in the neutral or slightly alkali range. Blast furnace slags must not be used in moisture so that no sulphur compounds are enriched in the water. The following table gives the leaching behaviour of slags. Table 36 shows the leaching values of slags from the iron and steel industry\textsuperscript{83}.

\textsuperscript{86} PROCTOR, D.M. ET AL. (2002)
### Table 36: Leaching of slags in water in mg/l

<table>
<thead>
<tr>
<th></th>
<th>Blast furnace slag</th>
<th>BOF-slag</th>
<th>EAF-slag</th>
<th>Ladle-slag</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>0.002</td>
<td>&lt; 0.001</td>
<td>&lt; 0.01</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Cd</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.0005</td>
<td>&lt; 0.0002</td>
</tr>
<tr>
<td>Cr</td>
<td>&lt; 0.002</td>
<td>0.006</td>
<td>&lt; 0.01</td>
<td>0.002</td>
</tr>
<tr>
<td>Cu</td>
<td>&lt; 0.001</td>
<td>0.001</td>
<td>&lt; 0.002</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>F</td>
<td>0.47</td>
<td>2.0</td>
<td>&lt; 0.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Hg</td>
<td>&lt; 0.0005</td>
<td>0.0006</td>
<td>&lt; 0.0005</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>Ni</td>
<td>&lt; 0.002</td>
<td>&lt; 0.002</td>
<td>0.005</td>
<td>0.003</td>
</tr>
<tr>
<td>Pb</td>
<td>&lt; 0.001</td>
<td>0.001</td>
<td>&lt; 0.002</td>
<td>0.02</td>
</tr>
<tr>
<td>SO₄</td>
<td>168</td>
<td>20</td>
<td>&lt; 15</td>
<td>70</td>
</tr>
<tr>
<td>Zn</td>
<td>&lt; 0.01</td>
<td>0.01</td>
<td>&lt; 0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>pH-value</td>
<td>11.0</td>
<td>12.1</td>
<td>&lt; 11.5</td>
<td>12.0</td>
</tr>
</tbody>
</table>

### Table 37: Leaching of slags

<table>
<thead>
<tr>
<th></th>
<th>Blast furnace slag</th>
<th>BOF-slag</th>
<th>EAF-slag</th>
<th>Ladle-slag</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lump slag</strong> 8 - 11 mm</td>
<td>average</td>
<td>max.</td>
<td>average</td>
<td>max.</td>
</tr>
<tr>
<td>pH</td>
<td>11</td>
<td>11.4</td>
<td>11.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Cond. MS/m</td>
<td>82</td>
<td>126</td>
<td>46</td>
<td>100</td>
</tr>
<tr>
<td>COD mg/l</td>
<td>78</td>
<td>182</td>
<td>&lt;20</td>
<td>&lt;20</td>
</tr>
<tr>
<td><strong>Granulated cinder 0 - 5 mm</strong></td>
<td>average</td>
<td>max.</td>
<td>average</td>
<td>max.</td>
</tr>
<tr>
<td>pH</td>
<td>11</td>
<td>11.4</td>
<td>11.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Cond. MS/m</td>
<td>82</td>
<td>126</td>
<td>46</td>
<td>100</td>
</tr>
<tr>
<td>COD mg/l</td>
<td>78</td>
<td>182</td>
<td>&lt;20</td>
<td>&lt;20</td>
</tr>
</tbody>
</table>

| **in mg/l:**    |                |          |          |              |          |
| Al               | 1.3             | 2.9      | 0.07     | 1.1         | 1.7      | 7.0  | 9.5     | 40   |
| As               | 0.002            | 0.005    | 0.001    | 0.003       | <0.001   | <0.001| 0.001   | 0.003 |
| Cd               | <0.0001          | <0.0001  | <0.0001  | <0.0001     | <0.0001  | <0.0001| <0.0001 | <0.0001 |
| Co               | <0.002           | <0.002   | <0.002   | <0.002      | <0.002   | <0.002| <0.002  | <0.002 |
| Cr               | 0.001            | 0.002    | 0.001    | 0.001       | 0.001    | 0.04 | 0.026   | 0.08  |
| Cr VI+           | <0.01            | <0.01    | <0.01    | <0.01       | 0.01     | 0.02 | 0.016   | 0.04  |
| Cu               | <0.001           | <0.001   | <0.001   | <0.001      | 0.01     | 0.02 | 0.01    | 0.03  |
| Hg               | <0.0005          | <0.0005  | <0.0005  | <0.0005     | 0.0006   | 0.001| 0.0005  | 0.0005 |
| Mo               | <0.01            | <0.01    | <0.01    | <0.01       | 0.01     | 0.02 | 0.01    | 0.03  |
| Ni               | <0.002           | <0.002   | <0.002   | <0.002      | <0.002   | <0.002| <0.002  | <0.002 |
| Pb               | <0.001           | 0.001    | 0.001    | 0.001       | 0.001    | 0.02 | 0.002   | 0.006 |
| Se               | 0.006            | 0.009    | 0.0009   | 0.002       | 0.0005   | 0.0005| 0.0005  | 0.002 |
| Ti               | <0.0005          | <0.0005  | <0.0005  | <0.0005     | <0.0005  | <0.0005| <0.0005 | <0.0005 |
| V                | 0.01             | 0.02     | 0.005    | 0.01        | 0.02     | 0.05 | 0.06    | 0.38  |
| Zn               | 0.01             | 0.02     | 0.01     | 0.01        | 0.01     | 0.01 | 0.01    | 0.02  |
| **Anions**       |                  |          |          |              |          |
| F                | 0.5              | 1.0      | <0.2     | <0.2        | 2.0      | 8    | 0.5     | 1.5   |
| Cl               | 5                | 10       | <5       | <5          | 5        | 20   | 1       | 7     |
| SO₄²⁻            | 288              | 598      | 34       | 106         | 22       | 45   | 15      | 18    |
| CN ges.          | <0.01            | <0.01    | <0.01    | <0.01       | 0.01     | 0.02 | <0.01   | 0.01  |
| CN l.fr.         | <0.01            | <0.01    | <0.01    | <0.01       | <0.01    | <0.01| <0.01   | <0.01 |

[1] Table 36: Leaching of slags in water in mg/l.
4.3 Processes applied

4.3.1 Technical description

4.3.1.1 Blast furnace slag
Currently there are three processes in operation to treat blast furnace slag:

- Slag granulation process
- Slag pit process
- Slag pelletizing process

**Slag granulation process**

When cooling the fluid blast furnace slag a vitreous, fine-grained granulated cinder is formed. Granulation plants have a granulation and de-watering system. The granulation system determines the quality of the produced slag. There are different processes for the production of granulated cinder.

The slag is rapidly cooled through a high-pressure water spray in a granulation head. After granulation, the slag/water slurry is transported to a drainage system. In several cases, the slag/water slurry is transported to a separation tank prior to water drainage. After dewatering the residual moisture of the slag sand is generally around 100%.\(^7\)

**Slag pit process**

The slag pit process involves pouring thin layers of molten slag directly into slag pits adjacent to the furnaces. Alternatively, after collection of the slag in ladles the molten slag is slowly cooled and crystallised in the open air. The pits are alternately filled and excavated, and lump slag is broken up and crushed for use as coarse aggregate. The cooling time can be reduced by spraying the hot slag with a controlled amount of water. When properly applied, the cooling water is totally consumed by evaporation.

The slag pit process produces lump slag that is a desirable raw material for road construction. The cooling time has a strong influence on the quality of the lump slag produced.

**Slag pelletizing process**

This process is only used in a few plants in the EU. The molten slag is spread in a layer on a plate, which acts as a deflector. The sheet of slag is sheared by controlled water jets. The slag is then projected centrifugally into the air on a rotating drum to complete the blowing up and cooling.

When properly applied, process water is totally consumed by evaporation and as moisture in the product.

4.3.1.2 BOF slag

The iron content of the BOF slag is recovered in a treatment process and reused in the iron and steel plant.
After casting, the hot slag is continuously treated with water until it granulates. The slag is further treated with water until it has cooled. The iron content of the slag is then separated in a magnetic process. Cooling water is normally re-circled in a closed circuit. Because of the quick cooling when granulating blowholes are encased in the slag, they could be useful for noise insulation.

4.3.1.3 EAF-slag

Clean-bed process

The molten EAF-slag is casted in a slag ladle and transported to the slag treatment plant. The slag is not stabilised at this stage, because of its high basicity and high amount of free CaO and MgO. The quenching of the slag with water (spraying) helps to reduce the free CaO and MgO amounts.

In the process, the first slag created during the steelmaking is not poured into a cinder-pot, but into a box-bed (clean-bed), created under the furnace. During this the slag is continuously treated by water spray between the furnace and the 0.00 m level. The slag that has cooled down to 1000 °C is picked up by a special loading machine and transported to the rest-bed created in the slag processing area. There it is again treated by water spray. It is further treated by magnetic separation during which the randomly remaining ferrous metals metallic material is extracted. The cooling water circulated in a closed circle.

4.3.1.4 Production of fertilizer

Figure 7: Production of fertilisers from Blast Furnace and Steel Slags in Europe.

![Image of a diagram showing the process of production of fertilizers from Blast Furnace and Steel Slags in Europe.](image)
4.3.2 Emission levels and consumption of utilities

4.3.2.1 Blast furnace slag

The reaction of water with molten slag, particularly with sulphur compounds, generates both steam and diffuse $\text{H}_2\text{S}$ and $\text{SO}_2$ emissions. These emissions cause potential odour and corrosion problems.

If slag is not exposed to water but air-cooled, long-lasting low emissions, mainly of $\text{SO}_2$ will occur.

The water used in the granulation and pelletizing process can largely be collected and reused.

The production of lump slag from pits usually leads to higher emission of $\text{SO}_2$ and $\text{H}_2\text{S}$.

Table 38: Example (from Stahlwerke Bremen GmbH) of the composition of wastewater from slag granulation in 1996/1997\textsuperscript{87}:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Number of Measurement</th>
<th>Average concentration</th>
<th>Median concentration</th>
<th>Emission Factor\textsuperscript{88}</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>[m$^3$/d]</td>
<td>16,000</td>
<td>16,000</td>
<td>1.96</td>
<td>[m$^3$/t]</td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>[µg/l]</td>
<td>19</td>
<td>3.45</td>
<td>2.0</td>
<td>3.92</td>
<td>[mg/t pig iron]</td>
</tr>
<tr>
<td>Cr</td>
<td>[µg/l]</td>
<td>19</td>
<td>3.32</td>
<td>2.0</td>
<td>3.92</td>
<td>[mg/t pig iron]</td>
</tr>
<tr>
<td>Cu</td>
<td>[µg/l]</td>
<td>19</td>
<td>5.99</td>
<td>4.20</td>
<td>8,232</td>
<td>[mg/t pig iron]</td>
</tr>
<tr>
<td>Zn</td>
<td>[µg/l]</td>
<td>19</td>
<td>37.63</td>
<td>20.00</td>
<td>39.2</td>
<td>[mg/t pig iron]</td>
</tr>
<tr>
<td>Ni</td>
<td>[µg/l]</td>
<td>19</td>
<td>4.91</td>
<td>3.00</td>
<td>5.88</td>
<td>[mg/t pig iron]</td>
</tr>
<tr>
<td>TOC</td>
<td>[mg/l]</td>
<td>19</td>
<td>4.40</td>
<td>4.10</td>
<td>8,036</td>
<td>[g/t pig iron]</td>
</tr>
<tr>
<td>COD</td>
<td>[mg/l]</td>
<td>19</td>
<td>20.62</td>
<td>20.30</td>
<td>39,788</td>
<td>[g/t pig iron]</td>
</tr>
</tbody>
</table>

\textsuperscript{87} WEIGEL, S. (1998)

\textsuperscript{88} Based on the median.
5 ASHES FROM COAL COMBUSTION PROCESSES

Residues from coal combustion give information about the quality of coal used for power generation, of the combustion behaviour (burn out) and of the use of pollution abatement technologies. The environmental impact caused by the handling and reuse of residues can be low if concentrations of pollutants are low and residues are utilised or disposed of in an environmentally safe way.

However, high concentrations of pollutants, as well as unsafe utilisation, storage or disposal bear the risks of water and air pollution.

Residues directly related to the process of combustion of fossil fuels are ashes (esp. fly and bottom ash) and residues that are generated by the desulphurisation of flue gases.

5.1 Material streams

Ash and flue-gas desulphurisation residues are by far the largest quantities of waste from large combustion plants. These residues are partly disposed of in a landfill or can be used for different purposes such as additives in cement and concrete production; aggregates in concrete, asphalt, mine reclamation or waste stabilisation; and as ingredients in many other products.

The extent of utilisation depends on many factors, such as origin, type, physical and chemical quality of the residues, the availability of natural resources and the legislative framework.

Fluidised bed combustion residue

The operation of a fluidised bed combustion installation for a solid fuel such as coal but also for burning biomass and peat is related to the generation of ash, which is a composition of (spent) bed material and fuel ash. This residue is removed from the bottom of the fluidised bed combustion chamber.

Fly ash

Fly ash represents a part of the non-combustible material that is carried out of the boiler along with the flue gas. Fly ash is collected from the particulate control equipment, such as the electrostatic precipitator of the bag filter, and also from different parts of the boiler, such as the economiser and the air pre-heater. The largest amount of ash is generated by the combustion of coal and lignite, followed by the combustion of peat and biomass, whereas gas-fired facilities generate virtually no quantities of ash. The amount of ash generated from a liquid fuel fired facility is much higher than from a gas-fired boiler, but compared with the amount of ash from coal combustion, the quantities are rather small.

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89 EUROPEAN COMMISSION (2006)
Flue-gas desulphurisation gypsum

Fuels such as coal, peat and oil contain varying amount of sulphur. To avoid high emissions of sulphur dioxide into the atmosphere, large combustion plants (in particular plants over 50 MWth) are usually equipped with flue-gas desulphurisation plants (FGD). The different desulphurisation techniques currently in use result in the generation of a number of residues and by-products.

Wet lime/limestone scrubbers, for instance, produce gypsum as a by-product, whereas dry scrubber systems produce a mixture of un-reacted sorbent (e.g. lime, limestone, sodium carbonates, calcium carbonates, calcium chloride, calcium fluoride), sulphur salts and fly ash as residue.

Gypsum, a by-product from the desulphurisation plant, is largely used in the production of gypsum board, and makes a significant and increasing contribution towards the demand for gypsum. However, a certain contribution is also made by natural gypsum^89^.

Spray dry absorption residue (SDA residue)

The SDA residue is a mixture of the following minerals: calcium sulphite hemihydrates, calcium sulphate dehydrate (gypsum), calcium carbonate, calcium hydroxide, calcium chloride, calcium fluoride and fly ash.

5.1.1 Generation process

In a combustion system fuel energy (net calorific value) is converted to heat. This conversion efficiency which is referred to as ‘boiler efficiency’ limits the overall efficiency of all processes. Generally, and in most applications, this released net fuel heat is transferred to, and applied in, steam processes. The unburned carbon in the ash, CO, and VOCs, contain the losses of fuel energy during the combustion process.

The choice of system employed at a facility is based on many factors, such as the demand for energy (heat and power), flexibility to be able to deal with changing load conditions, availability of fuels, and the environmental situation on a local, regional and national level.

Pulverised solid fuel firing

In more than 90% of the installed capacity of solid fuel combustion systems the fuel is pulverised before combustion. Two general types are possible:

- Dry bottom ash furnace: This type operates at temperatures far below the melting point of the ash. To avoid slagging, the ash temperature should be low enough so as to not stick to the wall, and ash collected at the bottom remains solid;
- Slag tap furnace: This type operates at temperatures above the melting point of the ash to ensure liquid ash with sufficient fluidity to flow down the protected walls. The liquid ash is quenched in a water filled collector. This type is often used for fuels with poor combustion characteristics and involves the recycling of fly ash.
Fluidised bed combustion furnace

For this type of furnace, solid fuel generally has to be reduced in size and homogenised. Fine particulates would be blown out of the fluidised bed, large particulates would stop fluidisation.

- Small units (rated thermal input below 50 MW) operate at atmospheric pressure and static fluidisation. With increasing boiler size, the application of circulating fluidised bed combustion becomes more attractive. To utilise the whole furnace, volume particulate extraction, cyclone separation and the returning of coarse particles to the bed form is an integral part of the design.

5.1.2 Quality

Coal itself occurs in several forms (anthracite, bituminous or hard coal, lignite, and brown coal), each comprising a combination of carbon and a combination of carbon and a mixture of various minerals (shales, clays, sulphides and carbonates).

Composition of lignite and coal differs widely as shown in Table 39. This is also true for the concentration of (heavy) metals in lignite and coal.

The best known method for obtaining data on the behaviour of (heavy) metals during combustion and flue gas cleaning is to establish a mass balance across the total combustion installation considered. (Heavy) Metal mass balance investigations have been carried out for various types of large-scale hard coal and lignite-fired power plants, and also presented in the BREF LCP 2006.

Because volatile metal elements are emitted in the gaseous form or enriched in the fine-grained particulate material carried downstream of the combustion chamber, the emission of these elements depends more on the efficiency of the gas cleaning system than upon the method of fuel conversion.
Table 39: Typical concentrations of heavy metals in coals from different regions.

<table>
<thead>
<tr>
<th>Values in mg/kg</th>
<th>Australia</th>
<th>Canada</th>
<th>US</th>
<th>Poland</th>
<th>Russian and CIS</th>
<th>Europe (15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash (%)</td>
<td>12.5</td>
<td>12.9</td>
<td>9.9</td>
<td>15.9</td>
<td>15.4</td>
<td>14.4</td>
</tr>
<tr>
<td>As</td>
<td>1.4</td>
<td>2.9</td>
<td>8.7</td>
<td>3.4</td>
<td>4</td>
<td>18.5</td>
</tr>
<tr>
<td>Ag</td>
<td></td>
<td>0.86</td>
<td>&lt;1.7</td>
<td>&lt;1.6</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>Ba</td>
<td></td>
<td>280</td>
<td>500</td>
<td>210</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>Be</td>
<td>1.4</td>
<td>0.8</td>
<td>1.9</td>
<td>1.6</td>
<td>0.7</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>12.3</td>
<td>58</td>
<td>46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>0.06</td>
<td>0.3</td>
<td>0.24</td>
<td>0.73</td>
<td>0.27</td>
<td>0.2</td>
</tr>
<tr>
<td>Cr</td>
<td>7.4</td>
<td>7.4</td>
<td>13.9</td>
<td>16.3</td>
<td>40</td>
<td>18.7</td>
</tr>
<tr>
<td>Cu</td>
<td>13.3</td>
<td>16.9</td>
<td>16.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>300</td>
<td>300</td>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co</td>
<td></td>
<td></td>
<td>6.2</td>
<td>5.3</td>
<td>3.2</td>
<td>6.2</td>
</tr>
<tr>
<td>Cs</td>
<td></td>
<td>1.92</td>
<td>3.3</td>
<td>0.9</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>62</td>
<td>82</td>
<td>55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hf</td>
<td></td>
<td>1.1</td>
<td>1.6</td>
<td>1.2</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Hg</td>
<td>0.04</td>
<td>0.05</td>
<td>0.11</td>
<td>0.09</td>
<td>0.12</td>
<td>0.131</td>
</tr>
<tr>
<td>La</td>
<td></td>
<td></td>
<td>13.9</td>
<td>11.3</td>
<td>10.4</td>
<td>11.1</td>
</tr>
<tr>
<td>Mn</td>
<td>132</td>
<td>149</td>
<td>19</td>
<td>200</td>
<td>135</td>
<td>80</td>
</tr>
<tr>
<td>Mo</td>
<td>0.9</td>
<td>1.6</td>
<td>5.3</td>
<td>&lt;1.1</td>
<td>&lt;1.1</td>
<td>&lt;0.87</td>
</tr>
<tr>
<td>Ni</td>
<td>9.5</td>
<td>7.3</td>
<td>10.7</td>
<td>&lt;24</td>
<td>21</td>
<td>&lt;12.5</td>
</tr>
<tr>
<td>Pb</td>
<td>4.8</td>
<td>6.8</td>
<td>8.6</td>
<td>32</td>
<td>12.2</td>
<td>9.9</td>
</tr>
<tr>
<td>Rb</td>
<td></td>
<td></td>
<td>16.1</td>
<td>23</td>
<td>12.3</td>
<td>21</td>
</tr>
<tr>
<td>Sb</td>
<td>1.15</td>
<td>1.6</td>
<td>0.65</td>
<td>1.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sc</td>
<td></td>
<td>5.6</td>
<td>5.9</td>
<td>6.9</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>&lt;26</td>
<td>&lt;62</td>
<td>&lt;57</td>
<td>&lt;25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>0.8</td>
<td>1.1</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th</td>
<td>2.3</td>
<td>3.3</td>
<td>4.2</td>
<td>4.1</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>Ti</td>
<td>0.15</td>
<td>0.1</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>0.7</td>
<td>1.2</td>
<td>1.1</td>
<td>1.7</td>
<td>1.4</td>
<td>1.47</td>
</tr>
<tr>
<td>V</td>
<td>14.8</td>
<td>30</td>
<td>23.3</td>
<td>38</td>
<td>39</td>
<td>43</td>
</tr>
<tr>
<td>Zn</td>
<td>19</td>
<td>8.9</td>
<td>14.1</td>
<td>&lt;27</td>
<td>&lt;6.6</td>
<td>&lt;3.2</td>
</tr>
<tr>
<td>Zr</td>
<td>47</td>
<td>39</td>
<td>28</td>
<td>18.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.1.2.1 Fly ash

The nature and properties of fly ash are dependent on a variety of factors that include the type of coal, the type and fineness of coal and the conditions of combustion.

Some important variables of fly ash are the carbon content and chemical and mineralogical properties. The former, as assessed by measuring loss on ignition (LOI), can vary widely (1-10%) and depends on the particular plant configuration; the application of low NOx burners generally increases levels. The typical LOI value achieved under stationary operating conditions is 3.5%. However, the pattern of operation inevitably results in some fluctuations.
The chemical composition of ashes from coal and lignite combustion is oxides, silicates and aluminium silicates of the elements contained in the coal. Fly ash is precipitated from the flue gas as fine powder with grain sizes < 100 µm and a large specific surface (2,000 - 3,000 cm²/g).

The (heavy) metal content of some fly ashes and bottom ash are presented in Table 40 and Table 41. This data serves only as an example because the variability is very highly dependent on the type of coal and installation.

Table 40: (Heavy) metals of coal and some coal ashes, concentrations are given in ppm (mg/kg).

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Coal (ppm)</th>
<th>Bottom ash (ppm)</th>
<th>Fly ash (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>10.8</td>
<td>12.0</td>
<td>43.9</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.07</td>
<td>0</td>
<td>0.295</td>
</tr>
<tr>
<td>Chromium</td>
<td>39.1</td>
<td>204.7</td>
<td>154.5</td>
</tr>
<tr>
<td>Copper</td>
<td>16.0</td>
<td>63.2</td>
<td>67.6</td>
</tr>
<tr>
<td>Lead</td>
<td>6.7</td>
<td>11.6</td>
<td>27.7</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.28</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Nickel</td>
<td>40.5</td>
<td>204.0</td>
<td>158.7</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.99</td>
<td>0.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Vanadium</td>
<td>41.3</td>
<td>94.7</td>
<td>169.0</td>
</tr>
<tr>
<td>Zinc</td>
<td>26.1</td>
<td>38.1</td>
<td>116.1</td>
</tr>
</tbody>
</table>

Table 41: Typical ranges of (heavy) metals from UK sources of PFA (mg/kg).

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Typical range of results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>4 to 128</td>
</tr>
<tr>
<td>Boron</td>
<td>5 to 310</td>
</tr>
<tr>
<td>Barium</td>
<td>0 to 36,000</td>
</tr>
<tr>
<td>Cadmium</td>
<td>&lt;1.0 to 4</td>
</tr>
<tr>
<td>Chloride</td>
<td>0 to 2.099*</td>
</tr>
<tr>
<td>Cobalt</td>
<td>2 to 115</td>
</tr>
<tr>
<td>Chromium</td>
<td>33 to 192</td>
</tr>
<tr>
<td>Copper</td>
<td>33 to 474</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0 to 200</td>
</tr>
<tr>
<td>Mercury</td>
<td>&lt;0.01* to 0.61</td>
</tr>
<tr>
<td>Manganese</td>
<td>103 to 1,555</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>2 to 61</td>
</tr>
<tr>
<td>Nickel</td>
<td>35 to 583</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>372 to 2,818</td>
</tr>
<tr>
<td>Lead</td>
<td>&lt;1* to 876</td>
</tr>
<tr>
<td>Antimony</td>
<td>1 to 325</td>
</tr>
<tr>
<td>Selenium</td>
<td>&lt;1 to 162</td>
</tr>
<tr>
<td>Tin</td>
<td>&lt;10 to 1,647</td>
</tr>
<tr>
<td>Vanadium</td>
<td>96 to 1,339</td>
</tr>
<tr>
<td>Zinc</td>
<td>49 to 918</td>
</tr>
</tbody>
</table>

* Indicates below the limit of detection
* Includes seawater conditioned PFA

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90 United Kingdom Quality Ash Association (2003)
5.1.2.2 Bottom ash

In bottom ash, the concentrations of (heavy) metals are usually lower than in fly ash (see Table 40).

5.1.2.3 Gypsum

Generally the (heavy) metal concentration in gypsum is very low and within the range of concentrations in gypsum from natural resources. The following examples of gypsum show the (heavy) metal content of gypsum from different sources/countries.

Table 42: Trace element concentrations in FGD (flue gas desulphurisation) and natural gypsum, ppm.

<table>
<thead>
<tr>
<th>Trace element</th>
<th>FGD gypsum Europe*</th>
<th>FGD gypsum Japan</th>
<th>FGD gypsum USA**</th>
<th>Natural gypsum</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>&lt;1-1</td>
<td>2</td>
<td>1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>B</td>
<td>&lt;5-29</td>
<td>&lt;5</td>
<td>11-21</td>
<td>9</td>
</tr>
<tr>
<td>Ba</td>
<td>&lt;1-200</td>
<td>13</td>
<td>&lt;1-6,400</td>
<td>4</td>
</tr>
<tr>
<td>Cd</td>
<td>&lt;1-1</td>
<td>2</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cr</td>
<td>3-10</td>
<td>5</td>
<td>9-24</td>
<td>1</td>
</tr>
<tr>
<td>Cu</td>
<td>&lt;1-64</td>
<td>7</td>
<td>&lt;3-3</td>
<td>7</td>
</tr>
<tr>
<td>Hg</td>
<td>&lt;1-3</td>
<td>&lt;3</td>
<td>&lt;1</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Mn</td>
<td>3-49</td>
<td>94</td>
<td>10-35</td>
<td>4</td>
</tr>
<tr>
<td>Mo</td>
<td>&lt;3-19</td>
<td>17</td>
<td>&lt;3-1</td>
<td>2</td>
</tr>
<tr>
<td>Ni</td>
<td>&lt;3-19</td>
<td>17</td>
<td>&lt;3</td>
<td>2</td>
</tr>
<tr>
<td>Pb</td>
<td>1-28</td>
<td>3</td>
<td>1-47</td>
<td>1</td>
</tr>
<tr>
<td>Se</td>
<td>&lt;1-15</td>
<td>&lt;1</td>
<td>4-6</td>
<td>&lt;1</td>
</tr>
<tr>
<td>V</td>
<td>8-16</td>
<td>21</td>
<td>10-12</td>
<td>27</td>
</tr>
<tr>
<td>Zn</td>
<td>&lt;1-10</td>
<td>16</td>
<td>5-20</td>
<td>5</td>
</tr>
</tbody>
</table>

*... Range from nine plants in Germany and one in the UK.

**... Range from two plants in the USA.

5.1.3 Quantity

The amounts of solid residues generated by fossil fuel combustion depend on the content of non-combustible substances in the fuel, i.e. ashes, and sulphur. The main coal combustion residues are fly and bottom ash, boiler slag and fluidised bed combustion ash. In addition, the removal of SO₂ through flue gas desulphurisation or spray dry absorption generates solid sulphur residues such as gypsum².

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91 CLEAN COAL CENTRE UNITED KINGDOM IEA (2007): [http://www.iea-coal.co.uk](http://www.iea-coal.co.uk)

Residues from coal combustion in the EU-15 were stable in the 1990s and have increased since then to currently about 59 million tonnes annually\(^9^3^\) and approximately 65 million tonnes in the 10 new EU Member States (ca. 30 million tonnes) and other European Countries (ca. 35 million tonnes). These amounts represent about 3.6 % and 4 % respectively of the total generation of waste and residues from all economic activities in the EU-15 and EU10 (see Table 43 and Figure 8)\(^9^2^\).

**Table 43: Trend in the generation of coal combustion residues in the EU-15, 1993-2004\(^9^4^\).**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray dry absorption residue</td>
<td>0.467</td>
<td>0.637</td>
<td>0.596</td>
<td>0.586</td>
<td>0.587</td>
<td>0.573</td>
<td>0.521</td>
<td>0.476</td>
<td>0.615</td>
<td>0.560</td>
<td>0.491</td>
<td>0.435</td>
</tr>
<tr>
<td>Other</td>
<td>0.179</td>
<td>0.139</td>
<td>0.152</td>
<td>0.148</td>
<td>0.137</td>
<td>0.105</td>
<td>0.075</td>
<td>0.077</td>
<td>0.218</td>
<td>0.15</td>
<td>0.089</td>
<td>0.068</td>
</tr>
<tr>
<td>Fluidised bed combustion residue</td>
<td>0.511</td>
<td>0.736</td>
<td>0.765</td>
<td>0.758</td>
<td>1.043</td>
<td>1.023</td>
<td>0.965</td>
<td>1.015</td>
<td>1.06</td>
<td>1.07</td>
<td>1.09</td>
<td>0.99</td>
</tr>
<tr>
<td>Boiler slag</td>
<td>2.576</td>
<td>2.576</td>
<td>2.576</td>
<td>2.357</td>
<td>2.307</td>
<td>2.297</td>
<td>2.127</td>
<td>2.17</td>
<td>2.24</td>
<td>2.24</td>
<td>2.21</td>
<td>1.95</td>
</tr>
<tr>
<td>Bottom ash</td>
<td>7.165</td>
<td>7.234</td>
<td>6.685</td>
<td>6.415</td>
<td>6.162</td>
<td>5.892</td>
<td>5.822</td>
<td>5.678</td>
<td>5.64</td>
<td>5.94</td>
<td>6.65</td>
<td>5.84</td>
</tr>
<tr>
<td>Fly ash</td>
<td>41.881</td>
<td>42.038</td>
<td>40.529</td>
<td>39.392</td>
<td>38.671</td>
<td>37.792</td>
<td>37.144</td>
<td>38.959</td>
<td>39.847</td>
<td>42.08</td>
<td>44.22</td>
<td>43.48</td>
</tr>
</tbody>
</table>

Source: ECOBA (2008)

**Figure 8: Generation of coal combustion residues in the EU-15, 1993-2004\(^9^4^\).**

Note: Low-volume residues that comprise other solid and liquid streams such as coal mill rejects, coal pile runoff, boiler and cooling tower blowdown, or water and wastewater treatment sludge are not included. They account for less than 1% of the total volume of residues.

\(^9^3\) BRENNAN, P. ET AL. (2003)

The trend towards a rising amount of sulphur residues reflects the steady increase in the number of flue gas desulphurisation units used to control SO$_2$ emissions. There was a declining trend in ash generation during the 1990s and a re-increase from 1999 onwards. The decline in the 1990s can partly be explained by a reduction in the use of coal as fuel in this period, combined with a switch towards the use of coal of higher quality, with lower ash content\textsuperscript{93}. The increase by the turn of the century indicates a return to the use of coal as fuel. Some data on the ash content in different countries can be found in Table 44 and Table 39.

Table 44: Ash content of different coals (information from operators)\textsuperscript{95}.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Ash content [mass-%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite Köflach (A)</td>
<td>18,9 – 21,2</td>
</tr>
<tr>
<td>Hard coal Powstancow (PL)</td>
<td>14,8</td>
</tr>
<tr>
<td>Hard coal Kleofas (PL)</td>
<td>3,4</td>
</tr>
<tr>
<td>Hard coal Kuznezow (RUS)</td>
<td>14,8</td>
</tr>
</tbody>
</table>

The future generation of coal combustion residues is difficult to predict, because generation is affected by several factors. On the one hand, the progressive installation of air pollution control equipment in power plants, avoiding gas and particle release to the atmosphere, can result in increasing amounts of residues being generated in the coming years. On the other hand, a possible reduction in the use of coal for power generation and a switch to low-ash and low-sulphur containing coal can result in an overall decrease of residue generation.

Within the EU-27, six countries (Germany, Greece, Spain, Poland, Romania and the UK) account for more than 75% of the total generation of residues. Differences between countries are to a large extent due to different amounts of coal consumption, but also to differences in the efforts made in installing flue gas cleaning technologies.

Most residues from coal combustion are not hazardous and are used as by-products or as filling material, mainly in the construction industry. In the EU-15, almost all gypsum from flue gas desulphurisation and all boiler slags are used, mainly as construction materials. Ash is used as construction material but also as filling material in open cast mines, quarries and pits. Utilisation of fly and bottom ash increased by around 10 percentage points between 1993 and 2001 to reach 46% and 41% respectively\textsuperscript{93}.

Table 45 and Figure 9 show the generation of coal combustion residues in Europe 2004. The non-presented EU-27 countries have little or no residue generation from coal. Estonia has energy generation from Oil Shale. Lithuania and Latvia generate < 60 000 tons annually. No coal was imported for power generation after 1995 in Malta. No information is available from Cyprus. Luxembourg has no energy generation from coal\textsuperscript{94}.

\textsuperscript{95} BÖHMER, S. ET AL. (2003)
There are differences between the yearly arisings mentioned in Table 45 and the arisings reported from the Member States and documented in the Country Reports in Chapter 7. Especially for Austria (fly ash: 0.520 Mio. tons; bottom ash: 0.067 Mio. tons), Belgium (fly ash: 0.542 Mio. tons; bottom ash: 0.083 Mio. tons), Finland (fly ash: 0.670 Mio. tons; bottom ash: 0.380 Mio. tons), Denmark (total residues from coal combustion of 1.47 Mio. tons), Slovenia (fly ash: 0.690 Mio. tons; bottom ash: 0.230 Mio. tons) and the Czech Republic (fly ash: 2.13 Mio. tons; bottom ash: 3.03 Mio. tons) there are big differences for no apparent reason. In general it could be argued that the data reported by the national authorities or agencies are aggregated on a higher level summarising also waste types not typically related to coal combustion (e.g. ashes from waste incineration).

### Table 45: Generation of coal combustion residues in Europe 2004².

<table>
<thead>
<tr>
<th>Units: Million tonnes/year</th>
<th>Fly ash</th>
<th>Bottom ash</th>
<th>Boiler slag</th>
<th>Fine gas desulphurisation gypsum</th>
<th>Spray dry absorption residue</th>
<th>Total</th>
<th>Percentage of the total</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luxembourg</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>2004</td>
</tr>
<tr>
<td>Sweden</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>2003</td>
</tr>
<tr>
<td>Malta</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>2003</td>
</tr>
<tr>
<td>Latvia</td>
<td>0.015</td>
<td>0.002</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.017</td>
<td>0%</td>
<td>2003</td>
</tr>
<tr>
<td>Croatia</td>
<td>0.215</td>
<td>0.037</td>
<td>0.003</td>
<td>0.026</td>
<td>0.001</td>
<td>0.563</td>
<td>0.06%</td>
<td>2003</td>
</tr>
<tr>
<td>FYR Macedonia (*)</td>
<td>0.074</td>
<td>0.015</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.089</td>
<td>0.10%</td>
<td>2001</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.180</td>
<td>0.020</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.200</td>
<td>0.2%</td>
<td>2004</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.544</td>
<td>0.049</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.593</td>
<td>0.7%</td>
<td>2004</td>
</tr>
<tr>
<td>Austria</td>
<td>0.351</td>
<td>0.057</td>
<td>0</td>
<td>0.054</td>
<td>0.056</td>
<td>0.407</td>
<td>0.55%</td>
<td>2004</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.369</td>
<td>0.061</td>
<td>0</td>
<td>0.056</td>
<td>0</td>
<td>0.513</td>
<td>0.57%</td>
<td>2004</td>
</tr>
<tr>
<td>Finland</td>
<td>0.035</td>
<td>0.093</td>
<td>0</td>
<td>0.070</td>
<td>0.028</td>
<td>0.726</td>
<td>0.8%</td>
<td>2004</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.726</td>
<td>0.164</td>
<td>0</td>
<td>0.264</td>
<td>0.058</td>
<td>1.152</td>
<td>1.3%</td>
<td>2004</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1.017</td>
<td>0.183</td>
<td>0</td>
<td>0.307</td>
<td>0</td>
<td>1.507</td>
<td>1.68%</td>
<td>2004</td>
</tr>
<tr>
<td>France</td>
<td>1.341</td>
<td>0.142</td>
<td>0</td>
<td>0.068</td>
<td>0</td>
<td>1.551</td>
<td>1.73%</td>
<td>2004</td>
</tr>
<tr>
<td>Italy</td>
<td>1.130</td>
<td>0.126</td>
<td>0</td>
<td>0.362</td>
<td>0</td>
<td>1.618</td>
<td>1.8%</td>
<td>2004</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1.343</td>
<td>0.033</td>
<td>0</td>
<td>0.382</td>
<td>0</td>
<td>1.757</td>
<td>2.0%</td>
<td>2002</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1.500</td>
<td>0.666</td>
<td>0.230</td>
<td>0.326</td>
<td>0.007</td>
<td>2.731</td>
<td>3.0%</td>
<td>2005</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>2.038</td>
<td>0.330</td>
<td>0</td>
<td>0.300</td>
<td>0.193</td>
<td>2.923</td>
<td>3.3%</td>
<td>2006</td>
</tr>
<tr>
<td>Hungary</td>
<td>2.724</td>
<td>0.610</td>
<td>0</td>
<td>0.378</td>
<td>0</td>
<td>3.612</td>
<td>4.0%</td>
<td>2000</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>4.470</td>
<td>0.826</td>
<td>0</td>
<td>0.616</td>
<td>0</td>
<td>5.911</td>
<td>6.8%</td>
<td>2003</td>
</tr>
<tr>
<td>Serbia and Montenegro (*)</td>
<td>6.126</td>
<td>1.077</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7.203</td>
<td>8.9%</td>
<td>2001</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>6.513</td>
<td>0.810</td>
<td>0</td>
<td>1.950</td>
<td>0</td>
<td>8.373</td>
<td>9.3%</td>
<td>2004</td>
</tr>
<tr>
<td>Romania</td>
<td>7.159</td>
<td>1.378</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8.537</td>
<td>9.5%</td>
<td>2002</td>
</tr>
<tr>
<td>Spain</td>
<td>6.513</td>
<td>1.276</td>
<td>0</td>
<td>0.886</td>
<td>0</td>
<td>8.684</td>
<td>9.7%</td>
<td>2004</td>
</tr>
<tr>
<td>Greece</td>
<td>11.392</td>
<td>0.699</td>
<td>0</td>
<td>0.292</td>
<td>0</td>
<td>12.343</td>
<td>13.8%</td>
<td>2004</td>
</tr>
<tr>
<td>Turkey</td>
<td>11.884</td>
<td>1.064</td>
<td>0</td>
<td>0.036</td>
<td>0</td>
<td>12.985</td>
<td>15.5%</td>
<td>2002</td>
</tr>
<tr>
<td>Poland</td>
<td>13.517</td>
<td>2.348</td>
<td>0.809</td>
<td>2.629</td>
<td>0.057</td>
<td>19.359</td>
<td>21.6%</td>
<td>2001</td>
</tr>
<tr>
<td>Germany</td>
<td>13.880</td>
<td>2.280</td>
<td>1.950</td>
<td>7.660</td>
<td>0.280</td>
<td>25.050</td>
<td>29.1%</td>
<td>2004</td>
</tr>
</tbody>
</table>
Figure 9: Generation of coal combustion residues in Europe 2004\textsuperscript{94}.

5.2 Uses applied

In the EU-15, almost all gypsum from flue gas desulphurisation and all boiler slags are used, mainly as construction materials. Ash is used as construction material but also as filling material in open cast mines, quarries and pits. Utilisation of fly and bottom ash increased by around 10 percentage points between 1993 and 2001 to reach 46% and 41% respectively (see also Table 46 and Figure 10)\textsuperscript{93}.
Table 46: Disposal and utilisation routes for coal combustion residues in the EU-15\(^4\).

<table>
<thead>
<tr>
<th>Utilisation based on the substance’s properties in e.g. cement, concrete, gypsum</th>
<th>Use as filling material in civil works and underground mining</th>
<th>Use as restoration and filling material in open cast mines, quarries and pits</th>
<th>Temporary storage</th>
<th>Disposal (landfill, dumping)</th>
<th>Other uses: blasting grit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly Ash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>33.40%</td>
<td>12.50%</td>
<td>42.60%</td>
<td>7.70%</td>
<td>4.40%</td>
</tr>
<tr>
<td>2003</td>
<td>33.85%</td>
<td>12.98%</td>
<td>42.34%</td>
<td>7.83%</td>
<td>2.69%</td>
</tr>
<tr>
<td>2004</td>
<td>35.76%</td>
<td>13.20%</td>
<td>41.81%</td>
<td>7.14%</td>
<td>1.50%</td>
</tr>
<tr>
<td>Bottom Ash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>25.80%</td>
<td>15.20%</td>
<td>47.90%</td>
<td>2.70%</td>
<td>5.10%</td>
</tr>
<tr>
<td>2003</td>
<td>27.57%</td>
<td>16.00%</td>
<td>44.16%</td>
<td>2.10%</td>
<td>10.08%</td>
</tr>
<tr>
<td>2004</td>
<td>22.84%</td>
<td>14.28%</td>
<td>48.24%</td>
<td>3.35%</td>
<td>9.73%</td>
</tr>
<tr>
<td>Boiler Slag</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>6.70%</td>
<td>62.10%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>2003</td>
<td>7.53%</td>
<td>53.27%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>2004</td>
<td>9.08%</td>
<td>57.64%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>FBC-Ash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>1.90%</td>
<td>49.40%</td>
<td>13.50%</td>
<td>9.70%</td>
<td>23.20%</td>
</tr>
<tr>
<td>2003</td>
<td>0.00%</td>
<td>48.67%</td>
<td>16.35%</td>
<td>3.67%</td>
<td>28.83%</td>
</tr>
<tr>
<td>2004</td>
<td>2.15%</td>
<td>47.85%</td>
<td>29.88%</td>
<td>14.16%</td>
<td>3.91%</td>
</tr>
<tr>
<td>SDA-residue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>4.70%</td>
<td>43.60%</td>
<td>35.90%</td>
<td>0.00%</td>
<td>6.40%</td>
</tr>
<tr>
<td>2003</td>
<td>4.49%</td>
<td>6.50%</td>
<td>36.73%</td>
<td>0.00%</td>
<td>43.88%</td>
</tr>
<tr>
<td>2004</td>
<td>7.64%</td>
<td>23.94%</td>
<td>39.19%</td>
<td>0.00%</td>
<td>19.95%</td>
</tr>
<tr>
<td>FGD-Gypsum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>72.50%</td>
<td>0.00%</td>
<td>12.70%</td>
<td>14.20%</td>
<td>0.60%</td>
</tr>
<tr>
<td>2003</td>
<td>66.93%</td>
<td>0.00%</td>
<td>17.43%</td>
<td>15.41%</td>
<td>0.23%</td>
</tr>
<tr>
<td>2004</td>
<td>68.50%</td>
<td>0.00%</td>
<td>17.43%</td>
<td>15.41%</td>
<td>0.23%</td>
</tr>
</tbody>
</table>

Source: ECOBA (2003, 2006)

Notes: FBC: Fluidised bed combustion; SDA: Spray dry absorption; FGD: Flue gas desulphurisation
Gypsum from the desulphurisation plant has a strong commercial share of the gypsum market and is used as the most important raw material for the production of gypsum boards. Gypsum has been classified as non-hazardous in the European list of wastes.

The ECOBA statistics on the production and utilisation of residues from coal combustion reflect the typical combustion products fly ash (FA), bottom ash (BA), boiler slag (BS) and fluidized bed combustion (FBC) ashes as well as the products from dry or wet flue gas desulphurisation, especially spray dry absorption (SDA) residue and flue gas desulphurisation (FGD) gypsum. The amount of residues produced in European (EU-15) power plants totalled 65 million tonnes in 2003.

Most of the coal combustion residues are used in the construction industry, in civil engineering and as construction materials in underground mining (52.4 %) or for restoration of open cast mines, quarries and pits (35.9 %). In 2003, about 8.0 % were temporarily stockpiled for future utilisation and 3.7 % were disposed of (see Figure 11).
5.2.1 Utilisation of fly ash

Fly ash obtained by electrostatic or mechanical precipitation of dust-like particles from the flue gas represents the largest proportion of the total coal combustion residues. Siliceous, silico-calcareous or calcareous fly ashes, depending on the type of coal and the type of boiler, with pozzolanic and/or latent hydraulic properties are produced throughout Europe. The utilisation of fly ash across European countries is different and mainly based on national experience and tradition.

In 2003, about 21 million tonnes of fly ash were utilised in the construction industry and in underground mining. Most of the fly ash produced in 2003 was used as a concrete addition, in road construction and as a raw material for cement clinker production. Fly ash was also utilised in blended cements, in concrete blocks and for infill, i.e. for filling voids, mine shafts and subsurface mine workings.
Fly ash is the most important coal combustion residue and accounts for nearly 70% of the total amount. Approximately 33% of the total fly ash produced in Europe is used as cement raw material, as a constituent in blended cements and as an addition for the production of concrete. This means that it is a main constituent of the cement or else it replaces part of the cement necessary for the production of concrete.

The use as a concrete addition constitutes the highest added value for fly ash. So the European Standard EN 450 ‘Fly Ash for Concrete’ is particularly important for the marketing of fly ash. The standard was first published in 1994 and the revised standards EN 450-1 and EN 450-2 were published in 2005 by the National Standardization Bodies in Europe. The standard only refers to siliceous fly ash. Calcareous fly ash, which is mainly obtained from the combustion of lignite, cannot be utilised as a concrete addition as specified in EN 450.

5.2.2 Utilisation of bottom ash

Bottom ash is produced as a granular material and removed from the bottom of dry boilers. It is much coarser than fly ash but is also formed during the combustion of coal. In 2003 about 6 million tonnes of bottom ash were produced in Europe. About 2.7 million tonnes of bottom ash were used in the construction industry. 48% of this was used as fine aggregate in concrete blocks, 33% in road construction and about 14% in cement and concrete.

![Figure 13: Utilisation of bottom ash in the construction industry and in underground mining in Europe (EU-15) in 2003 (total utilisation 2.7 million tonnes)](image)

5.2.3 Utilisation of boiler slag

Boiler slag is a vitreous granular material derived from coal combustion in wet bottom boilers at temperatures of 1,500 to 1,700 °C. Due to the high temperatures in the furnace, some of the minerals in the boiler melt and flow down into a water bath at the bottom of the boiler where they are cooled down rapidly and form a coarse granular material with a maximum particle diameter of about 8 mm.
Boiler slag is a glassy material of which about 55% was used in road construction in 2003, e.g. as a drainage layer. Another 28% was used as blasting grit and smaller amounts as aggregates in concrete and grout (see Figure 14). In 2003, about 2.1 million tonnes of boiler slag were produced in Europe (EU-15). The utilisation rate was 100%.

Figure 14: Utilisation of boiler slag in the construction industry and as blasting grit in Europe (EU-15) in 2003 (total utilisation 2.1 million tonnes)

5.2.4 Utilisation of FBC ash

Fluidized bed combustion (FBC) ash is produced in fluidized bed combustion boilers. The technique combines coal combustion and flue gas desulphurisation in the boiler at combustion temperatures of 800 to 900 °C. This makes the FBC ash rich in lime and sulphate.

The amount of FBC ash produced in Europe (EU-15) in 2003 was about 1 million tons. Of this 0.5 million tonnes were utilised in the construction industry and for mining purposes. About 52% of the total FBC ash was used for infilling purposes, i.e. for filling enclosed voids, mine shafts and subsurface mine workings. About 13% was used in the production of pavement base courses as a foundation material or as a drying agent for wet soils, and about 11% was used for structural fill (see Figure 15). In 2002, about 29% of the FBC ash produced had to be disposed of.
5.2.5 Utilisation of SDA residue

About 0.5 million tonnes of spray dry absorption residue (SDA residue) were produced in 2003 in European power plants using spray dry absorption techniques for desulphurisation of the flue gases. The SDA residue is a mixture of the following minerals: calcium sulphite hemihydrates, calcium sulphate dehydrate (gypsum), calcium carbonate, calcium hydroxide, calcium chloride, calcium fluoride and fly ash.

Depending on the location of the SDA installation in the flue gas stream (upstream or downstream of the electrostatic precipitator) the SDA residue may contain up to 60 wt. % fly ash. Due to its high content of sulphur and chlorine the SDA residue cannot be used in cement-bonded systems used for construction purposes because of a risk of unsoundness.

The SDA residue is utilised in the mining industry as a component of mining mortar for stabilising underground cavities. In the building material industry it can also be used as an addition in the production of sand lime bricks. About 5 % of the total is used for plant nutrition. It has been proved that the SDA residue can be used without any harm to the environment as a sulphur fertiliser in agriculture. The SDA residue is increasingly used as sorbent in the wet FGD process in power plants.

In 2003 nearly 20 % of the total SDA residue was utilised in the construction industry and in underground mining, for plant nutrition and as sorbent in wet FGD 37 % was used for restoration purposes and about 44 % had to be disposed of at disposal sites.
5.2.6 Utilisation of FGD gypsum

FGD gypsum is produced in the flue gas desulphurisation process in coal-fired power plants that incorporate the desulphurisation of the flue gas in the power plant and have a refining process in the FGD plant that includes an oxidation process followed by gypsum separation, washing and dewatering. Studies have shown that FGD gypsum has the same properties as gypsum from natural resources with regard to health aspects. Based on these results and because of its consistent quality FGD gypsum is accepted in the gypsum and cement industry as a direct replacement of gypsum from natural sources. FGD gypsum has to meet the quality specifications of the gypsum industry as published by EURO GYPSUM.

The amount of FGD gypsum produced in Europe (EU 15) was approximately 11.3 million tonnes in 2003. About two thirds of this material was produced in Germany. Nearly 70 % of the total FGD gypsum produced in Europe is utilised in the gypsum and cement industry. 14 % of the total FGD gypsum produced was temporarily stockpiled as a raw material base for future utilisation, mostly for plasterboard production, and only 0.7 % was landfilled.

FGD gypsum is used as a raw material for a number of gypsum products by the gypsum industry because of its purity and homogeneity when compared to natural gypsum. In 2003, 4.9 million tons of FGD gypsum was used for the production of plasterboard. Other applications include the production of gypsum blocks, projection plasters and self-levelling floor screeds.

FGD gypsum is used in the cement industry as a set retarder. The total amount of FGD gypsum used for this purpose was about 0.8 million tonnes. To control the set retardation FGD gypsum is often mixed with anhydrite from natural sources in order to take advantage of the different solubility of the two minerals.

5.2.7 Technical limitations

5.2.7.1 Fly ash

Fly ash contains the largest part of condensed (heavy) metal. Critical parameters for use in concrete are ignition loss, Cl, free CaO. Critical parameters for use in cement ignition loss, sulphates, Cl (physical, chemical, mechanical parameters of cement are regulated in the European Standard EN 197-1).

The use as a concrete addition has the highest added value for fly ash so the European Standard EN 450 ‘Fly Ash for Concrete’ particularly is important for the marketing of fly ash. The standard was first published in 1994 and the revised standards EN 450-1 and EN 450-2 were published in 2005 by the National Standardization Bodies in Europe. The standard only refers to siliceous fly ash. Calcareous fly ash, which is mainly obtained from the combustion of lignite, cannot be utilised as a concrete addition as specified in EN 450.

5.2.7.2 Bottom ash

Bottom ash generally has lower heavy metal content. It can be used in the brick and cement industry.
5.2.7.3 Requirements and standards for the use of fly ash and bottom ash

As raw material for cement clinker production:

There are no standards or directives for the use of coal ash as a raw material for cement clinker production. Nevertheless, the raw material situation of a cement plant, i.e. the composition of the limestone and marl resources and the plant technology cause specific requirements on fly ash quality. Furthermore, fly ash need to be licensed as a raw material component for the cement plant.

As constituent of blended cement:

The requirements for siliceous and calcareous fly ash for the use as a constituent of blended cements are defined in EN 197-1. Beside requirements for the basics composition in view of reactivity limit values are defined for specific parameters (loss on ignition, sulphur, chlorine) to avoid unsoundness of or damaging reactions in concrete constructions. Over the last years about 2 million tonnes of fly ash per year have been used for this application. As the cement industry is obliged to reduce CO2 emissions from cement production this amount is expected to increase.

As addition to concrete:

Fly ash has been successfully used in concrete around the world for more than 50 years. In Europe approximately 30 % of the fly ash produced is used as concrete addition and is replacing a part of the cement necessary for the production of concrete. Technical requirements for the use of fly ash for concrete are given with the European Standard EN 450 "Fly Ash for Concrete". The standard was first published in 1994 and the revised standards EN 450-1 “Fly ash for concrete – Part 1: Definition, specifications and conformity criteria” and EN 450-2 “Fly ash for concrete – Part 2: Conformity evaluation” will be published this year by the National Standardization Bodies in Europe. The standards refer to siliceous fly ash, only. Calcareous fly ash - mostly obtained from the combustion of lignite cannot be utilised as concrete addition according to the EN 450.

In road construction:

For the use of coal ashes in road construction bound and unbound applications have to be considered. Unbound applications cover the use e.g. in base layers as filling material, in dam construction or soil beneficiation. Bound applications cover the use in hydraulic road binders and in concrete for road construction. For these applications national and/or country specific regulations of road construction authorities have to be fulfilled. Furthermore, the European standards for soil beneficiation with fly ash (prEN 14227-13), fly ash bound mixtures (prEN 14227 – part 3) and for fly ash for hydraulically bound mixtures (prEN14227 – part 4) have to be considered.

96 FEUERBORN, H.-J. (2005)
The two last European standards refer to siliceous or calcareous fly ash which is produced from the combustion of pulverized coal or lignite in power plants. For the use in hydraulic road binders the requirements of the European standard prEN 13282, currently under revision, have to be considered. The requirements for fly ash are based on the definitions given in the cement standard EN 197-1.

It has to be noted that these European standards, as of now, are not harmonized. They can be used in addition to or instead of national regulations. In Germany, national regulations to be considered for road construction are i.e. the regulations of the Road and Transport Research Society ("FGSV - Forschungsgesellschaft für Straßen- und Verkehrswesen"), in the Netherlands those based on the "Building Materials Decree" (Boustoff-Besluiten).

As aggregates:

On June 1, 2004 new harmonized European Standards for (heavy) aggregates for concrete (EN 12620) and for lightweight aggregates for concrete, mortar and grout (EN 13055-1) were introduced. These standards contain requirements regarding the characteristics of aggregates and the conformity criteria. The standards have a common structure in view of the definition of categories, as in European countries different climates cause different requirements. National authorities have to introduce the relevant categories in their country by e.g. national application documents. In Germany, the application document DIN V 2000-103 for aggregates for concrete and DIN V 2000-104 for lightweight aggregates (defined in clauses 1 'area of application') give types of industrially manufactured aggregates that may be used in concrete in accordance with the technical standards, i.e. bottom ash.

5.2.7.4 Gypsum

- Main component: calcium sulphate-dehydrates, may contain fly ash and comparable higher concentrations of Hg and Se.
- Critical parameters for use in the construction industry: crystal size, crystallisation and water content.

5.2.7.5 Residue from spray dry absorption

Residues from spray dry absorption consist of a mixture of gypsum, calcium-sulphite and fly ash; the major part is landfilled or used as a sealing material for landfills.
5.2.8 Environmental risks

There are many environmental benefits connected with the use of coal combustion residues. Anyway, the environmental impact of the use of coal combustion residues also has to be considered in any application.

With regard to fly ash and bottom ash risks can arise from

- storage (e.g. risk of groundwater pollution from wet storage of fly ash (lagoons); risk of inhalation of dust);
- disposal (e.g. risk of groundwater pollution by leaching of pollutants);
- recovery (e.g. risk of soil and groundwater pollution when used as road construction material).

Each of the options for utilisation of fly ash and bottom ash from coal combustion described in the previous sections has different specific criteria for the quality of ash it needs. In general the quality criteria are connected to the physical and structural properties of the ash and the content and mobilisation potential of (heavy) metals. In some cases the amount of unburned coal in the ash needs careful evaluation.

Fly ash and bottom ash utilisation varies between Member States, since climate, taxes and the legal situations also vary. In some EU-15 countries the utilisation rate for these residues is nearly 100 %, whereas in other countries the utilisation rate will not exceed 10 % due to existing unfavourable conditions, such as (heavy) metal content, loss of ignition, free and total Ca content, Cl, etc.

There are no general binding rules regulating the (heavy) metal content in fly ash and bottom ash intended to be reused. However, there are a certain number of studies with the aim of assessing the possible risks (see for example the study on the ‘Assessment of the Leaching Risk to the Environment from the Use of Pulverised Fuel Ash (PFA)’\textsuperscript{96} from the United Kingdom Quality Ash Association 2003) from the use of these residues.

The following paragraphs should give an indication as to which metals and organic pollutants should be given special attention when ashes are to be reused and summarise the factors influencing the risks stemming from fly ash and bottom ash recovery.

The pollutants of priority concern are (heavy) metals. Provided that the combustion behaviour of power plants is good concentrations of organic compounds (e.g. PAH, PCDD/F) are low to negligible.

Depending on their nature, some (heavy) metals detected in fly ash and bottom ash show a variety of adverse effects on human beings. From a toxicological point of view some (heavy) metals are classified as toxic (e.g. Pb, Cd, Cr(VI) and Hg), carcinogenic (e.g. Cd, Cr(VI)) or possibly carcinogenic (Hg and Ni). Some of them accumulate in the human being (such as Pb and Cd) and cause chronic diseases; others show strong irritating effects (such as Cr(VI)). Some are mutagenic and/or teratogenic.

Metals which are major concern with respect to fossil fuel utilisation are As, B, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se, V, Ti, Sb, Mn, Sn and Zn (see table below and previous chapters).
A reduction of (heavy) metal concentrations in the residues from coal incineration can be achieved by the use of “clean” coal with a high heating value, with the ash content being an important parameter for the concentration of hazardous substances.

Generally, coal purification is not a common practice in Europe.

(Heavy) Metals bound in coals are liberated during combustion and are released into the atmosphere on particles or as vapours. Most metal elements are condensing on the surface of particulates at lower temperature and thus are enriched by a factor of 10 – 20 compared to coal. Volatile elements preferentially condense onto the surface of smaller particles in flue-gas streams because of the larger surface area. Hg is a highly toxic metal with low vapour pressure thus escaping capture by flue-gas control devices. It occurs in coals of low quality and in some waste fractions being co-incinerated in power plants (e.g. sewage sludge). Hg is emitted to a large extent gaseous. An example of the distribution of selected (heavy) metals is shown in Table 47.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Input (%)</th>
<th>Output (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coal</td>
<td>Chalk</td>
</tr>
<tr>
<td>Arsenic</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Chromium</td>
<td>99.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Copper</td>
<td>98.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Lead</td>
<td>99.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Mercury</td>
<td>99.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Nickel</td>
<td>97.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Selenium</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Vanadium</td>
<td>99.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Zinc</td>
<td>99.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Note: Output based on 100% input of the metal element and chalk in relation to the output.

Table 47 Input and output of metals in coal-fired combustion plants (this data serves as an example because the variability is highly dependent on the type of coal and installation).

It has been shown that metals which condense on the surface of particulates (esp. B, Mo, Se, As) are easier to mobilise than metals which are incorporated into the particulates matrix. Weathering will increase mobilisation of metals.

The actual behaviour of pollutants in the ashes depends on the source of the ash and the total amount present.

Besides, leaching behaviour is strongly influenced by the pH value of the solution with higher leaching rates at lower pH values.

Rules for specific utilisation options of fly ash and bottom ash can be developed based on the leaching behaviour and also on the total content of (heavy) metals. In Austria a guideline establishing (heavy) metal limits for substituted fuels is based on the general requirement that the (heavy) metal concentration in the end-product cement is comparable to soil.
Special attention has to be paid to the quality of fly ash and bottom ash when waste is co-incinerated in power plants:

Depending on the amount and composition of co-incinerated waste, the co-incineration of wastes in coal-fired power stations tends to lead to higher levels of contamination (compared to coal-only incineration) of fly ash and bottom ash. In addition to this, burn out behaviour may be badly influenced leading to higher concentrations of organic pollutants in solid residues.

Higher contents of Cl, P and (heavy) metals have to be expected in ashes from co-incineration, compared to ashes from coal-only incineration.

From a precautionary point of view, the quality of ashes and FGD gypsum must not deteriorate as a result of the co-incineration of waste, in order to be able to sell them to the construction industry. Thus only waste types with (heavy) metal concentrations similar to coal and slight quality variations may be co-incinerated. From an economic (operators) point of view the use of bottom and fly ash in the construction industries is of commercial interest. Therefore it should be common practice to monitor the waste composition (physical and chemical composition and the hazardous potential) strictly and to limit the share of waste input to a few percent.

However, with a quantitative limitation of co-incinerated waste alone there are still emissions of certain hazardous substances into air and water, as well as residues and products, even if emission limit values and standards are met, as the waste residues are not brought to a final sink (in contrast to most municipal solid waste incineration plants).

5.3 Processes applied

5.3.1 Technical description

5.3.1.1 Ash Beneficiation

Coal ash taken as run-of-station is limited in the markets into which it can be sold. Developing specifications for construction products and other higher value applications demands some form of residue improvement. There is the concept that materials initially regarded as wastes may be improved through a process of quality control and upgrading to become increasingly accepted as a valuable resource, and ash can be treated in this way via beneficiation processes.

A number of methodologies and systems for improving ash quality have been developed which include:

5.3.1.2 Classification and Blending

Ash may be separated into components having useful properties through classification, usually by sieving into different size fractions. This process often helps reduce residual carbon content. A number of plants have been set up within Europe for beneficiation and blending. An example is shown in Figure 16.

5.3.1.3 Ash Milling

The size range distribution of fly ash is sometimes non-ideal for specific applications and cannot be improved by classification and blending alone. For example, in high strength and high durability concretes, finer fly ash (<10 µm) would be the preferred feedstock. Grinding or micronisation is sometimes used to reduce all particles to below the maximum size specified, allowing product properties to be enhanced.

5.3.1.4 Ash Floatation

Ash flotation is practised in its simplest form by the separation of cenospheres from the surface of fly ash ponds. More complex flotation systems based on minerals processing technology use frothing and other agents to separate materials as a suspension. The process has been demonstrated as a viable method for separating carbon from fly ash. The downside is that the materials may require drying.

5.3.1.5 Magnetic Separation Technologies

Many fly ashes contain significant concentrations of ferromagnetic material and this may be refined by magnetic separation. Removing the magnetic fraction from fly ash, using an electromagnet, can produce ash which may impart higher flowability to mortars. The process often forms part of a combined system.

*Figure 16: Example of a classification process*. 

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**Notes:**

- The fly ash size distribution is a critical factor in its practical applications.
- Grinding or micronisation techniques are employed to improve particle size distribution.
- Ash floatation is a method for separating cenospheres from fly ash, but it may require drying.
- Magnetic separation can be used to remove ferromagnetic material from fly ash for enhanced properties.
5.3.1.6 Carbon Removal

The presence of high levels of carbon restricts applicability. Consequently, considerable efforts have been made to develop techniques for its reduction. These techniques include carbon burn-out (in an FBC), electrostatic separation, froth flotation, pneumatic transport separation, and triboelectric separation. The first two are being used commercially and a schematic of the latter is shown in Figure 17.

![Example for Schematic of a STI electrostatic carbon reduction process](image)

**Figure 17: Example for Schematic of a STI electrostatic carbon reduction process**97.

The electrostatic separator can readily process a wide range of fly ashes, reducing unburned carbon content from 30% to a consistent 2%, thus meeting all standards for use in concrete.

5.3.1.7 Chemical Processing

Where a fly ash has a low pozzolanic activity, its reactivity can be enhanced by treatment with Na2SO4 or CaCl2. Ashes having relatively high concentrations of leachable salts can be rendered usable by “weathering over” in long-term storage ponds. Ash residues with high levels of free lime, particularly those from the newer clean coal technologies, can be rendered usable for cement and concrete applications by a hydration processing step.
5.3.1.8 Combined Beneficiation Technologies

A number of beneficiation and blending facilities have been set up for the production of quality-assured ash products. Some may specialise in, for instance, the supply of premium PFA and PFA cementitious products primarily to the construction sector, although specialist materials may also be produced.

Several processes are in use in the UK, one being that of RockTron. This processes run-of-station and reclaimed ashes to yield a range of products. The process treats both fresh fly ash and material that has been stockpiled for protracted periods. The process also yields energy savings and a reduction in overall environmental impact.

Figure 18: Simplified schematic of the RockTron ash beneficiations process.

5.3.2 Emission levels and consumption of utilities

Where dust is generated, engineering control measures should be considered (water sprayers) to maintain the airborne dust concentration as low as is reasonably practical. If fly ash is to be stockpiled for a long period (several months), dust suppressants can be used to treat the surface and eliminate the problem of dust blow.
6 MARKET ASSESSMENT

One of the principles that have to be met according to the ‘Thematic Strategy on the Prevention and Recycling of Waste’ is that there has to be a market for recycled and secondary materials.

End of waste criteria for defined wastes would influence the market situation for these materials in a positive way and would improve the possibilities for the produced recycled and secondary aggregates to compete with primary aggregates. Above all, it has to be ensured that there is no additional negative impact on the environment by producing or using them.

Some examples of important criteria which have a major influence on the existence of a market for recycled and secondary aggregates are given below.

6.1 Consumer acceptance

Even if the technical properties of recycled or secondary aggregates are better than the ones of primary aggregates, consumers show little trust in new products especially when these products are made of waste. In this context a simple question can be asked: Would you prefer primary aggregates or aggregates made of waste to build your own house? Active awareness raising and promotion campaigns are needed to establish new products on the market even if they are cheaper. In any case, if end of waste criteria will enhance the possibilities for trading recycled and secondary materials as a product, consumer acceptance will be influenced in a positive way. CE marking supports this positive influence without a definite guarantee of environmental safety.

By way of example, CE marking seems to be very important for the use of recycled asphalt planings (RAP). For RAP it is important to know exactly where the virgin aggregate has come from, what sizes are in the mix, which bitumen binder was used, where the asphalt was produced and under what conditions, how the asphalt was transported to the site and laid. Knowing these characteristics enables the recycling operator to re-use the material by taking into account environmental and technical safety.

Aggregates, bitumen and fillers have been CE marked since 2004 and legislation for the marking of asphalt mixes will come into force soon, followed by surface dressing and micro surfacing in 2008/2009. CE marking will help provide a good legislative driver but taxes or incentives to reduce reliance on virgin aggregates and make recycling a financially attractive alternative are also necessary.

Further restrictions on planning permission for new extraction sites will make recycling essential – the scarcity of virgin aggregates that will inevitably arise with dwindling reserves will push up aggregate prices, making the re-use of existing materials vital.

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98 EUROPEAN COMMISSION (2005)
99 AGGREGATES BUSINESS EUROPE (2007B)
6.2 Transport – Import and export

In normal cases, primary aggregates have to be mined outside of highly populated regions and transported over long distances to the production areas or the areas where they are used. Recycled and secondary aggregates are firstly generated within production or construction processes taking place nearby highly populated regions. This gives recycled and secondary aggregates some cost advantages in terms of shorter transport distances. In some Member States obligations for recycling activities are related to the transport distance.

Figure 19 shows the aggregates trade in natural aggregates. Higher recovery rates would increase the production of recycled and secondary aggregates and influence the trade in natural aggregates.

Norway and the UK were the largest net exporters. Germany was the largest gross exporter, but was also, with the Netherlands and Belgium-Luxembourg, a major importer. Total imports and exports of the EU-31 are closely balanced from year to year and the considerable overall trade (215 million tonnes) takes place almost within the EU-31 area.
6.3 Administrative burdens

With regard to the situation in the Netherlands the study on the ‘Effectiveness of landfill taxation’ stipulates that a landfill tax has a significant effect on the amount of waste landfilled. High landfill taxes prompt incineration of combustible waste and recycling of non-combustible waste, or the considering of alternatives in other Member States so that export could also play a more significant role. Just to give an example regarding the situation in the Netherlands: Exports of construction and demolition waste have seen a major increase from April 2000, when this waste stream became subject to a landfill ban. Construction and demolition waste is exported to Germany in particular: 940,000 tonnes in 2002. Of this amount, about 80% is recovered and 20% disposed of. Landfilling is cheaper in Germany than in the Netherlands. Also, the managers of German waste disposal sites have every interest in filling up their sites as quickly as possible in view of the impending landfill ban. This is an incentive not to sort imported waste, as required, but to dispose of it immediately in landfills.

The purpose of taxation is to make the landfilling of waste more expensive than alternatives to landfill, with the result that the separation or post-separation of waste streams into sub streams suitable for recovery became financially more attractive. Table 48 and Table 49 show examples of taxes in European Countries and Table 50 shows the development of the landfill tax in the Netherlands.

Table 48: Landfill taxes in selected Member States with a focus on the disposal of inert wastes – Part 1.

<table>
<thead>
<tr>
<th>Member State</th>
<th>Tax description</th>
<th>Legal regulation</th>
<th>Tax per ton of waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Since 2006 for excavated materials and inert construction waste</td>
<td>Federal Legal Gazette I No 299/1989 – Act on the Remediation of Contaminated Sites</td>
<td>8.00 €</td>
</tr>
<tr>
<td></td>
<td>Since 2006 for inert residues</td>
<td>Federal Legal Gazette I No 299/1989 – Act on the Remediation of Contaminated Sites</td>
<td>18.00 €</td>
</tr>
<tr>
<td>Belgium (Flanders region)</td>
<td>Specific waste from mining and mineral industries, and recycling and soil sanitation residues</td>
<td>-</td>
<td>0.32 – 7.73 €</td>
</tr>
<tr>
<td></td>
<td>Inert waste and inert asbestos</td>
<td>-</td>
<td>10.83 €</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Basic fee rate for disposal of non-hazardous waste on landfills for 2007 and 2008</td>
<td>Act 185/2001 Coll., on waste and amendment of some other acts, in the wording of later regulations</td>
<td>15.85 € (Calculation based on €/CZK = 25.2340 on 18th of February 2008)</td>
</tr>
</tbody>
</table>

100. WASTE MANAGEMENT COUNCIL (2003)

101. BARTELINGS, H. ET AL. (2005)
Table 49: Landfill taxes in selected Member States with a focus on the disposal of inert wastes – Part 2.

<table>
<thead>
<tr>
<th>Member State</th>
<th>Tax description</th>
<th>Related regulation</th>
<th>Tax per ton of waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>Waste taxes are paid on wastes left at public landfill sites, but are not applied to private or industrial landfills where these do not routinely receive wastes produced elsewhere</td>
<td>-</td>
<td>30 €</td>
</tr>
<tr>
<td>France</td>
<td>Standard rate of 9.5 €, sites with EMAS or ISO 14000 certification pay a reduced rate of € 7.50 per tonne, non-authorised landfills pay a rate of € 18.29 per tonne for municipal waste, The rate for landfills operating without a licence is € 123.63 per tonne</td>
<td>-</td>
<td>7.5 – 18.29 €</td>
</tr>
<tr>
<td>Germany</td>
<td>Germany does not have any taxation on the disposal of waste on landfills.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Italy</td>
<td>Industrial waste from mining, extractive, building and metalworking sector activities</td>
<td>Law 549/95</td>
<td>1.03 – 10.33 €</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Waste more than 1,100 kg per m$^3$ (non-combustible waste)</td>
<td>Environmental Taxes Act entered into force on January 1, 1995</td>
<td>13.98 €</td>
</tr>
<tr>
<td>Spain</td>
<td>Construction and demolition waste in the region of Madrid</td>
<td>Taxes for landfills are not generally implemented.</td>
<td>3.00 €</td>
</tr>
<tr>
<td></td>
<td>Average value in the region Catalonia</td>
<td>Taxes for landfills are not generally implemented.</td>
<td>10.00 €</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Since 1 of April 2008 £2.50 per tonne for all inactive waste (ceramic or concrete materials, furnace slags and ash)</td>
<td>Statutory Instrument 2002 No. 1559 – The Landfill Regulation 2002</td>
<td>3.36 € (Calculation based on £/€ = 0.7432 on 30th of January 2008)</td>
</tr>
</tbody>
</table>


103 NETHERLANDS MINISTRY OF HOUSING, SPATIAL PLANNING AND THE ENVIRONMENT (VROM): [http://www.vrom.nl](http://www.vrom.nl)
Table 50: Development of the landfill tax in the Netherlands\textsuperscript{101}.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustible waste</td>
<td>13.25</td>
<td>29.13</td>
<td>29.75</td>
<td>64.28</td>
<td>65.44</td>
<td>78.81</td>
<td>81.65</td>
<td>83.61</td>
<td>84.78</td>
</tr>
</tbody>
</table>

6.4 Prices and costs

Table 51 gives an overview on the specific takeover prices, treatment costs and sale proceeds applied in the Austrian and German aggregates market.

Table 51: Takeover prices, treatment costs and sale proceeds in Austria and Germany.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria\textsuperscript{104}</td>
<td>Takeover price, VAT and landfill costs excluded (if applicable)</td>
<td>Excavated soil depending on the quality</td>
<td>1.4 – 5.4 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction waste, sorted</td>
<td></td>
<td>10 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction waste, unsorted</td>
<td></td>
<td>19 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction waste, highly contaminated</td>
<td></td>
<td>up to 160 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Used asphalt</td>
<td></td>
<td>3.5 – 7.0 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Broken concrete</td>
<td></td>
<td>7.3 – 14.5 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany\textsuperscript{105}</td>
<td>Takeover price</td>
<td>Concrete and asphalt</td>
<td>4 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High share of bricks, soil</td>
<td></td>
<td>8 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austria - Treatment costs\textsuperscript{104}</td>
<td>Construction and demolition waste</td>
<td></td>
<td>6 – 7 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany - Treatment costs\textsuperscript{106}</td>
<td>Mineral construction materials (for plants with a capacity of 100.000 t/a)</td>
<td></td>
<td>8 – 10 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austria\textsuperscript{104}</td>
<td>Sale proceeds, VAT excluded</td>
<td>Mineral construction materials fulfilling the requirements defined in the guideline for construction materials</td>
<td>5 – 8 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany\textsuperscript{105}</td>
<td>Sale proceeds</td>
<td>Mineral anti-freeze layer</td>
<td>3 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crushed rock</td>
<td></td>
<td>5 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crushed concrete</td>
<td></td>
<td>6 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{104} BUCHER, P. (2004)
\textsuperscript{105} CONTACT GERMANY 01 (2008)
\textsuperscript{106} DEHOUST, G. (2007)
6.5 Competitive products – Natural aggregates

Secondary and recycled aggregates have to compete against primary aggregates (sand and gravel, and crushed rock). The availability and quality of both, the natural aggregates on the one hand and the materials which compete with them on the other hand are important criteria for the establishment of a market for secondary and recycled aggregates.

6.5.1 Production of natural aggregates

One indicator that stipulates the availability of natural aggregates is the amount of natural aggregates produced as published in the European Mineral Statistics\textsuperscript{107}.

![Figure 20: EU-31 Production of natural aggregates 2005\textsuperscript{107}.](image)

Spain was the largest EU-31 producer of primary aggregates in 2005, with 395 million tonnes (14\%)\textsuperscript{107}. In general, the production of natural aggregates saw an increase from 2001 to 2005 to 2,742 Million tons.

![Figure 21: Production of natural aggregates 2001-2005\textsuperscript{107}.](image)

\textsuperscript{107} NATURAL ENVIRONMENTAL RESEARCH COUNCIL (2007)
Prices of natural aggregates can vary dramatically from country to country depending on the availability of hard rock, limestone and sand and gravel resources, as well as quality\textsuperscript{108}.

For the current year 2008, the highest rises of prices for natural aggregates have been seen in Eastern Europe, particularly in Russia, Hungary, Romania and Bulgaria. But prices there, with the exception of Russia, have yet to reach the prevailing in more developed European markets. To compare aggregates prices around Europe, it is the prices for extracted resources that have to be considered rather than the cost at the construction site, which includes transportation costs that might distort the overall picture. The average price in European countries is not just influenced by market forces but also by the type of resources in a particular region, so that the cost structure for extracting hard rock is different from that for sand and gravel extraction\textsuperscript{108}.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{average_prices_2007.png}
\caption{Average natural aggregates prices 2007\textsuperscript{108}}
\end{figure}

\textsuperscript{108} Aggregates Business Europe (2007A)
The construction markets in Spain, Germany, UK, Italy and France represent more than 70% of Europe's overall market and are also home to the region's largest aggregates sectors too. The recovery of the German market has been a good surprise this year. The market prices for natural aggregates in Germany rose from a low of € 3.5 per tonne in 2004 to around € 6.5 per tonne in 2007. The Germany market is interesting in that only around 20% of the quarries are owned by the main global players, compared to 70-80% in France and the UK. In the UK prices for the extracted resources have increased by around € 7.5 to 8 per tonne today. Competition in the UK is tough with big supplies of virgin sand and gravel and more focus on making profit on downstream products. France's aggregates prices have also risen this year to reach € 7 per tonne, which is an increase from € 4.5 per tonne two or three years ago.

Italy and Spain are also interesting markets with an average aggregate price of around € 6 per tonne. This is an increase from € 4.5 per tonne for Italy and € 3.5 per tonne for Spain fixed by the market two years ago in 2004. The demand in Spain is likely to level off or drop in the next 12 months, so producers are unlikely to retain the higher aggregate price in 2008.

The Big 5 may claim the highest production volumes but the biggest growth in terms of aggregate price rises was seen in Eastern Europe this year. Western Russia currently has the highest aggregate prices in Europe with material prices of € 9 to € 12 per tonne. Similar rates can be found in Kazakhstan and the Ukraine. Prices in the Czech Republic, Poland, Romania, Bulgaria, Hungary and Croatia are now reaching € 6.5 per tonne compared to less than € 3 per tonne three or four years ago. Many countries in Eastern Europe are rich in mineral resources and oil, so we can expect prices there to continue to rise, particularly with the booming construction industry in that region. Prices in Albania, Slovakia and Macedonia are yet to feel the effect of the Eastern European construction boom and aggregates in these markets average at around € 2.5 to € 3 per tonne.

In Central Europe and Southern Europe prices are also fairly stable with the highest priced aggregates in Switzerland at € 10 to € 11, driven by the high costs of operation rather than the market forces. Central European countries such as Austria, Switzerland and Serbia are fairly small markets which have seen very little price fluctuation over the last year.

Aggregate prices in each nation are closely linked with the market price for cement and the rate of price growth in the aggregates sector is also linked to the overall rate of growth of the economy. This raises concerns about the growth of European aggregates market in 2008 with the potential for the US housing market crisis to affect the European economy. Many European banks have interests in the US and a long term slump there might affect investment levels in Europe.
6.5.2 Taxation on natural aggregates

There are different motives for taxation\(^{109}\):

- With a tax on resource extraction, the rate of extraction will slow down and the depletion of resource will not carry on at the same speed.

- Just as in many other production processes, natural resource extraction tends to give rise to pollution and waste. For instance, mining and minerals processing may cause air and underground water pollution, and also produce solid waste. Here the case for policy intervention in the form of pollution taxes and/or taxes on waste is very strong. With such a tax, the natural resource owner has an incentive to take these undesirables into account.

- Since all materials extracted eventually turn into emissions into nature, the current rate of extraction equals future amounts of emissions or waste. Taxing virgin material inputs can thus be a means of preventing the transformation of materials into waste and emissions. In this case one could think of taxes that are levied on the consumption of different natural resources (and not only on the extraction). For obvious reasons, the pros and cons of this type of input taxation are very similar to those outlined above for output taxes. Taxes on resource inputs levied at the point of distribution are likely to be cheaper from an administrative viewpoint than pollution charges.

Taxes on natural resources may be used as a way of encouraging the substitution of secondary and recycled materials for virgin materials. This approach can not always be justified on the grounds that it saves virgin resources. However, virgin materials in general are often associated with more negative externalities than recycled materials. One commonly cited reason for this is that the processing of secondary materials tends to be less energy intensive. In addition, recycling is one way of avoiding the disposal of solid waste. Taxes on virgin materials will change the relative price difference between virgin and recycled materials, and in this way influence waste disposal behaviour. Theoretically, charges on waste disposal would be a good policy in this case, but in several studies it also argued that direct charges on waste disposals can be ineffective because of the risk of illegal disposal\(^{109}\).

By way of example, Sweden introduced taxes on natural gravel in 1983. The main reasons for introducing these taxes were conservation and material substitution, knowing that keeping the level of the production of 1996 would have meant that natural gravel would have run out in 40 municipalities within 20 years. With the aim to decrease the annually extraction of natural gravel (down to 12 million tons per year) and to increase the use of recycled material (up to 15 % of total use) the tax was raised to SEK 10 in the year 2003. The tax is levied on gravel extracted and consumed in Sweden and on extractions for export, but not on imports. Theoretically, imports thus become cheaper but practically this is unlikely to happen because of high transportation costs\(^{109}\).

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\(^{109}\) THE SWEDISH ENVIRONMENTAL PROTECTION AGENCY (2004)
In Denmark there is a tax of DKK 5 per m³ for selected extracted raw materials that include, among others, sand, gravel, stones, clay and limestone. The Danish tax is levied on raw materials that are commercially extracted and consumed in Denmark or commercially imported, while no tax is levied on exports. The main purpose of the tax from 1990 is to reduce the use of these resources and encourage substitution by recycled materials\(^\text{109}\).

The UK tax on aggregates came into effect in 2002. It is targeted at the extraction of sand, gravel and crushed rock and it is set at GBP 1.6 per tonne. The tax is levied on all extraction operations and imports to the UK (with the exemption of recycled aggregates), but it excludes exports. The main objective of the aggregates tax is to address the environmental costs associated with quarrying operations (noise, dust, visual intrusion, loss of amenity and damage to biodiversity). The tax is also intended to reduce demand for aggregates and encourage the use of alternative materials where possible\(^\text{109}\).

The motives for taxing aggregates for environmental reasons appear to be mixed, and not all of these motives find strong support in the economics literature. The virgin material conservation motive (i.e., reduce gravel use) may be valid if a relevant market failure can be identified, but in the presence of a well-defined owner of the resource, scarcity of the resource is not a market failure in itself. Moreover, a tax on aggregates extraction also reduces the incentive to find new deposits thereby limiting the economic availability of the resource. Taxing aggregates to promote the use of recycled materials is motivated if the environmental net benefits increase as a result\(^\text{109}\).
SCREENING OF MEMBER STATES

Data gathered on Member States are presented in the following Chapter. In general, the Ministries of the Member States were contacted by questionnaire to get information concerning the related issues. In addition and where necessary, the Environmental Agencies of the Member States were contacted. If data on a Member State could be gathered via contacts and research, a separate Report for each of these Member States was prepared. Table 52 shows for which Member States reports could be prepared and when the final feedback on the provided ‘Member States Reports’ was given by the contacts.

Table 52: Reports on Member States.

<table>
<thead>
<tr>
<th>Member State</th>
<th>Report available</th>
<th>Feedback on the ‘Member State Report’</th>
<th>Main contact for data gathering and feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Yes</td>
<td>26.02.2008</td>
<td>Ms. Evelyn Wolfslehner (Ministry for Environment)</td>
</tr>
<tr>
<td>Belgium</td>
<td>Yes</td>
<td>15.02.2008</td>
<td>Ms. Mieke de Schoenmaker (Environmental Agency)</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>No</td>
<td>X</td>
<td>Ms. Maria Ninova (Ministry for Environment)</td>
</tr>
<tr>
<td>Cyprus</td>
<td>No</td>
<td>X</td>
<td>Ms. Meropi Samara Miliotou (Ministry for Environment)</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>Yes</td>
<td>15.02.2008</td>
<td>Mr. Jaromir Manhart (Ministry for Environment)</td>
</tr>
<tr>
<td>Denmark</td>
<td>Yes</td>
<td>No feedback</td>
<td>Mr. Peter Bentzen (Ministry for Environment)</td>
</tr>
<tr>
<td>Estonia</td>
<td>Yes</td>
<td>18.02.2008</td>
<td>Mr. Matti Viisima (Environmental Agency)</td>
</tr>
<tr>
<td>Finland</td>
<td>Yes</td>
<td>18.01.2008</td>
<td>Ms. Anna-Maija Pajukallio (Environmental Agency)</td>
</tr>
<tr>
<td>France</td>
<td>Yes</td>
<td>18.02.2008</td>
<td>Mr. Laurent Chateau (Environmental Agency)</td>
</tr>
<tr>
<td>Germany</td>
<td>Yes</td>
<td>09.02.2008</td>
<td>Mr. Claus Bannick (Environmental Agency)</td>
</tr>
<tr>
<td>Greece</td>
<td>No</td>
<td>X</td>
<td>Ms. Fotini Boura (Ministry for Environment)</td>
</tr>
<tr>
<td>Hungary</td>
<td>No</td>
<td>X</td>
<td>Mr. Szabolcs Horváth (Ministry for Environment)</td>
</tr>
<tr>
<td>Ireland</td>
<td>Yes</td>
<td>No feedback</td>
<td>Mr. Bart Felle (Ministry for Environment)</td>
</tr>
<tr>
<td>Italy</td>
<td>Yes</td>
<td>No feedback</td>
<td>Mr. Alfonso Martinini (Ministry for Environment)</td>
</tr>
<tr>
<td>Latvia</td>
<td>No</td>
<td>X</td>
<td>Mr. Juris Fridmanis (Environmental Agency)</td>
</tr>
<tr>
<td>Lithuania</td>
<td>No</td>
<td>X</td>
<td>Ms. Raminta Radavícienė (Ministry for Environment)</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Yes</td>
<td>05.02.2008</td>
<td>Ms. Serge Less (Environmental Agency)</td>
</tr>
<tr>
<td>Malta</td>
<td>Yes</td>
<td>No feedback</td>
<td>Mr. Andrew Vella (Ministry for Environment)</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Yes</td>
<td>No feedback</td>
<td>Ms. Rianne Dobbelsteen (Ministry for Environment)</td>
</tr>
<tr>
<td>Poland</td>
<td>Yes</td>
<td>No feedback</td>
<td>Ms. Beata Klopotek (Ministry for Environment)</td>
</tr>
<tr>
<td>Portugal</td>
<td>No</td>
<td>X</td>
<td>Ms. Joana Sabino (Environmental Agency)</td>
</tr>
<tr>
<td>Romania</td>
<td>No</td>
<td>X</td>
<td>Ms. Aurora Ion (Ministry for Environment)</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>No</td>
<td>X</td>
<td>Mr. Jaroslav Jadiš (Ministry for Environment)</td>
</tr>
<tr>
<td>Slovenia</td>
<td>No</td>
<td>X</td>
<td>Ms. Lucija Jukič Soršak (Ministry for Environment)</td>
</tr>
<tr>
<td>Spain</td>
<td>Yes</td>
<td>No feedback</td>
<td>Mr. Francisco Aleza (Ministry for Environment)</td>
</tr>
<tr>
<td>Sweden</td>
<td>Yes</td>
<td>18.02.2008</td>
<td>Mr. Carl Mikael Strauss (Environmental Agency)</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Yes</td>
<td>15.02.2008</td>
<td>Mr. Mark Shotton (Ministry for Environment)</td>
</tr>
</tbody>
</table>

For Cyprus, Greece, Hungary, Latvia, Lithuania, Portugal, Slovak Republic and Slovenia as well as for the new Member States Romania and Bulgaria, no country report was prepared.
7.1 Austria

7.1.1 Existing standards and regulation

The legal requirements concerning waste management are defined in the ‘Waste Management Act’ and accompanying ordinances. Paragraph 1 of the waste management act includes the principles of waste management. Paragraph 5 gives descriptions for ‘end of waste’.

Potential recyclables remain waste, until they, or materials recovered from them, directly substitute resources or products produced from primary resources. The Minister for environment is authorised to enact ordinances, in which requirements are stipulated defining in which state and for which fields of application specific wastes can lose their waste status. These ordinances have to consider aspects like a ‘description of the intention’, ‘fields of application’, ‘quality criteria regarding products, resources and processes’, ‘limitation of waste related pollutants’, ‘documentation of compliance to the quality criteria’ and ‘recording obligations’. These ordinances can only be enacted if:

- the object is normally used for this specific purpose;
- there is a market for it,
- there are quality criteria that take the waste-specific pollutants into account, especially in the form of technical or legal standards or recognised quality guidelines, and
- the object does not cause any more environmental pollution or risk than a comparable primary raw material or a comparable product from a primary resource.

The ‘Ordinance on quality requirements for compost from waste’ regulates the end of waste for compost from waste and is the only ordinance which defines end of waste criteria in Austria.

7.1.1.1 Construction and demolition waste

In 1990 a voluntary agreement was reached between the Ministry of the economy and the Federation of the construction industry to increase the recycling quotas in the construction industry. Based on this agreement the ‘Ordinance on the separation of materials generated during construction’ was established and entered into force on 1st January 1993.

The ordinance regulates the separation of materials which are generated during construction and demolition. The separation has to be done on-site or within a treatment installation.

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111 FEDERAL MINISTRY OF AGRICULTURE AND FORESTRY, ENVIRONMENTAL AND WATER MANAGEMENT (2001)
112 FEDERAL MINISTRY OF ENVIRONMENTAL, YOUTH AND FAMILY (1991)
The ordinance defines limit values for quantities per generated material stream, above which the constructor is obliged to separate the material streams in order to enable further recovery (see Table 53). Since this Ordinance entered into force, recycling has increased from the original level of 15 % (1985) to more than 70 % today.

Table 53: Limit values for the quantities of generated above which material streams have to be separated.

<table>
<thead>
<tr>
<th>Material stream</th>
<th>Limit value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavated soil</td>
<td>20 tons</td>
</tr>
<tr>
<td>Broken concrete</td>
<td>20 tons</td>
</tr>
<tr>
<td>Road construction waste</td>
<td>5 tons</td>
</tr>
<tr>
<td>Wood waste</td>
<td>5 tons</td>
</tr>
<tr>
<td>Metal waste</td>
<td>2 tons</td>
</tr>
<tr>
<td>Plastic waste</td>
<td>2 tons</td>
</tr>
<tr>
<td>Construction site waste</td>
<td>10 tons</td>
</tr>
<tr>
<td>Mineral construction waste</td>
<td>40 tons</td>
</tr>
</tbody>
</table>

If recovery is not possible for the separated material streams or long transport causes disproportional high costs the material streams have to be treated in another way. As defined in a decree to the ordinance, disproportionally high costs for recovery exist if there is no possibility for recovery within 50 street kilometres from the construction site and if the cost for recovery exceeds 125% of traditional disposal costs.

The obligation to separate collection and recovery of demolition and construction waste also facilitates the following:

- Recovery of homogeneous building materials as secondary raw materials and/or filling materials;
- Reduction of landfilled residual waste, thus reducing the utilisation of landfill volumes;
- Minimisation of costs by reducing the amount of waste to be ultimately landfilled;
- Deposit of residual waste according to regulations on appropriate landfills with input control;
- Conservation of natural primary materials (protecting the landscape by removing less material and improving groundwater protection).

Proper preliminary sorting on the construction site ensures higher quality of construction material recycling. In particular, construction site waste is increasingly separated from mineral construction waste on-site at the construction yard.

In 1990, the ‘Austrian Construction Materials Recycling Association’ (ÖBRV, www.brv.at) was founded. This Association represents the interests of the recycling and construction industry as regards recycled construction materials. The guidelines set out in Table 54 were prepared and published by the Association.
Table 54: Guidelines on recycled construction materials (Austria)\textsuperscript{113}.

<table>
<thead>
<tr>
<th>Title</th>
<th>Edition</th>
<th>Date of release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideline on flowable, self sealing trench filling material</td>
<td>2\textsuperscript{nd} edition</td>
<td>September 2007</td>
</tr>
<tr>
<td>from recycled, broken material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guideline for recycled construction materials</td>
<td></td>
<td>August 2007</td>
</tr>
<tr>
<td>Guideline for recycled building materials</td>
<td>7\textsuperscript{th} edition</td>
<td>January 2007</td>
</tr>
<tr>
<td>Guideline for processing of contaminated soil and constructional components</td>
<td></td>
<td>December 2004</td>
</tr>
</tbody>
</table>

These guidelines are not legally binding\textsuperscript{114}. They describe requirements, fields of application and general conditions for the processing of recycled construction materials. Furthermore, a quality assurance scheme is defined. Fully compliance with the requirements of a guideline, a quality mark can be granted by the ‘Austrian Recycled Construction Materials Quality Insurance Association’.

The ‘Guideline for recycled building materials’ Table 55 classifies recycled materials produced in recycling plants according to their composition. Limit values for three quality classes are defined (A+, A, B).

Table 55: Classification of recycled building materials according to environmental engineering aspects (Austria)\textsuperscript{115}.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Quality class A+</th>
<th>Quality class A</th>
<th>Quality class B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaching limits</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH value\textsuperscript{116}</td>
<td></td>
<td>7.5-12.5</td>
<td>7.5-12.5</td>
<td>7.5-12.5</td>
</tr>
<tr>
<td>Electric conductivity\textsuperscript{116}</td>
<td>mS/m</td>
<td>150\textsuperscript{117}</td>
<td>150\textsuperscript{117}</td>
<td>150\textsuperscript{117}</td>
</tr>
<tr>
<td>Chromium total</td>
<td>mg/kg DS</td>
<td>0.3</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/kg DS</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ammonium-N</td>
<td>mg/kg DS</td>
<td>1</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Nitrite-N</td>
<td>mg/kg DS</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sulphate-SO\textsubscript{4}</td>
<td>mg/kg DS</td>
<td>1,500</td>
<td>2,500</td>
<td>5,000</td>
</tr>
<tr>
<td>KW index</td>
<td>mg/kg DS</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Sigma$ PAH according to EPO</td>
<td>mg/kg TS</td>
<td>4</td>
<td>12</td>
<td>20</td>
</tr>
</tbody>
</table>

\textsuperscript{113} Reference date: October 2007.

\textsuperscript{114} Greich H. et al. (2002)

\textsuperscript{115} Austrian Construction Materials Recycling Association (2007)

\textsuperscript{116} Specific determinations for exceeding.

\textsuperscript{117} If the pH value ranges between 11.0 and 12.5 the limit value of the electric conductivity is 200 mS/m.
The use of recycled building materials of quality class A+, A and B is subject to defined conditions. This means that the quality of recycled building materials corresponds directly to their possible use (see Table 56).

Table 56: Fields of application according to environmental engineering aspects – minimum requirements (Austria).

<table>
<thead>
<tr>
<th>Form of application</th>
<th>Hydro-geologically less delicate area</th>
<th>Hydro-geologically delicate area</th>
</tr>
</thead>
<tbody>
<tr>
<td>In bound form or unbound with covering layer</td>
<td>Quality class B</td>
<td>Quality class A</td>
</tr>
<tr>
<td>Unbound without covering layer</td>
<td>Quality class A</td>
<td>Quality class A+</td>
</tr>
<tr>
<td>In bound form, used as aggregate</td>
<td>Quality class B</td>
<td>Quality class B</td>
</tr>
</tbody>
</table>

Depending on how the material is used, a distinction is made between the bound form (in line with the definition of a stable base according to the Austrian road construction guidelines and regulations RVS 8S.05.13 which defines a bound layer as being is reinforced with cement or where a bituminous binding agent is used) or loose form with a top layer (definition of the top layer according to RVS 1.112), and the loose form used without a top layer. Furthermore its use as an aggregate is permitted in asphalt and concrete production where it is made even safer by the process. The second determining factor, alongside how it is used, is the prevailing hydro-geological conditions on site. A less sensitive hydro-geological area is defined by the availability of suitably impervious structures or sufficient distance from the groundwater.120

For general quality properties the ‘Guideline for recycled building materials’ refers to provisions on environmental compatibility laid down in a study of the Umweltbundesamt114. These provisions stipulate that the following additional limits have to be considered for recycled building materials:

- Table 57 shows additional limits defined in the Waste Management Plan120 for quality requirements. If there are any indications (based on the provenance of the material) of possible contamination during use, or of increased levels of pollutants in the material (especially nickel and chromium content in rail ballast), or if a visual inspection raises concerns about possible contamination these parameters have to be checked where higher content levels are suspected. The limits are laid down with regard to soil protection.
- Referring to Council Decision of 19 December 2002 (2003/33/EC)119 an additional limit for the liquid to solid ratio (L/S) of 10 l/kg is obligatory. The limit is laid down with regard to landfill criteria.

118 Specific requirements for covering layer.
119 COUNCIL DECISION 2003/33/EC (2002)
The quality requirements listed above have been agreed between plant operators, the Austrian Association for Building Material Recycling, the Federal Environment Agency and the Federal Ministry of Agriculture, Forestry, Environment and Water Management.\textsuperscript{120}

Special requirements are stipulated for recovery railway ballast. Railway ballast which is intended for recovery must be examined by an authorised expert or specialist institution before being used. If a preparatory procedure such as reduction is carried out, the material must be examined before the procedure is carried out to prevent contaminated and non-contaminated materials from being mixed.\textsuperscript{120}

In addition to the guidelines, several guidance papers were published by the ‘Austrian Construction Materials Recycling Association’ concerning the processing, storage and recovery of recycled construction materials. The documents should support operators and national authorities to guarantee harmonized recycling processes.

---

\textbf{Table 57: Additional limit values obligatory if contamination is possible (Austria)}\textsuperscript{120}.

<table>
<thead>
<tr>
<th>Parameters\textsuperscript{1}</th>
<th>Unit</th>
<th>Grade A+</th>
<th>Grade A</th>
<th>Grade B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>mg/kg DM</td>
<td>0.06</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/kg DM</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/kg DM</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/kg DM</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/kg DM</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>mg/kg DM</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/kg DM</td>
<td>0.4</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/kg DM</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/kg DM</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg DM</td>
<td>4</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/kg DM</td>
<td>800</td>
<td>800</td>
<td>1,000</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/kg DM</td>
<td>10</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Phosphorus index</td>
<td>mg/kg DM</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>DOC\textsuperscript{2}</td>
<td>mg/kg DM</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>TDS\textsuperscript{3}</td>
<td>mg/kg DM</td>
<td>4,000</td>
<td>4,000</td>
<td>8,000</td>
</tr>
</tbody>
</table>

\textsuperscript{1} Significant CH content is only permitted on condition that this originates from primary construction materials and from oil contamination.

\textsuperscript{2} Can be investigated if own pH value or alternatively where L/S = 10 l/kg and pH value 7.5 to 8.0.

\textsuperscript{3} The values for totally dissolved solids (TDS) can be used instead of sulphate and chloride. However, sulphate must be determined in any case.
7.1.1.2 Slags from ferrous metal production

According to the Austrian Waste Management Plan 2006, slags are waste. In the event of compliance with the criteria contained in the relevant rulings of the European Court of Justice (ECJ), certain types of slags from the iron and steel industry may be considered to be products in individual cases.

Table 58 shows examples of standards for residues from the iron and steel industry published by the Austrian Standards Institute. These Standards define requirements for the different slag types.

Table 58: Standards for slags from the iron and steel industry (Austria)

<table>
<thead>
<tr>
<th>Title</th>
<th>Number</th>
<th>Date of release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast furnace slags; general aspects</td>
<td>ÖNORM B 3313</td>
<td>1980-10-01</td>
</tr>
<tr>
<td>Expanded blast furnace slag (foamed blast furnace slag) and porous blast furnace slag aggregates</td>
<td>ÖNORM B 3314</td>
<td>1980-10-01</td>
</tr>
<tr>
<td>Coarse dense blast furnace aggregates</td>
<td>ÖNORM B 3315</td>
<td>1980-10-01</td>
</tr>
<tr>
<td>Blast furnace fibres</td>
<td>ÖNORM B 3316</td>
<td>1955-10-28</td>
</tr>
<tr>
<td>Blast furnace slag aggregates for concrete</td>
<td>ÖNORM B 3317</td>
<td>1980-10-01</td>
</tr>
</tbody>
</table>

In the Austrian standard on cement (EN 197) the requirements for granulated cinder (granulated blast furnace slag) are given. Granulated cinder must consist of at least two thirds of CaO, MgO and SiO$_2$. The mass ratio \((\text{CaO} + \text{MgO}) / (\text{SiO}_2)\) has to be above 1.0.

7.1.1.3 Ashes from coal combustion processes

Table 59 shows examples of standards for ashes from coal incineration processes published by the Austrian Standards Institute.

Table 59: Standards for ashes from coal incineration processes (Austria)

<table>
<thead>
<tr>
<th>Title</th>
<th>Number</th>
<th>Date of release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cements according to ÖNORM EN 197-1 for special use - Part 1: Additional requirements</td>
<td>ÖNORM B 3327-1</td>
<td>2005-07-01</td>
</tr>
<tr>
<td>Processed hydraulic additions for concrete production, marking of conformity</td>
<td>ÖNORM B 3309</td>
<td>2004-02-01</td>
</tr>
</tbody>
</table>
7.1.2 Construction and demolition waste

The annual generation of demolition and construction waste and excavated soil was estimated to be approx. 28 million tonnes in 2004. This group of materials therefore accounts for approx. 52 % of the total waste generated (approx. 54 million tonnes) per year.\textsuperscript{120}

Demolition and construction waste from the housing construction industry, road works and bridge building, as well as general street and building demolition. Track ballast comes from the removal of railway track beds\textsuperscript{120}.

\textit{Table 60: Composition of demolition and construction waste (Austria)}\textsuperscript{120}.

<table>
<thead>
<tr>
<th>Type of waste</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction site waste</td>
<td>Insulation material, gypsum board, rock, foil strip, contaminated packaging; plastic tubes, cutting of various components, etc.</td>
</tr>
<tr>
<td>Mineral construction waste</td>
<td>Tiles, concrete, ceramic, rocks, etc.</td>
</tr>
<tr>
<td>Road construction waste</td>
<td>Asphalt, partly mixed with cement; bitumen</td>
</tr>
<tr>
<td>Asbestos cement; asbestos cement dust</td>
<td>Asbestos cement; fine material from asbestos cement</td>
</tr>
<tr>
<td>Concrete waste</td>
<td>Construction components or ready-made concrete parts</td>
</tr>
<tr>
<td>Track ballast</td>
<td>Crushed stone from railroad tracks</td>
</tr>
</tbody>
</table>

‘Excavated materials’ are considered in separate sections, as are ‘construction/demolition wood’ in the section ‘waste wood’\textsuperscript{120}.

On-site separation of defined fractions according to the ‘Ordinance on the separation of materials generated during construction’\textsuperscript{112} enables further recovery of construction and demolition waste.

According to the members of the ‘Austrian Construction Materials Recycling Association’ (ÖBRV, \texttt{www.brv.at}) approx. 3.8 million tonnes of waste of the components ‘mineral construction waste’, ‘road construction waste’ and ‘concrete waste’ were delivered for recovery in 2004. The rate of recycling, in terms of the amount of these waste fractions, amounted to approximately 76 %\textsuperscript{120}.

\textsuperscript{120} FEDERAL MINISTRY OF AGRICULTURE AND FORESTRY, ENVIRONMENTAL AND WATER MANAGEMENT (2006)
Table 61: Amounts and Recovery of demolition and construction waste in 2004 (Austria)\textsuperscript{120}.

<table>
<thead>
<tr>
<th>Type of waste</th>
<th>National code number</th>
<th>Total amount</th>
<th>Prepared in plants (rounded)</th>
<th>Possible recovery methods for demolition and construction waste treated in recycling plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction site waste</td>
<td>91206</td>
<td>1,100,000 t</td>
<td>93,000 t</td>
<td>After sorting; combustion for energy value</td>
</tr>
<tr>
<td>Share of total waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery rate</td>
<td></td>
<td></td>
<td>1.4 %</td>
<td></td>
</tr>
<tr>
<td>Construction waste - Mineral waste</td>
<td>31409</td>
<td>2,450,000 t</td>
<td>1,688,000 t</td>
<td>Aggregates for the production of masonry stone, concrete and lightweight concrete, stabilisation, filling, piling, lime flooring, playing field construction, drainage layers</td>
</tr>
<tr>
<td>Share of total waste</td>
<td></td>
<td></td>
<td>27 %</td>
<td></td>
</tr>
<tr>
<td>Recovery rate</td>
<td></td>
<td></td>
<td>68%</td>
<td></td>
</tr>
<tr>
<td>Construction waste (no construction site waste) - Only mixtures of selected waste from building and demolition measures</td>
<td>31409 18</td>
<td>52,000 t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road construction waste</td>
<td>31410</td>
<td>1,200,000 t</td>
<td>1,005,000 t</td>
<td>Upper and lower road bases, agricultural road building, aggregates for asphalt production</td>
</tr>
<tr>
<td>Recovery rate</td>
<td></td>
<td></td>
<td>84 %</td>
<td></td>
</tr>
<tr>
<td>Concrete waste</td>
<td>31427</td>
<td>1,300,000 t</td>
<td>1,034,000 t</td>
<td>Upper, lower, and cement-bonded road bases, agricultural road building, aggregates for cement-production; trench material; drainage layers</td>
</tr>
<tr>
<td>Share of total waste</td>
<td></td>
<td></td>
<td>16 %</td>
<td></td>
</tr>
<tr>
<td>Recovery rate</td>
<td></td>
<td></td>
<td>76%</td>
<td></td>
</tr>
<tr>
<td>Concrete waste - Only mixtures of selected waste from building and demolition measures</td>
<td>31427 17</td>
<td>53,000 t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Track ballast</td>
<td>31467</td>
<td>440,000 t</td>
<td>246,000 t</td>
<td>Sometimes reinstalled after cleaning</td>
</tr>
<tr>
<td>Share of total waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery rate</td>
<td></td>
<td></td>
<td>4 %</td>
<td></td>
</tr>
<tr>
<td>Asbestos cement</td>
<td>31412</td>
<td>12,600 t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asbestos cement dust</td>
<td>31413</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asbestos waste, Asbestos dust - De-classified</td>
<td>31437 88</td>
<td>1,300 t</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (rounded)</td>
<td></td>
<td>6.6 Million</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recycling rates by accumulation per type of waste, according to Members of the ÖBRV

Approx. 56% of the track ballast or ‘track excavation’ was cleaned and reinstalled as track ballast in 2004; the remainder of approx. 44% was mostly deposited in landfills as mineral construction waste or excavated material\textsuperscript{120}.
### Table 62: Deposited quantities of construction and demolition waste in tonnes in 2004 (Austria)\(^\text{120}\).

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Deposited amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction waste (no construction site waste)</td>
<td>649,000</td>
</tr>
<tr>
<td>Road construction waste</td>
<td>10,400</td>
</tr>
<tr>
<td>Asbestos cement</td>
<td>12,600</td>
</tr>
<tr>
<td>Concrete waste</td>
<td>163,000</td>
</tr>
<tr>
<td>Asbestos waste, asbestos dust</td>
<td>1,300</td>
</tr>
<tr>
<td>Track ballast (track excavation)</td>
<td>194,000</td>
</tr>
<tr>
<td>Construction site waste (no construction waste)</td>
<td>15,000</td>
</tr>
<tr>
<td><strong>Total (rounded)</strong></td>
<td><strong>1,045,000</strong></td>
</tr>
</tbody>
</table>

Non-recyclable demolition and construction waste is, due to the heterogeneity of the waste flows, largely deposited in landfills\(^\text{120}\).

### 7.1.3 Slags from ferrous metal production

In both 2003 and 2004 more than 2,000,000 tons of blast furnace slag and converter slags accumulated\(^\text{121}\).

### Table 63: Generation of slags in the iron and steel industry (Austria)\(^\text{122}\).

<table>
<thead>
<tr>
<th>Slags [tons]</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>voestalpine Stahl Linz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blast furnace slag</td>
<td>968,225</td>
<td>1,023,377</td>
<td>1,036,664</td>
<td>1,820,583</td>
<td>1,804,000</td>
</tr>
<tr>
<td>BOF-slag</td>
<td>600,573</td>
<td>509,589</td>
<td>517,849</td>
<td>1,820,583</td>
<td>1,804,000</td>
</tr>
<tr>
<td>voestalpine Stahl Donawitz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blast furnace slag</td>
<td>292,880</td>
<td>316,770</td>
<td>317,660</td>
<td>318,560</td>
<td>318,230</td>
</tr>
<tr>
<td>BOF-slag</td>
<td></td>
<td>190,818</td>
<td></td>
<td>211,906</td>
<td></td>
</tr>
<tr>
<td>Marienhütte Stahl- und Walzwerk GmbH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EAF-slag and secondary slags</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>71,600</td>
</tr>
<tr>
<td>Böhler Edelstahl GmbH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EAF-slag and secondary slags</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45,000</td>
</tr>
<tr>
<td>Breitenfeld Edelstahl GmbH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EAF-slag and secondary slags</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5,130</td>
</tr>
</tbody>
</table>

**Uses of slags**

**Linz**

A big amount of the blast furnace slag is used as secondary constituents in the cement industry.

---

\(^{121}\) \text{WINTER B. ET AL. (2005)}

\(^{122}\) \text{ANONYMOUS (2005)}
The BOF slag is used in large quantities in underground engineering. Others are used in the construction industry and in agriculture.

*Donawitz*

Blast furnace slag is sent to the cement industry and used as a secondary raw material or a secondary constituent. The quality of the slag for this use is prescribed in a special Austrian standard (ÖNORM EN 197).

BOF slag is partly used for the recycling of iron; otherwise it is pre-treated and landfilled.

EAF slag from Böhler-Edelstahl GmbH and Breitenfeld Edelstahl GmbH are landfilled. EAF slag from Marienhütte is used in road construction.

### 7.1.4 Ashes from coal combustion processes

The liberalization of the electricity market, trends of fuel and electricity prices and the growing demand for electricity have led to big changes in the power plants sector in Austria, including changes of the operating methods and operating times of power plants. While some plants have been put into so called ‘cold stand by’, coal inputs have risen dramatically in other power plants\(^{121}\).

A reduction of heavy metal concentrations in the residues from coal incineration can be achieved by the use of ‘clean’ coal with a high heating value, with the ash content being an important parameter for the concentration of hazardous substances. Generally, coal purification is not carried out in Austria prior to incineration\(^{121}\). Table 64 shows the information on the heavy metal content in several coal combustion plants in Austria.

*Table 64: Heavy metal content of brown coal and hard coal (content without water) as specified by Austrian coal combustion plants (Austria)\(^{121}\).*

<table>
<thead>
<tr>
<th>Heavy metal</th>
<th>Voitsberg</th>
<th>St. Andrä</th>
<th>Typical value</th>
<th>St. Andrä</th>
<th>Riedersbach</th>
<th>Mellach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown coal</td>
<td>Brown coal</td>
<td>Brown coal</td>
<td>1 – 5</td>
<td>Hard coal</td>
<td>Hard coal</td>
<td>Hard coal</td>
</tr>
<tr>
<td>Arsenic</td>
<td>10-25</td>
<td>11.0</td>
<td>3.0</td>
<td>&lt; 5</td>
<td>3 – 5</td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.08-0.12</td>
<td>2.0</td>
<td>0.07-0.12</td>
<td>2.0</td>
<td>&lt; 0.3</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>Chromium</td>
<td>39.1</td>
<td>36.0</td>
<td>10 – 20</td>
<td>23.0</td>
<td>&lt; 30</td>
<td>26 – 43</td>
</tr>
<tr>
<td>Copper</td>
<td>16.0</td>
<td>25.0</td>
<td>15 – 50</td>
<td>23.0</td>
<td>&lt; 30</td>
<td>18 – 34</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.28</td>
<td>0.15</td>
<td>0.13-0.18</td>
<td>0.15</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Nickel</td>
<td>40.5</td>
<td>38.0</td>
<td>10 – 25</td>
<td>26.0</td>
<td>&lt; 30</td>
<td>20 – 36</td>
</tr>
<tr>
<td>Lead</td>
<td>5-15</td>
<td>8.7</td>
<td>5 – 25</td>
<td>44</td>
<td>&lt; 20</td>
<td>12 – 16</td>
</tr>
<tr>
<td>Selene</td>
<td>0.99</td>
<td>3.0</td>
<td>&lt; 1</td>
<td>3.0</td>
<td>n.s.</td>
<td>n.m.</td>
</tr>
<tr>
<td>Vanadium</td>
<td>41.3</td>
<td>36.0</td>
<td>20 – 50</td>
<td>29.0</td>
<td>n.s.</td>
<td>23 – 41</td>
</tr>
<tr>
<td>Zinc</td>
<td>26.1</td>
<td>35.0</td>
<td>10 – 50</td>
<td>48.0</td>
<td>&lt; 30</td>
<td>24 – 31</td>
</tr>
</tbody>
</table>

n.s.: not specified; n.m.: not measurable
State-of-the-art plant operation and design includes a firing system and a flue gas cleaning system which permit use of the ashes and the FGD gypsum in the building materials industry\(^\text{121}\).

In Austria there are eight operating sites firing stone or brown coal in ten generating units (firing units of the industry not included) with a thermal output of 113 to 880 MW per unit\(^\text{121}\).

Regarding the Austrian Waste Management Act, residues from coal fired power plants are defined as waste. Important residues are bottom ash from precipitation in the boiler, fly ash from precipitation in electric or baghouse filters and flue gas desulphurisation gypsum (FGD) from desulphurisation. Table 65 shows volumes generated in 2004. Because of the temperatures within the combustion chamber there are only bottom ashes and no slags generated in Austrian coal fired power stations\(^\text{121}\).

Existing options for the recycling of power plant residues are as follows\(^\text{121}\):
- Use of fly ash as concrete additive and as additive in the cement industry;
- Use of bottom ash in brick industry;
- Use of FGD gypsum (desulphurisation product derived from wet flue-gas cleaning) after dewatering and drying in the cement and building material industry.

### Table 65: Amounts of residues from coal combustion processes in 2004 (Austria)\(^\text{120}\)

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Amount [tons/anno]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash and dust from combustion processes(^\text{123})</td>
<td>520,000</td>
</tr>
<tr>
<td>Fly ash and dust from combustion processes, hazardous waste</td>
<td>1,620</td>
</tr>
<tr>
<td>Coal ash (residues from coal combustion processes, including ashes from fluidized bed incineration)(^\text{123})</td>
<td>67,000</td>
</tr>
<tr>
<td>Solid residues from exhaust air cleaning systems of combustion plants for conventional firing (FGD not included)</td>
<td>5,400</td>
</tr>
<tr>
<td>Flue gas desulphurisation gypsum (FGD)(^\text{124})</td>
<td>130,000</td>
</tr>
</tbody>
</table>

Table 66 shows the composition of bottom ash from selected plants for coal combustion in Austria. In normal cases the concentrations of heavy metals are lower for the bottom ash than for the fly ash. Table 66 also shows the composition of ash from the incineration of municipal solid waste, which tends to have higher concentrations of heavy metals than bottom ashes from coal combustion\(^\text{121}\).

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\(^{123}\) Including ashes and dust from combustion processes other than coal combustion.

\(^{124}\) Including about 20,000 tons per annum from oil fired power plants.
**Table 66: Quality of bottom ash from coal combustion processes (Austria)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Voitsberg 3</th>
<th>Dürrrohr 1</th>
<th>Mellach</th>
<th>Spittelau</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Brown coal</td>
<td>Hard coal</td>
<td>Hard coal</td>
<td>Municipal solid waste</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>% DS</td>
<td>9–11</td>
<td>22-25</td>
<td>21.6</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>mg/kg</td>
<td></td>
<td></td>
<td></td>
<td>30,000–75,000</td>
</tr>
<tr>
<td>Ignition loss</td>
<td>% DS</td>
<td>10–40(^{125})</td>
<td>&lt; 5</td>
<td>12.2</td>
<td>0.9–5.63</td>
</tr>
<tr>
<td>Chloride</td>
<td>% DS</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
<td>0.1–0.75</td>
</tr>
<tr>
<td>Fluoride</td>
<td>% DS</td>
<td></td>
<td></td>
<td>&lt; 0.001</td>
<td>0.01–0.13</td>
</tr>
<tr>
<td>Sulphide</td>
<td>%</td>
<td></td>
<td></td>
<td>0.11</td>
<td>0.36–3.33</td>
</tr>
<tr>
<td>As</td>
<td>mg/kg</td>
<td>8.8</td>
<td></td>
<td>5</td>
<td>2–70</td>
</tr>
<tr>
<td>B</td>
<td>mg/kg</td>
<td>158</td>
<td>80–165</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ba</td>
<td>mg/kg</td>
<td>850</td>
<td>390–2,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>mg/kg</td>
<td>n.m.</td>
<td></td>
<td></td>
<td>2–50</td>
</tr>
<tr>
<td>Co</td>
<td>mg/kg</td>
<td>44</td>
<td>9–85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>mg/kg</td>
<td>204.7</td>
<td>127.7</td>
<td>100–550</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>mg/kg</td>
<td>63.2</td>
<td>92.8</td>
<td>500–4,010</td>
<td></td>
</tr>
<tr>
<td>Hg</td>
<td>mg/kg</td>
<td>n.m.</td>
<td></td>
<td></td>
<td>0.1–7</td>
</tr>
<tr>
<td>Mn</td>
<td>mg/kg</td>
<td>582</td>
<td>300–1,100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>mg/kg</td>
<td>214.9</td>
<td>94</td>
<td>42–420</td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>mg/kg</td>
<td>9.9</td>
<td>9</td>
<td>250–5,500</td>
<td></td>
</tr>
<tr>
<td>Sb</td>
<td>mg/kg</td>
<td>n.m.</td>
<td></td>
<td>23–62</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>mg/kg</td>
<td>0.6</td>
<td></td>
<td>n.m.</td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>mg/kg</td>
<td>96.6</td>
<td>22.7</td>
<td>91–130</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>mg/kg</td>
<td>204</td>
<td>27–32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>mg/kg</td>
<td>38.9</td>
<td>89</td>
<td>1,200–5,500</td>
<td></td>
</tr>
<tr>
<td>TOC as C</td>
<td>% TS</td>
<td>7.9</td>
<td>0.9–3.13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

n.s.: not specified; n.m.: not measurable; DS: dry substance

Table 67 shows the composition of fly ash from selected plants for coal combustion in Austria. The concentrations of several parameters (e.g. As, Cr, Cu, Hg and Ni) are higher than the limits defined in the ‘Guideline for recycled building materials’ (see Chapter 7.1.1.1). Table 67 also shows the composition of ash from the incineration of municipal solid waste, which tends to have higher concentrations of heavy metals than fly ashes from coal combustion. For some loads similar concentrations (e.g. B, Ba, Co, Cr, Mn and Ni) can be identified\(^{121}\).

\(^{125}\) In general, the ignition loss of bottom ashes is higher in lignite fired power plants than in hard coal fired ones. The upper value of 40% is not representative and shall be considered an outlier. In cases where burnout of bottom ash is insufficient it is circulated within the combustion process to guarantee a high burnout rate.
Table 67: Quality of fly ash from coal combustion processes (Austria).\(^\text{120}\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Voitsberg 3</th>
<th>Mellach</th>
<th>Riedersbach 1+2</th>
<th>Spittelau</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Brown coal</td>
<td>Hard coal</td>
<td>Hard coal</td>
<td>Municipal solid waste</td>
</tr>
<tr>
<td>Ignition loss</td>
<td>% DS</td>
<td>&lt; 3</td>
<td>2.1</td>
<td>0.3–3.8</td>
<td></td>
</tr>
<tr>
<td>TiO(_2)</td>
<td>% DS</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P(_2)O(_5)</td>
<td>% DS</td>
<td>0.77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>% DS</td>
<td>0.01</td>
<td>&lt; 0.1</td>
<td>5–11</td>
<td></td>
</tr>
<tr>
<td>Fluoride</td>
<td>% DS</td>
<td>&lt; 0.001</td>
<td>&lt; 0.1</td>
<td>0.1–1.5</td>
<td></td>
</tr>
<tr>
<td>Sulphide</td>
<td>% DS</td>
<td>0.4</td>
<td>0.52</td>
<td>&lt; 1</td>
<td></td>
</tr>
<tr>
<td>Ag</td>
<td>mg/kg</td>
<td>0.3</td>
<td>30–49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>mg/kg</td>
<td>40,000–80,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>mg/kg</td>
<td>106</td>
<td>32.5</td>
<td>&lt; 50</td>
<td>3–32</td>
</tr>
<tr>
<td>B</td>
<td>mg/kg</td>
<td>231</td>
<td>119–147</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ba</td>
<td>mg/kg</td>
<td>3.170</td>
<td>644–3,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Be</td>
<td>mg/kg</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>mg/kg</td>
<td>0.74</td>
<td>n.m.</td>
<td>&lt; 0.5</td>
<td>50–500</td>
</tr>
<tr>
<td>Co</td>
<td>mg/kg</td>
<td>82</td>
<td>15–120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>mg/kg</td>
<td>195</td>
<td>150</td>
<td>&lt; 400</td>
<td>164–700</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/kg</td>
<td>88.4</td>
<td>155</td>
<td>&lt; 100</td>
<td>400–1,200</td>
</tr>
<tr>
<td>Hg</td>
<td>mg/kg</td>
<td>0.86</td>
<td>&lt; 0.0002</td>
<td>&lt; 1</td>
<td>3–50</td>
</tr>
<tr>
<td>Li</td>
<td>mg/kg</td>
<td>131</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mn</td>
<td>mg/kg</td>
<td>510</td>
<td>500–800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mo</td>
<td>mg/kg</td>
<td>12.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>mg/kg</td>
<td>90</td>
<td>197</td>
<td>&lt; 250</td>
<td>42–240</td>
</tr>
<tr>
<td>Pb</td>
<td>mg/kg</td>
<td>45.2</td>
<td>81</td>
<td>&lt; 100</td>
<td>2,500–72,000</td>
</tr>
<tr>
<td>Sb</td>
<td>mg/kg</td>
<td>45.2</td>
<td>n.m.</td>
<td>550–1,038</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>mg/kg</td>
<td>2.8</td>
<td>n.m.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>mg/kg</td>
<td>6.7</td>
<td>651–867</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ti</td>
<td>mg/kg</td>
<td>n.m.</td>
<td>&lt; 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>mg/kg</td>
<td>264</td>
<td>301</td>
<td>24–31</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>mg/kg</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>mg/kg</td>
<td>236</td>
<td>210</td>
<td>&lt; 300</td>
<td>7,000–20,600</td>
</tr>
<tr>
<td>TOC as C</td>
<td>% TS</td>
<td>1.75</td>
<td>&lt; 8</td>
<td>0.8–2.5</td>
<td></td>
</tr>
</tbody>
</table>

n.s.: not specified; n.m.: not measurable; DS: dry substance
7.2 Belgium

In 2000, Belgium produced about 38 million tons of crushed rock and gravel, 10 million tons of sand (3 million tons of which marine dredged), 10 million tons of limestone, 5.8 million tons of clay, 4.0 million tons of silica sand and 3.6 million tons of fill material (mainly fine sand; see Figure 23). Belgium is a net exporter of crushed rock and gravel (7.9 million tons in 2000, mainly to the Netherlands and France) and a net importer of sand (about 15 million tons, from the Netherlands, Germany and the UK).

Belgium uses various secondary materials, such as construction and demolition waste, asphalt waste, industrial slag and ashes. The total production in 2000 was about 11 Million tons; the overall recycling percentage was about 75 %. The share of secondary materials in the total provision was about 9 %. The use of renewable raw materials for building and construction is limited to timber. The percentage of timber-built and timber-framed houses built yearly is estimated between 8 and 12 %.

The Belgian policy on raw materials and mineral planning is the responsibility of the regional governments. The federal government only provides a policy on related environmental issues. In the Flemish region, provinces and municipal administrations are extraction permission authorities for large and small exploitations, respectively. In the Walloon region, extractions of any size are permitted by the municipalities. Sea bed extraction permits are issued by the federal government. In the whole of Belgium, provision of raw materials for building and construction purposes is essentially left to the market.
In the Flemish Region, the so-called gravel decree (‘grinddecreet’) provides for the gradual reduction of gravel extraction. The Flemish government is currently redesigning its mineral planning policy. A new decree aims at a sustainable exploitation of mineral reserves. It introduces a mineral planning horizon of 25 years, stimulates the utilization of secondary materials, and addresses the environmental hygiene of minerals and restoration and aftercare of extraction sites. The Walloon regional government is also reconsidering its mineral planning policy, and aims to increase the export levels of quarry products for economical reasons. Views on sustainability, especially concerning the utilization of secondary materials, are similar to those in Flanders.\textsuperscript{126}

In 2005 a total amount of 65.1 million tons of aggregates was produced in Belgium. 12.0 million tons were recycled aggregates coming from construction and demolition waste used on the aggregates market. 1.2 Million tons were secondary aggregates including blast furnace slag, electric-arc-furnace slag, incinerator bottom ash (IBA), pulverised fuel ash (PFA) and other industrial and extraction by-products for construction and civil engineering.\textsuperscript{3}

### 7.2.1 Existing standards and regulation

Belgium is a federal state and environmental responsibility is divided between the federal level and its three regions (Flemish Region, Brussels Capital Region and the Walloon Region) (see Article 6, Special Law of 8 August 1980).\textsuperscript{127}

Federal responsibility is limited to:
- The designation of product standards.
- Protection against ionising radiation, including radioactive waste.
- Transit of waste.

The regions are responsible for:
- Protecting the environment, for instance soil, underground areas, water, and air against pollution and corrosion, including noise nuisance.
- Waste policy.
- Regulating dangerous, unhealthy and disturbing facilities, except for internal measures concerning employee protection.
- Water policy, including technical regulations concerning the quality of water, purification of wastewater and the sewerage system.

Thus, the regions are responsible for regulating the use of construction and demolition waste, slags from ferrous metal production and ashes from coal combustion processes as aggregates.

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\textsuperscript{126} MINISTRY OF TRANSPORT, PUBLIC WORKS AND WATER MANAGEMENT (2003)
\textsuperscript{127} PRACTICAL LAW COMPANY: \url{http://www.practicallaw.com}
To understand the system, it is essential to understand the hierarchy of the different
documents and laws. In the Federal State of Belgium, the state, the regions and the
communities are the competent authorities in those fields which were assigned to
them through the different state reforms. Whenever there is a discussion about
competency, the Council of State and the Court of Arbitrage are there to judge. This
means that a federal Law has the same impact as a regional Decree. For historical
reasons, former national laws may still be the legal basis of actions taken by re-

gional governments. A simplified scheme to explain the hierarchy of Laws, De-
crees, Ordinances and Orders is given in Figure 24.

<table>
<thead>
<tr>
<th>The Constitution of Belgium</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Federal Level</strong></td>
</tr>
<tr>
<td>Federal Law</td>
</tr>
<tr>
<td>Royal Decree</td>
</tr>
<tr>
<td>Ministerial Decree</td>
</tr>
<tr>
<td>Circular</td>
</tr>
</tbody>
</table>

Figure 24: Equivalence in the juridical hierarchy.

To protect the environment against possible hazards caused by the use of recycled
products, most of the authorities are preparing or have prepared environmental hy-

giene legislation to prevent such accidents. In Flanders, the VLAREA legislation es-


tablishes clear rules, mainly based on chemical composition and lixiviation charac-


teristics, for the recognition of waste materials as secondary products. A similar

regulation has been established in the Walloon region.126

### 7.2.1.1 Construction and demolition waste

For construction and demolition waste to be recognised as secondary raw materi-
als, several procedures exist.

Construction and demolition waste is defined in the regional decrees concerning
waste prevention and management. In the Flemish Region, procedures to allow
waste materials to be used as secondary products have been established (see fur-
ther on VLAREA). In the Walloon Region, waste must be declared and must follow
a long procedure to be considered as secondary material.

Beside these legislative documents concentrating on environmental hygiene as-

pects, technical documents have been established to define technical require-
ments. Reference documents in this context are the technical specifications for
road construction of Flanders (SB250) and the Walloon Region (RW 99), and the
COPRO Certification System for recycled aggregates produced from C&D waste. The COPRO quality label is essentially based upon the regional technical specification
documents. In Belgium, secondary materials such as construction and demolition
wastes are also used as filling materials.

It is interesting to note that in 2001 a new normative document concerning recycled
concrete, masonry and mixed aggregates, i.e. the PTV406, was approved by the
CRIC Certification Board for Aggregates.
In 2002, the responsibility for the certification of recycled aggregates was transferred from CRIC certification (only for concrete) to COPRO. The purpose is to establish new technical specifications for other types of recycled aggregates (for instance crushed asphalt) and certification guidelines. When available, the COPRO label would certify environmental hygiene quality, while the voluntary quality mark ‘BENOR’ would guarantee technical quality.\textsuperscript{126}

**Walloon Region**

The Decree on Environmental Planning in the Framework of Sustainable Development was adopted by the Walloon Regional Council on 19 April 1994 and promulgated on 21 April 1994. This decree introduces sustainable development as one of the main principles determining the regional policy and fixes the legal framework for environmental planning in the Walloon Region. According to the Decree, environmental planning aims to safeguard natural resources and ecosystems, to prevent and limit environmental nuisances and to install sustainable development. The Decree states that an Environmental Plan for Sustainable Development has to be developed. According to the Decree, the Plan should give a medium to long-term vision on environment and sustainable development in the Walloon Region. In principle, such a plan has to be reviewed every 5 years. The plan was adopted by the Walloon Government on 9 March 1995.

The Waste Decree of 5 July 1985 (a new Waste Decree was adopted on 27 July 1996) provides the legal basis for the waste prevention and management policy. One of the main purposes of the Decree is to encourage the use of waste materials similar to products (defined in French as ‘L’utilisation de matières assimilables à des produits’).\textsuperscript{126}

In its government declaration, the Walloon Government announced that it would review the Order of 20 May 1999 establishing a list of waste materials similar to products in order to make it conform to European prescriptions. This objective was realised with the Order of 14 June 2001 favouring the valorisation of certain wastes.

This Order is based upon article 3 § 1 of the Decree of 27 June 1996 and defines a registration procedure for the valorisation of non-hazardous wastes. Annex I of this Order consists of a list of wastes which can be used as products after a simple registration procedure provided all conditions defined in this annex are fulfilled. These conditions include requirements with regard to the origin of the waste material, the recycling process, the characteristics of the waste material and the place or product in which it will be used. With regard to the use in the construction industry, a whole range of materials is taken up, amongst others natural stony materials, natural sand, natural coarse aggregates, crushed concrete and masonry, slag, bottom ashes, foundry sand, fly ash, calcareous fillers, phosphor-gypsum, citro-gypsum, etc.

However, while it is quite impossible to list all valorisation possibilities for all sorts of non-hazardous waste, it is possible to register on an individual basis for waste materials which are not included in Annex I, or for other types of valorisation than the ones defined in Annex I. In these cases, the legal framework has to be respected.
The Decree obliges the Walloon Region to develop a waste plan. Waste management plans generally play an important role in implementing waste management policy. The first one (for 1991-1995) did not specify a clear recycling target for C&DW. Information and awareness raising campaigns aimed at both the public and private sectors and specifying ways to prevent waste arising, as well as directing C&DW towards controlled landfills and recycling plants were given a high priority.

‘Horizon 2010’, was published on 29 April 1998, following a public survey in June 1997. In ‘Horizon 2010’ different recycling targets relevant for the construction industry are defined:

- For construction and demolition waste, a 74% level of recycling in 2000 was proposed. In 2005 a level of 81% was to be reached and in 2010 a level of 87%. At the same time, disposal of C&D waste at dumpsites was to be decreased to a level of 10% in 2010. In its 2001 Annual Report, the Walloon Waste Office states that recycling companies, both private and public, processed more than 1,500,000 tonnes of construction and demolition waste in 2001.
- For bottom and fly ashes coming from household waste incineration installations a target of 75% valorisation was set in 2010. For certain industrial wastes released during incineration and heating processes, such as slag, foundry sand and fly ashes from electricity production plants, an overall target of 96% was defined in 2010.

Since 1 January 2006 there has been a ban on landfilling for:

- Certain inert waste (primarily construction and demolition waste);
- Slag (e.g. from waste incineration).

**Flemish Region**

The legal basis for waste policy in Flanders is set down in the Waste Decree of 2 July 1981, which was considerably modified by the new Decree of 20 April 1994. Article 11 explicitly opens up ways to use waste materials as secondary raw materials or products.

Subsequently an application order on the prevention and management of waste (the VLAREA legislation) was approved by the Flemish government on 17 December 1997 and published officially on 16 April 1998. The VLAREA legislation (‘Vlaams reglement inzake afvalvoorkoming en – beheer’ of January 1998) states that unsorted industrial waste, the category to which most C&DW belongs, may not be landfilled from 1 July 1998. Indirectly, this means that C&DW should pass through some kind of sorting process.

Articles 35 and 36 offer to the waste authorities (OVAM) the opportunity to develop implementation plans directed towards specific industrial sectors. Since this opportunity was already provided in the Flemish Strategic Waste Action Plan 1991-1995, OVAM elaborated, in 1995, together with the construction industry such an implementation plan for construction and demolition waste, in Dutch ‘Het Uitvoeringsplan Bouw- en Sloopafval’.

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128 European Topic Centre on Resource and Waste Management (2007)
The main objective of the latter plan was to realise a recycling level of 75% C&D waste for the year 2000. A maximum of 25% would then be available for removal through effective and environmentally sound techniques. Another key objective was to realise qualitative and quantitative prevention through the gradual reduction of the quantities of C&D waste produced.

The main objectives of the C&D waste plan have been reached, i.e. the Flemish region is recycling more than 75% of its C&D waste. A five-year progress report on the period 1995-2000 was published by OVAM in November 2001. According to this progress report the quantity processed by debris crushing installations and container companies showed an increase of 1 million tonnes between 1998 and 2000. A total of 4.5 million tonnes of construction and demolition waste was recycled during the year 2000. Even compared with a rough estimation of 5.2 tonnes of construction and demolition waste generated annually in the construction sector, one can conclude that over 85% of construction and demolition waste is being recycled.

In the meantime a new implementation plan ‘Environmentally sound use of materials and waste management 2007’ was established. The goal of a recycling level of 75% for 2000 was exceeded (approx. 85%). For this reason, no new goal for recycling was set out in the new plan. Instead, the focus is on the environmentally sound use of materials (e.g. prevention) and on improving the quality of the aggregates. Therefore different projects are planned. Attention is given to selective demolition, organising a practical system for sampling and analysing, a market for residual fractions such as bitumen, plaster, plastics, etc.

The rules and conditions of ‘The Use of Waste Materials as Secondary Raw Materials’ are defined in some detail in Chapter 4 of the VLAREA regulation. Of greatest relevance to the construction industry is appendix 4.2.2., in which the conditions for the use of waste in or as construction material are defined. Considerable scope is identified for C&DW-derived aggregates, provided certain requirements regarding composition, leachability and conditions of use are respected. C&DW crushers and processors require a permit to process waste, and a certified Quality Assurance system. Thus, not only do the products have to fulfil certain environmental conditions, but the processing company or unit is also subject to specific conditions. As well as C&DW-derived aggregates, the VLAREA legislation considers other wastes which can be re-used as secondary raw materials in the construction industry, such as slags, ashes and sludges.

Another key objective is to reduce the quantities of C&DW produced through qualitative and quantitative prevention measures.

Appendix 4.1 of VLAREA contains a list of waste materials that may be used as secondary raw materials provided that they suffice with regard to the conditions determined in appendix 4.2.2 of VLAREA. A waste material loses the status of waste material and becomes a secondary raw material from the time it meets the set conditions.
### Table 68: List of waste materials that may be used as secondary raw material – Part 1 (Belgium)\(^3\)

<table>
<thead>
<tr>
<th>Name of the waste material</th>
<th>Source and description</th>
<th>Conditions relating to composition and/or use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed and/or calibrated and/or sorted or pre-treated slag, ash or other story wastes</td>
<td>originating from the ferrous industry, the non-ferrous industry, the manufacture of non-metallic mineral products</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory</td>
</tr>
<tr>
<td>Crushed and/or calibrated and/or sorted or pre-treated slag or ash</td>
<td>originating from the combustion of waste materials</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory - material approved by the non-profit organisation COPRO (1) or subject to an equivalent quality control (2)</td>
</tr>
<tr>
<td>Unpolluted debris</td>
<td>obtained from selective construction and demolition activities by private persons</td>
<td>subsection II of section II of chapter IV - in quantities of less than 100 tonnes - art. 4.1.2. does not apply</td>
</tr>
<tr>
<td>Unpolluted crushed concrete granulates</td>
<td>obtained from road construction and demolition activities</td>
<td>subsection II of section II of chapter IV - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Unpolluted pieces of debris</td>
<td>originating from a licensed recovery installation for construction and demolition waste</td>
<td>subsection II of section II of chapter IV - only in hydraulic engineering for ga-bions and rubble layers - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Unpolluted rubble granulates</td>
<td>originating from a licensed recovery installation for construction and demolition waste</td>
<td>subsection II of section II of chapter IV - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Unpolluted sand sieved from rubble and sand</td>
<td>obtained from crushed rubble originating from a licensed recovery installation for construction and demolition waste or from a licensed cleaning plant</td>
<td>subsection II of section II of chapter IV - clearly physically separated from the soil - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Non-tarry milled asphalt</td>
<td>obtained when milling off non-tarry pavement or originating from a licensed recovery installation for construction and demolition waste</td>
<td>subsection II of section II of chapter IV - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Tarry milled asphalt</td>
<td>obtained when milling off tarry pavement or originating from a licensed recovery installation for construction and demolition waste</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory - clearly physically separated from the soil - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Tarry asphalt</td>
<td>originating from a licensed recovery installation for construction and demolition waste</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory - clearly physically separated from the soil - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Unpolluted sieved rubble sand from sorting</td>
<td>originating from a licensed recovery installation for construction and demolition waste</td>
<td>subsection II of section II of chapter IV - clearly physically separated from the soil - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Washed sorted and/or crushed concrete and/or brickwork rubble</td>
<td>originating from soil cleaning installations obtained by sieving soils at licensed establishment for soil recycling</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory - material approved by the non-profit organisation COPRO (1) or subject to equivalent quality control (2)</td>
</tr>
<tr>
<td>Fly ash and bottom ash</td>
<td>originating from combustion processes</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory for waste incineration plants and for plants where waste is used as fuel</td>
</tr>
<tr>
<td>Granulated non-tarry building materials</td>
<td>originating from a licensed recovery installation obtained through grinding of bituminous roofing materials</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory</td>
</tr>
<tr>
<td>Sludges resulting from clearing and deepening operations</td>
<td>originating from clearing the beds of surface waters as defined in the order of the Flemish Government of 1 June 1995 concerning general and sectoral provisions relating to environmental protection, insofar as this does not concern navigable or terrestrial beds</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory</td>
</tr>
<tr>
<td>Dredging sludges</td>
<td>originating from maintaining, deepening and/or widening of navigable watercourses of the public hydro graphic network and/or the construction of new waterworks</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory</td>
</tr>
</tbody>
</table>
Table 69: List of waste materials that may be used as secondary raw material – Part 2 (Belgium)\textsuperscript{131}.

<table>
<thead>
<tr>
<th>Waste Material</th>
<th>Description</th>
<th>Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavated soil, excavated soil that has been physically separated and cleaned excavated soil not in the area of application of VLAREBO</td>
<td>originating from excavation work and from licensed installations for the processing of contaminated soil and soil materials</td>
<td>subsection II of section II of chapter IV</td>
</tr>
<tr>
<td>Processed soil and soil materials</td>
<td>originating from licensed installations for the cleaning of sludge from sewer inlet wells and sand traps, or clearing and dredging sludges</td>
<td>subsection II of section II of chapter IV - certificate for use compulsory</td>
</tr>
<tr>
<td>Sludge from natural stone processing</td>
<td>produced during the sawing, grinding, polishing and smoothing of calciferous natural stone</td>
<td>subsection II of section II of chapter IV</td>
</tr>
</tbody>
</table>

(1) ... an independent institution for the control of road products.

(2) ... certification and inspection carried out by an institution having the required accreditation for the material concerned. At least the same control procedures and the same guarantees as with a COPRO inspection must be present. The control procedure includes both the internal quality control (acceptance policy, registration of all deliveries and removals, quality control) and the external control of this by an accredited independent institution. The 'same guarantees' is understood to mean that the operator of the recovery installation must have the necessary licences to ensure compliance with all relevant regulations concerning environmental protection and technical construction quality.

Appendix 4.2.2 A of VLAREA specifies conditions for use in or as a building material (Table 70, Table 71 and Table 72)\textsuperscript{131}.

Table 70: Conditions for use in or as a building material – PAH (Belgium)\textsuperscript{131}.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Total Concentration (A) (mg/kg dry substance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>0.5</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>5</td>
</tr>
<tr>
<td>Styrene</td>
<td>1.5</td>
</tr>
<tr>
<td>Toluene</td>
<td>15</td>
</tr>
<tr>
<td>Xylene</td>
<td>15</td>
</tr>
<tr>
<td>Benzo(a)anthracene</td>
<td>35</td>
</tr>
<tr>
<td>Benzo(a)pyren</td>
<td>8.5</td>
</tr>
<tr>
<td>Benzo(ghi)perylene</td>
<td>35</td>
</tr>
<tr>
<td>Benzo(b)fluoranthene</td>
<td>55</td>
</tr>
<tr>
<td>Benzo(k)fluoranthene</td>
<td>55</td>
</tr>
<tr>
<td>Chrysene</td>
<td>400</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>30</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>40</td>
</tr>
<tr>
<td>Indeno(1,2,3cd)pyrene</td>
<td>35</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>20</td>
</tr>
</tbody>
</table>

(A) ... determination of the concentration of organic pollutants according to the method included in part 3 of the Compendium for Sampling and Analysis.
Table 71: Conditions for use in or as a building material – Metals (Belgium)\(^{2/2}\).

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>TOTAL CONCENTRATION (A) (mg/kg dry substance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic (As)</td>
<td>250</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>10</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>1250</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>375</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>5</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>1250</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>250</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>1250</td>
</tr>
</tbody>
</table>

(A) … the determination of the metal concentration is to be performed according to WFC method 2/II/A.3., included in the Compendium for Sampling and Analysis.

Table 72: Conditions for use in or as a building material – Other organic substances (Belgium)\(^{2/2}\).

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>TOTAL CONCENTRATION (A) (mg/kg dry substance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extractable organohalogen compounds (EOX)</td>
<td>10</td>
</tr>
<tr>
<td>Hexane</td>
<td>1</td>
</tr>
<tr>
<td>Heptanes</td>
<td>25</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>1000</td>
</tr>
<tr>
<td>Octane</td>
<td>90</td>
</tr>
<tr>
<td>Polychlorinated biphenyls (PCB)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

(A) … determination of the concentration of organic pollutants according to the method included in part 3 of the Compendium for Sampling and Analysis.

Appendix 4.2.2.B of VLAREA lists conditions for use as non-shaped building material (Table 73).

Table 73: Conditions for use as non-shaped building material – Metals (Belgium)\(^{2/2}\).

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>LEACHABILITY (A) (in mg/kg dry substance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic (As)</td>
<td>0.8</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>0.03</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>0.5</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.5</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.02</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>1.3</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>0.75</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>2.8</td>
</tr>
</tbody>
</table>

(A) … leachability is determined by means of the column test, WFC method 2/II/A.9.1. The leachability measured with the column test is calculated on the basis of a standard application with the height of the building material at 0.7 m and a specific weight of 1550 kg/m\(^3\). For calculation of the height of use see appendix 4.2.2.C.
Appendix 4.2.2.C of VLAREA specifies immission limit values for soil (Table 74).

Table 74: Immission limit values for soil (Belgium)\textsuperscript{131}.

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>MAXIMUM IMMISSION (mg/m\textsuperscript{2} over 100 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>285</td>
</tr>
<tr>
<td>Cadmium</td>
<td>12</td>
</tr>
<tr>
<td>Chromium</td>
<td>555</td>
</tr>
<tr>
<td>Copper</td>
<td>255</td>
</tr>
<tr>
<td>Mercury</td>
<td>8.2</td>
</tr>
<tr>
<td>Lead</td>
<td>609</td>
</tr>
<tr>
<td>Nickel</td>
<td>136</td>
</tr>
<tr>
<td>Zinc</td>
<td>924</td>
</tr>
</tbody>
</table>

The calculations of the immission values from emission values are carried out on the basis of the column test for non-shaped building materials as well as on the basis of a diffusion test for shaped building materials (for the calculation method see the literature ‘Definition of end-of-waste criteria for construction and demolition waste\textsuperscript{131}’).

In conclusion aggregates can be used as a secondary raw material if a number of conditions are fulfilled:\textsuperscript{131}

- The aggregates have to fulfill the requirements of VLAREA (the Flemish Regulation on Waste Prevention and Management): There are requirements for e.g. heavy metals (maximum total concentrations-guide value) (maximum leachable concentrations on heavy metals (imperative value - based on a marginal increase of soil concentration)) and different organic parameters (imperative value – derived from VLAREBO). If the total concentration is higher than the background value of the soil (Annex 6 of VLAREBO) leaching has to be investigated via a column test. VLAREA stipulates that once a year the wastes have to be sampled and analysed by a permitted lab.

- The amount of not-stony materials is max. 1 \% and the amount of organic materials is max. 0.5\%: these things are visually tested and are part of the COPRO – certification (COPRO = Control Products). It is important to note that the organisation ‘COPRO’ is working on two different levels. On the one hand COPRO is working with requirements for technical issues regarding construction. On the other hand, it also stipulates requirements for environmental issues with clear limit values. It is important to mention the existence of a document stating ‘standard specifications’. All inert aggregates and asphalt aggregates need the COPRO-certification.

- The aggregates have to be free of asbestos. It is almost unfeasible to attain a totally asbestos free mixture and that is why a maximum permitted level is fixed.

- In almost all the cases, breakers are used which have to be permitted.

- Only for the tarry aggregates, a certification for use is compulsory.

- The decisions of the European court have to be followed: waste can only be considered a secondary raw material if the destination is well known or if it is clearly stated that it will be used as a building material.
Brussels Capital Region

The ‘Waste Prevention and Management Ordinance’ of 7 March 1991 determines amongst others that the government must define, every 5 years, a waste management plan. Prevention is identified as a priority objective. The first such plan (1992-1995) included a 70% target (by 1996) for C&DW recycling. This objective was achieved by 1995, since at that time it was estimated that some 75% of C&DW was recycled or recovered.

Therefore, a new objective of 95% re-use or recycling of C&DW by 2002 was proposed in the Waste Management Plan for 1998-2002, which was under public inquiry from 19 January to 18 March 1998. Tools to realise this objective were the incorporation of specific clauses allowing the use of recycled C&DW in public works and the organisation of major awareness-raising campaigns directed at the construction and demolition industry in order to stimulate on-site sorting. With regard to the first of these two tools, a Ministerial Circular of 9 May 1995 had already allowed the re-use of certain C&DW in public road and infrastructure works.\textsuperscript{128}

According to this plan non-domestic and non-dangerous waste, including excavated soil and excluding slurries, amounts in the Brussels Capital Region to 2.3 million tonnes a year (figure based upon the quantity produced in 1995). The plan specifies that 88% of this waste stream should be recycled or valorised in 2002. For bottom ashes from soil and municipal solid waste incineration the regions aims at 100% recycling or valorisation. For construction and demolition waste, i.e. without the soil fraction, the aim is 95% recycling or valorisation. For other non-domestic and non-dangerous waste the objective for 2002 is set at 55% recycling or valorisation.

To reach these objectives, sectoral policies and policies directed at specific types of waste are developed. Moreover, Brussels wants to optimise the use of existing incineration capacities and wants to encourage sorting and recycling by adapting tariffs. Non domestic and dangerous waste is estimated to amount to between 40,000 and 60,000 tonnes per year, of which 11,600 t are MSWI fly ash. The Region aims to manage the complete stream of non-domestic and dangerous waste.

Several Orders with regard to waste prevention and management, important for the construction industry have been published. An Order of 19 September 1991 considers the elimination of PCB, hazardous waste and waste oils. The Order of 14 October 1993 deals with asbestos waste and the Order of 16 March 1995 specifies the mandatory recycling of certain types of construction and demolition waste. The Ministerial Circular of 9 May 1995 with regard to the reuse of rubble in road construction and infrastructure allows the use of recycled materials as filling materials, sub base and base materials, stabilised sand and lean concrete.

The Waste Prevention and Management Ordinance of 7 March 1991 is also relevant for soil quality and remediation. Contaminated soils should be considered waste materials. Non-contaminated soils may be used as filling material on the condition that they fulfil certain requirements.\textsuperscript{126}
The ‘Arrêté du 16 mars 1995 du Gouvernement de la Région de Bruxelles-Capitale relative’ about the obligatory recycling of certain types of non-contaminated C&D wastes (M.B. 06.05.1995) obliges the contractor to assure the recycling of debris defined as the stony and sabulous fraction of the C&D wastes. If the contractor does not recycle himself, he is obliged to render the debris to recycling / sorting companies. If there is no recycling / sorting company within a range of 60 km exemptions are granted. 129

Currently, a third Waste Prevention and Management Plan is in preparation; the publication is foreseen for 2003 or 2004. 126

7.2.1.2 Slags from ferrous metal production

**Walloon Region**

The Decree of 9 May 1985 enables the Walloon Region to exercise its competences with regard to the valorisation of slag heaps. Permits delivered within the context of this Decree do not only cover the exploitation, but also the rehabilitation of the site and the prevention of environmental pollution. The Order of 5 October 1989 defines the classification of slag heaps. Three categories are identified: non-exploitable slag heaps, exploitable slag heaps and slag heaps where more research is necessary. The Decree of 9 May 1985 was modified by the Decree of 6 May 1993. Since then, the power for decisions with regard to exploitation permits for slag heaps has been lying with the level of the Mayor and the College of Aldermen. A possibility for appeals to the higher regional level is foreseen.

**Flemish Region**

For slags (and zinc ashes) the Decree on the decontamination of soils applies (see Chapter 7.2.1.1) 131.

7.2.1.3 Ashes from coal combustion processes

**Flemish Region**

See Chapter 7.2.1.1.

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129 INSTITUT BRUXELLOIS POUR LA GESTION DE L’ENVIRONNEMENT (2000)
7.2.2 Construction and demolition waste

14 million tons of construction and demolition waste were generated in Belgium in 2005. 12 million tons were recovered and 2 million tons were landfilled. Thus the total recovery rate is 86 %.

Walloon Region

![Diagram](Image)

Figure 25: Generation and use of construction and demolition waste in the Walloon Region in 1995 (Belgium).

In 1995, 2,100,000 tons of construction and demolition waste were generated. 400,000 t were reused and 1,150,000 tons were recycled. The amount of 350,000 tons was disposed of, whereas the deposition of 200,000 tons is unknown. An estimated amount of 52 % was derived from demolitions.

In the Walloon Region, the Walloon Waste Office (OWD) is in charge of monitoring the waste streams. No obligation exists for the registration of C&D waste. However, rough figures are available in a recent waste management plan ‘Horizon 2010’. There are no separate data on reuse, landfilling or valorisation for the above materials individually. For all these waste materials together, 2.7% are reused, 91.3% valorised and 6.0% landfilled.

Flemish Region

In the Flemish region there was about 9,000,000 t of construction and demolition waste in 2006. This amount consists of the following types of waste:

- 8,250,000 tons of aggregates and
- 750,000 t of residual waste (consisting of 300,000 tons of wood waste and other waste).

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130 MINISTERE DE L’ENVIRONNEMENT, DES RESSOURCES NATURELLES ET DE L’AGRICULTURE POUR LA RÉGION WALLONNE (2000)

131 DE SCHOENMAKER (2007)
The 8,250,000 tons of aggregates are subdivided as follows:

- concrete aggregates: 3,000,000 t
- mixed aggregates: 2,750,000 t
- brickwork aggregates: 500,000 t
- asphalt aggregates: 400,000 t
- the rest is sieved sand.

Construction and demolition waste contains more than 90% of stony harmless waste. The only harmful wastes that are thus intrinsically present in construction and demolition waste are asbestos and tarry asphalt.

All the 8,250,000 tons of aggregates are recycled and COPRO-tested (1.4 tons/inhabitant). In 2006 this recycling level was achieved by 100 fixed permitted breakers, 30 mobile installations and 70 sorting installations.

After being recycled and COPRO-tested these aggregates can be reused as a secondary raw material. Figure 26 gives an overview of the amounts of aggregates that were recycled (from 1996 until 2006).

In 1998 VLAREA was introduced as a legal framework for the use of aggregates as a secondary raw material. You can clearly see that this was a stimulant for recycling.

After the thorough change of VLAREA in 2004, you can see that this uncertainty was removed.

Figure 26: Amounts of aggregates that were recycled (from 1996 until 2006) (Belgium).
### Brussels Capital Region

*Table 75: Production and use of construction and demolition waste in Brussels Capital Region (data for 2000)*\(^\text{126}\), no exports.

<table>
<thead>
<tr>
<th>Part</th>
<th>Production</th>
<th>Usage</th>
<th>Landfilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction and demolition waste</td>
<td>1.23 million tons</td>
<td>59%</td>
<td>22%</td>
</tr>
</tbody>
</table>

The Brussels Capital Region aimed to reuse and recycle 90% of the demolition and renovation waste.\(^\text{132}\)

#### 7.2.3 Slags from ferrous metal production

### Walloon Region

*Table 76: Production and use of slags from ferrous metal production in the Walloon Region (no imports, no exports).*

<table>
<thead>
<tr>
<th>Slag Type</th>
<th>Million tons</th>
<th>Production</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast furnace slag</td>
<td>0.085</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>Steel slag</td>
<td>0.109</td>
<td>100 %</td>
<td></td>
</tr>
</tbody>
</table>

The data summarised in Table 76 are referring to 1995.

### Flemish Region

The production and use of slags from ferrous metal production is summarised in Table 77.

\(^{132}\) INSTITUT BRUXELLOIS POUR LA GESTION DE L'ENVIRONNEMENT (2007)
Table 77: Production and Use of slags from ferrous metal production in the Flemish Region (data for 2006) (Belgium).

<table>
<thead>
<tr>
<th>Type of slag</th>
<th>Linz-Donawitz slag</th>
<th>Blast furnace slag</th>
<th>Electric-arc furnace + Converter slag from production of stainless steel</th>
<th>LD gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume generated</td>
<td>about 400 000 t/year (later 200kt)</td>
<td>1.2 Million tons</td>
<td>about 250,000 tons/year</td>
<td>production starts in 2008 (foreseen 200kt)</td>
</tr>
<tr>
<td>Quality data</td>
<td>CE marks 13383, 13242</td>
<td>due to specifications in the cement industry like “hydraulic” indices</td>
<td>yes</td>
<td>due to specs for concretes/asphalts like Los Angeles, PSV, CE marks 12620, 13383, 13043, Benor</td>
</tr>
<tr>
<td>Environmental data</td>
<td>VLAREA-certificate (secondary raw material) certificates Bouwstoffenbesluit NL</td>
<td>Product leaching results</td>
<td>VLAREA-certificate (secondary raw material)</td>
<td>Product certificates Bouwstoffenbesluit NL</td>
</tr>
<tr>
<td>Use</td>
<td>building granules, soil improvement, fertilizer, waterways</td>
<td>cement production</td>
<td>use in concrete and asphalt products</td>
<td>concrete, asphalt, waterways</td>
</tr>
</tbody>
</table>

Brussels Capital Region

In the past years there were no slags from ferrous metal production generated in the Brussels Capital Region.126

7.2.4 Ashes from coal combustion processes

Walloon Region

Table 78: Production and Use of Ashes from coal combustion processes in the Walloon Region (no imports, no exports) (data for 2000)126.

<table>
<thead>
<tr>
<th>Million tons</th>
<th>Production</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal bottom ash</td>
<td>0.012</td>
<td>100%</td>
</tr>
<tr>
<td>Coal fly ash</td>
<td>0.080</td>
<td>100%</td>
</tr>
</tbody>
</table>

The data summarised in Table 80 are referring to the year 2000.
Flemish Region

Table 79: Production and Use of Ashes from coal combustion processes in the Flemish Region (no imports, no exports) (data for 2000).  

<table>
<thead>
<tr>
<th>Million tons</th>
<th>Production</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal bottom ash</td>
<td>0.071</td>
<td>0.071</td>
</tr>
<tr>
<td>Coal fly ash</td>
<td>0.462</td>
<td>0.400</td>
</tr>
</tbody>
</table>

The production and use of slags from ferrous metal production is summarised in Table 79.

Brussels Capital Region

In the past years there were no ashes from coal combustion processes generated in the Brussels Capital Region.
7.3 Czech Republic

7.3.1 Existing standards and regulation

The urgent need for adopting legal regulations concerning waste management along with the transformation towards a market economy following the Velvet Revolution in 1989 was dealt with in Act 238/1991 Coll., on waste, laying down essential rules for waste management\textsuperscript{133}. Furthermore, the law placed waste producers, District Offices and the Czech Republic under the obligation to process waste management programmes. It ensued that there was a lack of necessary data concerning waste production and management for the processing of such concepts. For this reason the Ministry of the Environment established an Information System of Waste Management in 1994\textsuperscript{134}.

Further Acts on Waste\textsuperscript{135}, amending Act 185/2001 Coll.\textsuperscript{136} on waste and amendments to other pertinent laws fully transpose the EC regulations into the Czech laws within the entire scope of waste management. Along with the amendments to the waste act, changes were made to the implementing regulations, including the Catalogue of Waste (the European Waste List), according to which individual sorts of waste are classified and according to which the waste production and management is registered. Decree 381/2001 Coll. of the Ministry of the Environment, promulgating the Catalogue of Waste, the List of Hazardous Waste and establishing further lists of wastes\textsuperscript{137}, is now in full compliance with the European List of Waste. The existing Catalogue of Waste distinguishes only between two categories of wastes, i.e. hazardous and other wastes.

Fees on landfilling were introduced in 1991. The fee consists of two components, the basic part and the risk part. The tariff for the basic component of the fee applies to all categories of waste (and is differentiated into two levels, one for municipal and other waste and the other for hazardous waste). The risk component of the fee is paid only for hazardous waste. The operator of the landfill transfers collected fees to their recipients, i.e. the municipality where the landfill is located (basic component) and the Czech Republic State Environmental Fund (SEF-CR risk component)\textsuperscript{138}.

Properties (leachability classes; limit concentrations for harmful substances; etc.) of the waste to be accepted in certain types of landfills (for hazardous, non-hazardous and inert waste) are given in 294/2005 Coll.\textsuperscript{139}.

\textsuperscript{133} CZECH REPUBLIC PARLIAMENT (1991)
\textsuperscript{134} INFORMATION SYSTEM OF WASTE MANAGEMENT (ISOH): http://seho.vuv.cz
\textsuperscript{136} CZECH REPUBLIC PARLIAMENT (2001)
\textsuperscript{137} MINISTRY OF ENVIRONMENT OF THE CZECH REPUBLIC (2001A)
\textsuperscript{138} MINISTRY OF ENVIRONMENT OF THE CZECH REPUBLIC (2004)
\textsuperscript{139} MINISTRY OF ENVIRONMENT OF THE CZECH REPUBLIC (2005)
Decree No. 376/2001 Coll.\textsuperscript{140} regulates the evaluation of hazardous properties of waste. Criteria for the evaluation of hazardous properties of waste are given in Annexes 1 and 2. It is stipulated that the waste shall be evaluated as hazardous if the value of at least one criterion for the considered hazardous properties is exceeded.

A target of increasing the recovery of wastes giving preference to the recycling of 55% of all waste produced by the year 2012, and to increase the material recovery of municipal waste to 50% by 2010 compared with 2000 was established in the national Waste Management Plan of the Czech Republic 2003 – 2012\textsuperscript{141}. Furthermore, the elaboration of implementation plans for – amongst others – C&D waste for industrial waste and for wastes from energy production was promulgated.

The production of waste in the country has oscillated between 36 and 39 million tons in recent years. In 1995, 66.3 million tons of waste were produced overall; in 2002 37.9 and in 2004 38.8 million tons; in 2005, 29.8 million tons and in 2006, 28.1 million tons. The largest share of this amount is accounted for construction and demolition wastes, industrial and energy waste, as well as municipal waste with its production of about 4 million tons per year\textsuperscript{142}.

In 2005, a total of 17.9 million tons of waste (both non-hazardous and hazardous) were recycled and used as a secondary material. Waste disposal facilities have sufficient capacity, mainly facilities for waste landfilling, which remains to be the most common disposal method, mainly for municipal waste.

The amount of waste incinerated and used for energy purposes remains to be small. In 2005, a total amount of 748,500 tons of waste were energetically used. In the Czech Republic, there are 3 incinerators of municipal waste, 24 incineration plants for hazardous waste and 3 cement kilns.

The total amount of separately collected, usable municipal waste and hazardous municipal waste types has been growing.

### 7.3.1.1 Construction and demolition waste

The national Waste Management Plan of the Czech Republic\textsuperscript{141} formulates the following target for C&D waste: Reduction by 50% of the weight of produced C&D waste by December 31, 2005 and 75% of the weight of produced C&D waste by December 31, 2012 compared with the year 2000. The ratio of C&D waste to the overall production of wastes, the fraction of recovered C&D waste (R1, R3, R4, R5, R11, N1), the fraction of construction and demolition wastes disposed of by landfilling (D1, D5, D12) as well as the fraction of construction and demolition wastes disposed of by other deposition (D3, D4) have been defined as specific indicators for evaluating Czech Waste Management.

A specific guideline for the management of Construction and Demolition Wastes (available in Czech only) has been established in the Czech Republic and was published in February 2008\textsuperscript{143}.

\textsuperscript{140} MINISTRY OF ENVIRONMENT OF THE CZECH REPUBLIC (2001B)

\textsuperscript{141} MINISTRY OF ENVIRONMENT OF THE CZECH REPUBLIC (2003)

\textsuperscript{142} CZECH ENVIRONMENTAL INFORMATION AGENCY (CENIA): \url{http://www.cenia.cz}

\textsuperscript{143} MINISTRY OF ENVIRONMENT OF THE CZECH REPUBLIC: \url{http://www.env.cz}
Under special conditions which are directly bound to Act on Waste No. 185/2001 Coll. and also to Building Act No.183/2006 Coll., waste producers are entitled to give their waste to the appropriate and certified facility for recycling (recovery). Table 80 shows waste types which are intended for separation and further reuse.

Table 80: Waste types intended for separation and further reuse.

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 01 01</td>
<td>Concrete</td>
</tr>
<tr>
<td>17 01 02</td>
<td>Bricks</td>
</tr>
<tr>
<td>17 01 03</td>
<td>Tiles and ceramics</td>
</tr>
<tr>
<td>17 01 07</td>
<td>Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06</td>
</tr>
<tr>
<td>17 02 02</td>
<td>Glass</td>
</tr>
<tr>
<td>17 03 02</td>
<td>Bituminous mixtures other than those mentioned in 17 03 01</td>
</tr>
<tr>
<td>17 05 04</td>
<td>Soil and stones other than those mentioned in 17 05 03</td>
</tr>
<tr>
<td>17 05 08</td>
<td>Track ballast other than those mentioned in 17 05 07</td>
</tr>
<tr>
<td>17 08 02</td>
<td>Gypsum-based construction materials other than those mentioned in 17 08 01</td>
</tr>
<tr>
<td>17 09 04</td>
<td>Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03</td>
</tr>
</tbody>
</table>

Furthermore, under special conditions and after separation of hazardous components/substances it is possible to recycle the wastes listed in Table 81.

Table 81: Waste types with the possibility for recycling under special conditions or after separation.

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 01 06*</td>
<td>Mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances</td>
</tr>
<tr>
<td>17 02 04*</td>
<td>Glass, plastic and wood containing or contaminated with dangerous substances</td>
</tr>
<tr>
<td>17 03 01*</td>
<td>Bituminous mixtures containing coal tar</td>
</tr>
<tr>
<td>17 05 03*</td>
<td>Soil and stones containing dangerous substances</td>
</tr>
<tr>
<td>17 05 05*</td>
<td>Dredging spoil containing dangerous substances</td>
</tr>
<tr>
<td>17 05 07*</td>
<td>Track ballast containing dangerous substances</td>
</tr>
<tr>
<td>17 06 03*</td>
<td>Other insulation materials consisting of or containing dangerous substances</td>
</tr>
<tr>
<td>17 08 01*</td>
<td>Gypsum-based construction materials contaminated with dangerous substances</td>
</tr>
<tr>
<td>17 09 01*</td>
<td>Construction and demolition wastes containing mercury</td>
</tr>
<tr>
<td>17 09 02*</td>
<td>Construction and demolition wastes containing PCB (for example PCB-containing sealants, PCB-containing resin-based floorings, PCB-containing sealed glazing units, PCB-containing capacitors)</td>
</tr>
<tr>
<td>17 09 03*</td>
<td>Other construction and demolition wastes (including mixed wastes) containing dangerous substances</td>
</tr>
</tbody>
</table>

Wastes that must not be accepted by a facility for separation and subsequent reuse are listed in Table 82.
Table 82: Wastes that must not be accepted by a facility for separation and subsequent re-use.

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 06 01*</td>
<td>insulation materials containing asbestos</td>
</tr>
<tr>
<td>17 06 05*</td>
<td>construction materials containing asbestos</td>
</tr>
</tbody>
</table>

However, the guideline does not include limit values for contents of hazardous substances; neither for C&D waste used as feedstock material for the production of recycled aggregates nor for the recycled aggregates themselves. General limits for concentrations of hazardous substances in wastes are set in Decree No. 376/2001 Coll., and Decree No. 294/2005 Coll.

7.3.1.2 Slags from ferrous metal production
Except for general rules in Act 185/2001 Coll., on waste and its Decrees, no specific national regulation on slags from the ferrous metal production regarding their management has been established yet. The following standards regarding slags from the ferrous metal production have been published by the Czech Standards Institute in the area of waste management:

- CSN 72 2009, Granulate blast-furnace slag, Testing;
- CSN 72 2030-1, Chemical analysis of blast-furnace slag;
- CSN 72 2041-1, Chemical analysis of steel-making slag.

7.3.1.3 Ashes from coal combustion processes
Except for general rules in Act 185/2001 Coll., on waste and its Decrees, no specific national regulation on ashes from coal combustion processes regarding their usage has been established yet. The following standards regarding ashes have been published by the Czech Standards Institute in the area of waste management:

- CSN 07 7002, Disposal of solid residues from combustion of coal;

7.3.2 Construction and demolition waste
Information on the arisings of C&D waste within the sectors “construction and demolition” and “mining and quarrying” was extracted from the Statistical Environmental Yearbook of the Czech Republic, 2006\(^ {144} \). Table 83 shows the overall generation of C&D waste as well as the amount which was classified as hazardous waste thereof for the years 2002 to 2005.

\(^ {144} \text{MINISTRY OF THE ENVIRONMENT (2007A)} \)
Table 83: Generation of C&D waste according to Branch Classification of Economic Activities in the Czech Republic (in thousand tonnes)\(^{144}\).

<table>
<thead>
<tr>
<th>Branch</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total</td>
<td>hazard-</td>
<td>total</td>
<td>hazard-</td>
</tr>
<tr>
<td>construction &amp; demolition</td>
<td>5,924</td>
<td>269</td>
<td>6,632</td>
<td>88</td>
</tr>
<tr>
<td>mining &amp; quarrying</td>
<td>597</td>
<td>40</td>
<td>689</td>
<td>23</td>
</tr>
</tbody>
</table>

Further data - derived from the Czech Information System of Waste Management\(^{134}\) - was provided by the Czech Ministry for Environmental Protection. The total arisings of C&D waste in 2006 were 8,446,846 tonnes. 271 tonnes thereof can be assigned to hazardous coal tar and tarred products. Figure 1 illustrates the composition of C&D waste generated in the Czech Republic in 2006 with concrete, bricks and mixed mineral C&D waste accounting for approximately one third of the total arising each.

Figure 27: Composition of C&D waste generated in 2006 in the Czech Republic (in tonnes)\(^{134}\).

Part II of the national Waste Management Plan of the Czech Republic\(^{141}\), which evaluates the state of waste management, says that in 2001 construction materials were most frequently recycled with the use of mobile units. This category also includes facilities for recycling mineral components of construction waste whose current capacity was not fully utilized then. Approximately 30 % of C&D wastes were processed and recovered and approximately 65 % were used in the reclaiming of excavated spaces or in terrain modifications.

Table 84 gives an overview on the treatment options and uses applied to C&D waste in 2006\(^{134}\). Amounts are presented for the non hazardous waste types “concrete” (EWC-Code: 170101), “bricks” (EWC-Code: 170102), “tiles and ceramics” (EWC-Code: 170103), “mixtures of concrete, bricks, tiles and ceramics…” (EWC-Code: 170107) and for hazardous “coal tar and tarred products” (EWC-Code: 170303*) separately.
However, it seems difficult to correlate the information available with definite treatment options.

Table 84: Treatment options and uses applied to C&D waste in 2006

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste treatment option</th>
<th>170101</th>
<th>170102</th>
<th>170103</th>
<th>170107</th>
<th>170303*</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Deposition in or under the terrain level (landfilling)</td>
<td>40,519</td>
<td>66,914</td>
<td>4,442</td>
<td>74,858</td>
<td>36</td>
</tr>
<tr>
<td>D10</td>
<td>Incineration on land</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>D12</td>
<td>Final or permanent deposition (e.g. deposition of containers in)</td>
<td>32</td>
<td>158</td>
<td>38</td>
<td>579</td>
<td>-</td>
</tr>
<tr>
<td>D13</td>
<td>Modification of waste composition or mixture before their disposal</td>
<td>8,476</td>
<td>22,146</td>
<td>639</td>
<td>4,044</td>
<td>-</td>
</tr>
<tr>
<td>D14</td>
<td>Modification of other waste properties (except the modification in-...)</td>
<td>1,609</td>
<td>1</td>
<td>11</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>D8</td>
<td>Biological treatment that is not specified elsewhere in this Decree,</td>
<td>1,236</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>D9</td>
<td>Physical and chemical treatment that is not specified elsewhere in</td>
<td>210</td>
<td>66,914</td>
<td>1</td>
<td>-</td>
<td>37</td>
</tr>
<tr>
<td>N1</td>
<td>Using wastes for re-cultivation, terrain works, etc.</td>
<td>232,525</td>
<td>709,498</td>
<td>5,519</td>
<td>170,228</td>
<td>-</td>
</tr>
<tr>
<td>N10</td>
<td>Sale of waste as a raw material</td>
<td>65,454</td>
<td>3,293</td>
<td>-</td>
<td>146,532</td>
<td>-</td>
</tr>
<tr>
<td>N11</td>
<td>Use of wastes for land reclaiming</td>
<td>20,777</td>
<td>26,171</td>
<td>246</td>
<td>35,557</td>
<td>-</td>
</tr>
<tr>
<td>N12</td>
<td>Deposition of wastes as technical</td>
<td>95,142</td>
<td>92,308</td>
<td>3,269</td>
<td>116,383</td>
<td>-</td>
</tr>
<tr>
<td>N14</td>
<td>Biological decontamination</td>
<td>24</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13</td>
</tr>
<tr>
<td>N3</td>
<td>Handing over to another licensed person (except the carrier) or an-</td>
<td>1,283,405</td>
<td>1,203,779</td>
<td>45,054</td>
<td>1,247,889</td>
<td>107</td>
</tr>
<tr>
<td>N5</td>
<td>Remaining in store on December 31, in the year under review</td>
<td>239,630</td>
<td>116,817</td>
<td>1,518</td>
<td>252,517</td>
<td>56</td>
</tr>
<tr>
<td>N8</td>
<td>Provision of waste parts for reuse</td>
<td>24</td>
<td>660</td>
<td>-</td>
<td>1,174</td>
<td>-</td>
</tr>
<tr>
<td>R1</td>
<td>Recovery waste as fuel or in another way to generate energy</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R10</td>
<td>Application on land to benefit agriculture or improve environmental</td>
<td>13,222</td>
<td>4,169</td>
<td>-</td>
<td>38,992</td>
<td>-</td>
</tr>
<tr>
<td>R11</td>
<td>Recovery of wastes produced during application of one of the processes R1</td>
<td>6,848</td>
<td>1,301</td>
<td>66</td>
<td>2,624</td>
<td>-</td>
</tr>
<tr>
<td>R12</td>
<td>Waste pre-treatment for application of one of the processes R1</td>
<td>17,120</td>
<td>28,499</td>
<td>7</td>
<td>93,390</td>
<td>6</td>
</tr>
<tr>
<td>R13</td>
<td>Storage of wastes pending any</td>
<td>1,608</td>
<td>688</td>
<td>26</td>
<td>1,376</td>
<td>-</td>
</tr>
<tr>
<td>R3</td>
<td>Acquiring / regeneration of organic substances not used as solvents</td>
<td>3,103</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R4</td>
<td>Recycling/recovery of metals and metal compounds</td>
<td>793,834</td>
<td>143</td>
<td>257</td>
<td>4,360</td>
<td>-</td>
</tr>
<tr>
<td>R5</td>
<td>Recycling/recovery of other inorganic materials</td>
<td>7</td>
<td>585,839</td>
<td>4,369</td>
<td>501,265</td>
<td>10</td>
</tr>
<tr>
<td>R6</td>
<td>Regeneration of acids and bases</td>
<td>-</td>
<td>2,134</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2,824,804</td>
<td>2,864,523</td>
<td>65,464</td>
<td>2,691,784</td>
<td>271</td>
</tr>
</tbody>
</table>

### 7.3.3 Slags from ferrous metal production

Data on the arising of wastes from the processing of slag (EWC-Code: 100201) and unprocessed slag (EWC-Code: 100202) extracted from the Czech Information System of Waste Management was provided by the Czech Ministry for Environmental Protection. The total generation of wastes from the processing of slag in 2006 was 664,352 tonnes. The total generation of unprocessed slag was 1,509,523 tonnes.

Table 85 shows treatment options for wastes from the processing of slag and of unprocessed slag as obtained by the Czech Information System of Waste Management.
Table 85: Treatment options and uses applied to slag from the ferrous metal production in 2006.

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste treatment option</th>
<th>100201</th>
<th>100202</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Deposition in or under the terrain level (landfilling)</td>
<td>77</td>
<td>5,674</td>
</tr>
<tr>
<td>N1</td>
<td>Using wastes for re-cultivation, terrain works, etc.</td>
<td>478</td>
<td>458,179</td>
</tr>
<tr>
<td>N10</td>
<td>Sale of waste as a raw material</td>
<td>1</td>
<td>19,169</td>
</tr>
<tr>
<td>N12</td>
<td>Deposition of wastes as technical material for securing landfills</td>
<td>-</td>
<td>1,315</td>
</tr>
<tr>
<td>N3</td>
<td>Handing over to another licensed person (except the carrier) or another workshop</td>
<td>654,031</td>
<td>286,196</td>
</tr>
<tr>
<td>N5</td>
<td>Remaining in store on December 31, in the year under review</td>
<td>9,765</td>
<td>17,940</td>
</tr>
<tr>
<td>R4</td>
<td>Recycling/recovery of metals and metal compounds</td>
<td>-</td>
<td>706,511</td>
</tr>
<tr>
<td>R5</td>
<td>Recycling/recovery of other inorganic materials</td>
<td>-</td>
<td>14,540</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>664,352</td>
<td>1,509,523</td>
</tr>
</tbody>
</table>

7.3.4 Ashes from coal combustion processes

Data on the arising of bottom ash, slag and boiler dust (EWC-Code: 100101) and coal fly ash (EWC-Code: 100102) extracted from the Czech Information System of Waste Management was provided by the Czech Ministry for Environmental Protection. The total generation of bottom ash, slag and boiler dust in 2006 was 3,025,001 tonnes. The total generation of coal fly ash was reported with 2,130,045 tonnes.

Table 86 shows treatment options for ashes from coal combustion processes as obtained by the Czech Information System of Waste Management.
Table 86: Treatment options and uses applied to ashes from coal combustion processes in 2006.

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste treatment option</th>
<th>100101</th>
<th>100102</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Deposition in or under the terrain level (landfilling)</td>
<td>14,422</td>
<td>78,997</td>
</tr>
<tr>
<td>D10</td>
<td>Incineration on land</td>
<td>1,190</td>
<td>1,828</td>
</tr>
<tr>
<td>D12</td>
<td>Final or permanent deposition (e.g. deposition of containers in mines)</td>
<td>404</td>
<td>-</td>
</tr>
<tr>
<td>D13</td>
<td>Modification of waste composition or mixture before their disposal using one of the processes marked D1 through D12</td>
<td>-</td>
<td>98</td>
</tr>
<tr>
<td>D2</td>
<td>Treatment using soil processes (e.g. biodegradation of liquid wastes or sludge in soil etc.)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>D3</td>
<td>Deep grouting (e.g. grouting of liquid waste into bore holes, salt chambers, or spaces of natural origin etc.)</td>
<td>136</td>
<td>13</td>
</tr>
<tr>
<td>D4</td>
<td>Deposition in surface lagoons (e.g. discharge of liquid waste or sludge into hollows, water impoundment, lagoons, etc.)</td>
<td>89,151</td>
<td>48,284</td>
</tr>
<tr>
<td>D9</td>
<td>Physical and chemical treatment that is not specified elsewhere in this Decree, the final products of which are compounds or mixtures that are disposed of using one of the processes marked D1 through D12 (e.g. evaporation, drying, calcination)</td>
<td>47,137</td>
<td>178,398</td>
</tr>
<tr>
<td>N1</td>
<td>Using wastes for re-cultivation, terrain works, etc.</td>
<td>481,640</td>
<td>355,011</td>
</tr>
<tr>
<td>N10</td>
<td>Sale of waste as a raw material</td>
<td>91,652</td>
<td>110,439</td>
</tr>
<tr>
<td>N11</td>
<td>Use of wastes for land reclaiming</td>
<td>12,023</td>
<td>24,912</td>
</tr>
<tr>
<td>N12</td>
<td>Deposition of wastes as technical material for securing landfills</td>
<td>18,714</td>
<td>490</td>
</tr>
<tr>
<td>N13</td>
<td>Composting</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>N16</td>
<td></td>
<td>-</td>
<td>1,328</td>
</tr>
<tr>
<td>N3</td>
<td>Handing over to another licensed person (except the carrier) or another workshop</td>
<td>1,487,112</td>
<td>1,137,802</td>
</tr>
<tr>
<td>N5</td>
<td>Remaining in store on December 31, in the year under review</td>
<td>679,671</td>
<td>6,312</td>
</tr>
<tr>
<td>N7</td>
<td>Export of waste</td>
<td>-</td>
<td>1,008</td>
</tr>
<tr>
<td>R1</td>
<td>Recovery waste as fuel or in another way to generate energy</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>R10</td>
<td>Application on land to benefit agriculture or improve environmental conditions</td>
<td>297</td>
<td>9</td>
</tr>
<tr>
<td>R11</td>
<td>Recovery of wastes produced during application of one of the processes R1 through R10</td>
<td>88,144</td>
<td>156,144</td>
</tr>
<tr>
<td>R12</td>
<td>Waste pre-treatment for application of one of the processes R1 through R11</td>
<td>5,597</td>
<td>15,985</td>
</tr>
<tr>
<td>R3</td>
<td>Acquiring / regeneration of organic substances not used as solvents (including composting and other biological processes)</td>
<td>-</td>
<td>360</td>
</tr>
<tr>
<td>R5</td>
<td>Recycling/recovery of other inorganic materials</td>
<td>7,707</td>
<td>12,625</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3,025,001</td>
<td>2,130,045</td>
</tr>
</tbody>
</table>
7.4 Denmark

Residues from coal-fired power plants and construction and demolition waste are recycled to a very large extent: in 2003, 97 per cent and 93 per cent respectively. It is recognised that these two fractions play a very significant role in the compliance with overall waste treatment targets in the Danish government's Waste Strategy 2005-2008.

7.4.1 Existing standards and regulation

The Danish waste model is based on a combination of traditional administrative instruments (Acts, Statutory Orders, and Circulars), and various other instruments such as taxes and charges, subsidy schemes and agreements.

Denmark has a general state tax on waste, introduced in 1987. The waste tax is differentiated so that it is most expensive to landfill waste, cheaper to incinerate it and tax free to recycle it. Municipal councils may charge fees to finance their waste management.

7.4.1.1 Construction and demolition waste

In the regulation of construction and demolition waste, the waste tax has played a significant role, as waste for recycling is not subject to the tax.

In spring 1994, the Minister for Environment and Energy, the National Association of Local Authorities in Denmark, the City of Copenhagen, and the Municipality of Frederiksberg entered into an Agreement on waste suitable for incineration, construction and demolition waste, organic waste, and landfilling. In connection with this agreement, a Circular (No. 94 of 21st June 1995) was issued on municipal regulations on the separation of construction and demolition waste for recycling. The Minister for Environment and Energy also entered into an Agreement with the Danish Demolition Association (Environmental Control Agreement of Danish Demolition Industries) on the selective demolition of building materials. With this agreement, separation at the source was ensured.

The Circular lays down the requirement that in demolition works with more than 1 tonne of construction and demolition waste, waste shall be separated at the source into clean fractions, so that for example bricks and concrete are not mixed.

In pursuance of this Circular, local authorities issued regulations with requirements for separation. These regulations took effect at the latest on 1st January 1997.

---

146 DANISH ENVIRONMENTAL PROTECTION AGENCY (http://glwww.mst.dk)
The high recycling rate for construction and demolition waste is due partly to the fact that recycled waste, unlike landfilled or incinerated waste, is exempt from taxation, and partly due to a departmental circular on municipal regulation concerning the separation of construction and demolition waste intended for recycling. In addition, the Danish Ministry of Environment and Energy (now Ministry of the Environment) and the Danish Contractors’ Association entered into an agreement on the selective demolition of buildings so that waste is sorted at an early stage\(^{148}\).

### 7.4.1.2 Slags from ferrous metal production

No results until now.

### 7.4.1.3 Ashes from coal combustion processes

The Statutory Order No. 655 of 27\(^{th}\) of June 2000 regulates the recycling of residual products and soil in building and construction work. The following residual products from coal-fired power stations are covered by the Statutory Order:

<table>
<thead>
<tr>
<th>Bottom ash from coal-fired power stations:</th>
<th>Residual products from burning of coal collected from the incinerating chamber at installations based solely on burning coal.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash from coal-fired power stations:</td>
<td>Residual products (particulates) from burning coal retained from the flue gas at installations based solely on burning coal. The fly ash should not contain desulphurisation products.</td>
</tr>
</tbody>
</table>

As defined by the Statutory Order building and construction work includes construction of roads, paths, squares, sound-absorbing walls, ramps, dykes, dams, railway embankments, pipe/cable trenches, landscaping, construction in territorial waters, and refilling floors and foundations. Recycling is defined as the use of residual products and soil for filling in building and construction work as a substitute for primary raw materials and uncontaminated soil. The Statutory Order does not cover residual products and soils which are classified as hazardous waste under the Statutory Order (No. 619 of 27\(^{th}\) of June 2000) on Waste from the Ministry of Environment and Energy\(^{147}\).

The residual products and soils are categorized in three different quality categories. A substance is categorised by firstly determining whether it complies with the requirements for category 1 for solid content and concentration in eluate. If the substance cannot be put in category 1, category 2 is examined and then category 3. Table 88 shows the limit values for solid content and concentration in eluate for the three categories.

\(^{147}\) THE DANISH MINISTRY OF THE ENVIRONMENT AND ENERGY (2000)
Table 88: Limit values for the three quality categories on residual products (Denmark)\textsuperscript{147}.

<table>
<thead>
<tr>
<th></th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solid content mg / kg dry matter TS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>0-20</td>
<td>&gt; 20</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>Lead</td>
<td>0-40</td>
<td>&gt; 40</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0-0.5</td>
<td>&gt; 0.5</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>Chromium, total</td>
<td>0-500</td>
<td>&gt; 500</td>
<td>&gt; 500</td>
</tr>
<tr>
<td>Chromium (VI)</td>
<td>0-20</td>
<td>&gt; 20</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>Copper</td>
<td>0-500</td>
<td>&gt; 500</td>
<td>&gt; 500</td>
</tr>
<tr>
<td>Mercury</td>
<td>0-1</td>
<td>&gt; 1</td>
<td>&gt; 1</td>
</tr>
<tr>
<td>Nickel</td>
<td>0-30</td>
<td>&gt; 30</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>Zinc</td>
<td>0-500</td>
<td>&gt; 500</td>
<td>&gt; 500</td>
</tr>
</tbody>
</table>

| **Concentration in eluate µg/l** |            |            |            |
| Chlorides*             | 0-150,000  | 0-150,000  | 150,000-3,000,000 |
| Sulphates              | 0-250,000  | 0-250,000  | 250,000-4,000,000 |
| Sodium                 | 0-100,000  | 0-100,000  | 100,000-1,500,000 |
| Arsenic                | 0-8        | 0-8        | 8-50       |
| Barium                 | 0-300      | 0-300      | 300-4,000  |
| Lead                   | 0-10       | 0-10       | 10-100     |
| Cadmium                | 0-2        | 0-2        | 2-40       |
| Chromium, total        | 0-10       | 0-10       | 10-500     |
| Copper                 | 0-45       | 0-45       | 45-2,000   |
| Mercury                | 0-0.1      | 0-0.1      | 0.1-1      |
| Manganese              | 0-150      | 0-150      | 150-1,000  |
| Nickel                 | 0-10       | 0-10       | 10-70      |
| Zinc                   | 0-100      | 0-100      | 100-1,500  |

* The result should be corrected for CaCl\textsubscript{2} added in connection with the leaching test for soil. Results of the chemical analysis shall refer to dry weight for bottom ash from waste incineration, after separation of metal items.

Residual products and soil in category 1 may be recycled without a permit in building and construction work covered by this Statutory Order, unless provisions in the Environmental Protection Act or other legislation apply. Residual products and soil in category 2 and category 3 may be recycled without a permit in building and construction work carried out under specific conditions defined in the Statutory Order (e.g. maximum total height for fitting during road construction)\textsuperscript{147}. 


7.4.2 Construction and demolition waste

Residues from construction and demolition waste are recycled to a very large extent: in 2003, 93 per cent. It is recognised that this fraction play a very significant role in the compliance with overall waste treatment targets in the Danish government’s Waste Strategy 2005-2008.

Table 89: Generation of construction and demolition waste (Denmark).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Building &amp; Construction</td>
<td>3,223,000</td>
<td>3,391,000</td>
<td>4,044,000</td>
<td>3,785,000</td>
<td>- 6</td>
<td>+ 56,000</td>
</tr>
</tbody>
</table>

The generation of waste in the building and construction sector decreased from 2002 to 2003. Volumes of building and demolition waste amounted to 3,785,000 tonnes in 2003, which is 259,000 tonnes, or 6 per cent, less than in 2002. The fall is primarily due to reductions in the fractions: not suitable for incineration; concrete; tiles; soil and stone; and other recyclable waste. These fractions were reduced by 24 per cent, 0.1 per cent, 13 per cent, 36 per cent, and 6 per cent respectively. Conversely, waste from the following fractions increased: other construction and demolition waste; asphalt; and other waste, which increased by 30 per cent, 28 per cent, and 19 per cent respectively. In 2003, 476,278 tonnes less soil and stone were reported. By far the major part, or 93 per cent, of waste generated by the building and construction sector is recycled.

As Figure 6 shows, the recycling rate for construction and demolition waste increased by 9 percentage points in the period 1994 to 2003. At the same time the landfilling rate dropped by 11 percentage points.

Storage means that the waste in question has been assigned to temporary storage by local authorities (the local council). Denmark has excess incineration capacity, but storage can be due to e.g. repairs or shut down of operations at installations.

Figure 29 shows construction and demolition waste analysed between mixed and separately collected fractions in 2003. The major part of separated building waste consists of concrete, asphalt, soil and stone.
Figure 29: Waste from building and construction 2003 analysed between mixed and separated fractions (Denmark)\

A large part of the waste from the building and construction sector is reprocessed at mobile crushing plants which are used for different assignments at different locations throughout Denmark.

7.4.3 Slags from ferrous metal production

No results until now.

7.4.4 Ashes from coal combustion processes

Residues from coal-fired power plants are recycled to a very large extent: in 2003, 97 per cent. It is recognised that this fraction play a very significant role in the compliance with overall waste treatment targets in the Danish government’s Waste Strategy 2005-2008.

Table 90: Generation of ashes and slags (Denmark).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Slag, fly ash, etc. (coal)</td>
<td>1,176,000</td>
<td>1,211,000</td>
<td>1,228,000</td>
<td>1,473,000</td>
<td>+ 20</td>
<td>- 25,000</td>
</tr>
</tbody>
</table>
Waste generation at coal-fired power plants increased by 20 per cent, from 1,228,000 tonnes in 2002 to 1,473,000 tonnes in 2003. This is first and foremost due to the fact that energy generation was larger in 2003 than in 2002. The increase is due e.g. to the fact that in 2003 Denmark had net exports of electricity which constituted more than three times the total net exports in 2002. During the period 1996 to 2000, waste arisings from coal-fired power plants fell. This can be attributed e.g. to the fact that there has been a conversion of energy generation from coal to renewable energy resources. Denmark had net imports of electricity for the first time in this period in 2000.\(^{148}\)

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>Target 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling</td>
<td>1,176</td>
<td>1,202</td>
<td>1,190</td>
<td>1,413</td>
<td>1,325</td>
</tr>
<tr>
<td>Landfilling</td>
<td>0</td>
<td>10</td>
<td>38</td>
<td>60</td>
<td>147</td>
</tr>
</tbody>
</table>

Note that the target for 2008 has been set to correspond to arisings in 2003.

Figure 30: Treatment of residues from coal-fired power plants (Denmark)\(^{148}\).

Amounts of residues have decreased steadily since 1996, but show an increase from 2002 to 2003 of 20 per cent. The decrease is mainly explained by the last 10 years’ strategy to phase out coal, so that in the long term coal will be replaced by natural gas and renewable energy sources, including bio-fuels. Also, in future, the strategy to phase out coal will result in a decrease in residues from coal-based energy generation, whereas there will be an increase in fly ash and bottom ash from bio-fuels.\(^{148}\)

As Figure 30 shows, in 2003 96 per cent of residues were recycled and 4 per cent were landfilled\(^{148}\).
Table 91: Recovery of residues coal fired power plants in 2003 (Denmark)\textsuperscript{148}.

<table>
<thead>
<tr>
<th>Use of residues from coal-fired power plants in 2003 (tonnes)</th>
<th>fly ash</th>
<th>slag/bottom ash</th>
<th>plaster\textsuperscript{149}</th>
<th>dry desulphurization product</th>
<th>sulphuric acid</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscellaneous</td>
<td>201,055</td>
<td>25,452</td>
<td>155,993</td>
<td></td>
<td></td>
<td>382,500</td>
</tr>
<tr>
<td>Backfilling</td>
<td>277,891</td>
<td>39,718</td>
<td></td>
<td></td>
<td></td>
<td>317,609</td>
</tr>
<tr>
<td>Cement</td>
<td>191,300</td>
<td>33,900</td>
<td></td>
<td></td>
<td></td>
<td>225,200</td>
</tr>
<tr>
<td>Concrete</td>
<td>182,300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>182,300</td>
</tr>
<tr>
<td>Plasterboards</td>
<td></td>
<td>94,600</td>
<td></td>
<td></td>
<td></td>
<td>94,600</td>
</tr>
<tr>
<td>Exported for recovery</td>
<td>88,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>88,000</td>
</tr>
<tr>
<td>Landfilled</td>
<td>14,654</td>
<td>3,600</td>
<td>7,159</td>
<td>34,500</td>
<td></td>
<td>59,913</td>
</tr>
<tr>
<td>Roofing felt/concrete block</td>
<td></td>
<td>38,300</td>
<td></td>
<td></td>
<td></td>
<td>38,300</td>
</tr>
<tr>
<td>Desulphurisation</td>
<td></td>
<td></td>
<td></td>
<td>32,700</td>
<td></td>
<td>32,700</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>20,066</td>
<td></td>
<td></td>
<td>5,600</td>
<td></td>
<td>25,666</td>
</tr>
<tr>
<td>Asphalt</td>
<td>24,100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24,100</td>
</tr>
<tr>
<td>Granulate</td>
<td></td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>979,300</strong></td>
<td><strong>127,136</strong></td>
<td><strong>291,652</strong></td>
<td><strong>67,400</strong></td>
<td><strong>5,600</strong></td>
<td><strong>1,471,088</strong></td>
</tr>
</tbody>
</table>

Table 91 shows, that more than 90 per cent of residues is used as raw materials in the industrial manufacture of, for example, cement, concrete and plaster board, whereas the remaining part is primarily used as backfilling, either in accordance with the provisions of Statutory Order no. 655 of 27 June 2000 from the Ministry of the Environment, or as backfilling with special approval under the Danish Environmental Protection Act\textsuperscript{148}.

\textsuperscript{148} Plaster is a type of building material based on calcium sulfate. It is created by heating gypsum to about 150 °C.
7.5 Estonia

7.5.1 Existing standards and regulation

The European waste legislation has been transposed into the Estonian national legislation. The Waste Act (RT I 2004, 9, 52) provides the general requirements for preventing waste generation and the health and environmental hazards arising therefrom and for organising waste management with the objective to reduce the harmfulness and quantity of waste. The Landfill Directive (1999/31/EC) has been transposed into the Estonian legislation through the Waste Act (RT I 2004, 9, 52) including inter alia the prohibition on depositing of untreated waste in landfills.

The first strategic document directing waste handling in Estonia at the national level was the National Waste Management Plan from the year 2002. The second Estonian Waste Management Plan, which covers the years 2008-2013, will enter into force in the beginning of the year 2008.

Environmental fees have been implemented in Estonia already since 1991. The new Environmental Fees Act entered into force in January 2006. Environmental fees have to be paid in Estonia for the right to use all the main natural resources belonging to the state (including minerals) and for releasing pollutants and waste into the environment (including waste disposal).\textsuperscript{150}

7.5.1.1 Construction and demolition waste

According to the Waste Act (RT I 2004, 9, 52), the Minister of the Environment has the right to establish handling requirements inter alia for construction and demolition waste. However, such specific requirements have not been established to date.

Handling of construction and demolition waste is regulated on municipality level. According to the Waste Act (RT I 2004, 9, 52), local government waste management rules have to set out requirements for handling construction and demolition waste not subject to organised waste transport.

7.5.1.2 Slags from ferrous metal production

There is no ferrous metal production in Estonia\textsuperscript{151}.

7.5.1.3 Ashes from coal combustion processes

There are no specific, national standards or regulations regarding the recovery or disposal of ashes from coal combustion\textsuperscript{151}.

\textsuperscript{150}\textsc{Ministry of Environment (2005)}

\textsuperscript{151}\textsc{Contact Estonia 01 (2007)}
7.5.2 Construction and demolition waste

The development of the generation of construction and demolition waste is directly connected with an increase in living standards, the development of enterprises and the accompanying investments. In recent years the construction sector has been booming in Estonia which has led to increasing quantities of construction and demolition waste. At the moment, the building boom is slowing down. Consequently, it can be expected that the generation of construction and demolition waste will stabilize in the future.\textsuperscript{151}

The mineral part of construction waste, e.g. stones, sand, concrete, is primarily used as filling material in the building sector and in land recovery.\textsuperscript{151} A part of construction waste is landfilled. Construction waste can also be used in landfills e.g. for the construction of temporary roads.\textsuperscript{152}

Figure 31 represents the development of quantities of construction and demolition waste generated and recovered in Estonia in recent years.

Figure 31: Generation and recovery of construction and demolition waste (including metal wastes) (Estonia).\textsuperscript{153}

Table 92 and Table 93 give a more detailed picture of the composition of the construction and demolition wastes generated and recovered in Estonia.

\textsuperscript{152} MINISTRY OF ENVIRONMENT (2002)
\textsuperscript{153} ESTONIAN ENVIRONMENT INFORMATION CENTRE (2003); ESTONIAN ENVIRONMENT INFORMATION CENTRE (2004); ESTONIAN ENVIRONMENT INFORMATION CENTRE (2005); ESTONIAN ENVIRONMENT INFORMATION CENTRE (2007A); ESTONIAN ENVIRONMENT INFORMATION CENTRE (2007B)
Table 92: Composition of the construction and demolition waste generated (Estonia).  

<table>
<thead>
<tr>
<th>Waste Category</th>
<th>Generation (t/a)</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 01 Concrete, bricks, tiles and ceramics</td>
<td></td>
<td>136.242</td>
<td>84.678</td>
<td>156.540</td>
<td>263.491</td>
<td>183.066</td>
</tr>
<tr>
<td>17 02 Wood, glass and plastic</td>
<td></td>
<td>15.747</td>
<td>14.304</td>
<td>15.535</td>
<td>18.530</td>
<td>33.733</td>
</tr>
<tr>
<td>17 03 Bituminous mixtures, coal tar and tared products</td>
<td></td>
<td>41.153</td>
<td>47.771</td>
<td>69.374</td>
<td>93.653</td>
<td>95.666</td>
</tr>
<tr>
<td>17 04 Metals (including their alloys)</td>
<td></td>
<td>345.138</td>
<td>376.514</td>
<td>454.684</td>
<td>403.572</td>
<td>461.683</td>
</tr>
<tr>
<td>17 05 Soil (including excavated soil from contaminated sites), stones and dredging spoil</td>
<td></td>
<td>566.187</td>
<td>563.815</td>
<td>566.544</td>
<td>1.177.925</td>
<td>1.275.808</td>
</tr>
<tr>
<td>17 06 Insulation materials and asbestos-containing construction materials</td>
<td></td>
<td>2.200</td>
<td>1.963</td>
<td>1.618</td>
<td>2.648</td>
<td>4.825</td>
</tr>
<tr>
<td>17 08 Gypsum-based construction material</td>
<td></td>
<td>8.944</td>
<td>4.971</td>
<td>3.276</td>
<td>1.985</td>
<td>2.187</td>
</tr>
<tr>
<td>17 09 Other construction and demolition wastes</td>
<td></td>
<td>175.162</td>
<td>167.478</td>
<td>235.933</td>
<td>198.960</td>
<td>338.334</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>1.290.773</td>
<td>1.261.493</td>
<td>1.503.504</td>
<td>2.160.766</td>
<td>2.395.303</td>
</tr>
</tbody>
</table>

Table 93: Recovery of construction and demolition waste per waste category (Estonia).  

<table>
<thead>
<tr>
<th>Waste Category</th>
<th>Recovery (t/a)</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 01 01 Concrete</td>
<td></td>
<td>88.600</td>
<td>120.513</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 01 02 Bricks</td>
<td></td>
<td>13.976</td>
<td>13.990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 01 03 Tiles and ceramics</td>
<td></td>
<td>806</td>
<td>803</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 01 07 Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06</td>
<td></td>
<td>79.684</td>
<td>86.129</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 03 02 Bituminous mixtures other than those mentioned in 17 03 01</td>
<td></td>
<td>95.666</td>
<td>81.972</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>278.732</td>
<td>303.407</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 94 represents detailed information on the generation and recovery of concrete, bricks, tiles and ceramics in Estonia, giving the year 2006 as an example.

Table 94: Generation and Recovery of concrete, bricks, tiles and ceramics in 2006 (Estonia).  

<table>
<thead>
<tr>
<th>Waste Type</th>
<th>Generation</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 01 01 Concrete</td>
<td>88.600</td>
<td>120.513</td>
</tr>
<tr>
<td>17 01 02 Bricks</td>
<td>13.976</td>
<td>13.990</td>
</tr>
<tr>
<td>17 01 03 Tiles and ceramics</td>
<td>806</td>
<td>803</td>
</tr>
<tr>
<td>17 01 07 Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06</td>
<td>79.684</td>
<td>86.129</td>
</tr>
<tr>
<td>17 03 02 Bituminous mixtures other than those mentioned in 17 03 01</td>
<td>95.666</td>
<td>81.972</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>278.732</td>
<td>303.407</td>
</tr>
</tbody>
</table>
7.5.3 Slags from ferrous metal production

There is no ferrous metal production in Estonia\textsuperscript{151}.

7.5.4 Ashes from coal combustion processes

Coal is used in Estonia only in households and in small local boiler houses. The amount of coal ash generated by the local boiler houses is not remarkable and there is no clear overview of the quantities of coal ash which is generated by households. The data from the Estonian Environment Information Centre shows that only about 30 to 100 tons of fly ash from coal combustion are annually generated in Estonia.

Oil shale provides over 75\% of Estonia’s total energy supply, making Estonia the only country in the world where oil shale is the primary source of energy\textsuperscript{154}. Oil shale is mined in the north-eastern part of the country. Oil shale is consumed for power generation by the three electric companies and for shale-to-oil processing\textsuperscript{151}.

The calorific value of oil-shale is quite low and the oil shale industry generates remarkable amounts of hazardous wastes; about 7 million tones annually. The most important hazardous waste types generated by the oil-shale industry are oil-shale fly ash, oil shale bottom ash and oil-shale semi coke.

A small part of oil-shale fly ash from cyclones and electric filters is recovered in cement production and in the production of some other construction materials like blocks. The recovery of slag-like bottom ash from the oil-shale industry is very difficult.

A challenge for the future will be to find new ways to recover and use oil-shale ashes. However, it is very difficult to find recovery options for the huge amounts of these hazardous wastes.

\textsuperscript{154} ESTONIA ENERGY: \url{http://www.estoniaenergy.com/}.\textsuperscript{151}
7.6 Finland

7.6.1 Existing standards and regulation

*General Waste Policy*

Finnish waste legislation is largely based on EU legislation, but includes in some cases stricter standards and limits than those applied in the EU as a whole. Finland also has legislation on some issues related to wastes that have not yet been covered by EU legislation[^155]. The Waste Act (1072/1993) sets out general objectives and requirements for waste management (disposal and recovery).[^156]

The negative environmental impacts of wastes are also addressed in legislation on environmental protection[^155]. An environmental permit according to the Environmental Protection Act (86/2000) is needed for establishments or undertakings intending to carry out professional disposal or recovery of wastes[^155].

According to the Waste Tax Act (495/1996), a state tax has to be paid on waste deposited at landfills. Waste taxes are to be paid on wastes deposited at public landfill sites, but are not applied to private or industrial landfills if these do not routinely receive wastes generated by other parties. Among others, fly ashes from power plants and waste that will be recovered at the landfill are exempt from the waste tax.[^157]

According to an assessment carried out by the Ministry of the Environment (2005), waste taxation has helped to reduce the amounts of waste ending up in public landfills. Reductions have been particularly significant for construction, commercial and industrial wastes[^155].

The first National Waste Plan issued under the Waste Act was approved by the Finnish Government on July 2, 1998. The plan was revised in 2002 and the revised plan remains in force until a new plan is accepted. The proposal for a new national waste plan was handed to the Ministry of the Environment in January 2007. The proposal describes how waste management in Finland should look in 2016 and how the goals will be achieved.[^155]

According to the proposal for a new waste plan, recycling will be advanced through actions that increase demand for recycled materials. These actions include inter alia developing criteria for quality and environmental friendliness of recycled products and favouring recycled materials in public buildings. Permit conditions and waste type specific guidelines can be used to speed up the recycling of material from large industrial sources. Furthermore, the proposal sets as a goal the further investigation of methods for the reduction of construction waste and the recycling of construction waste.[^155]

[^156]: CONTACT FINLAND 01 (2007)
**Distinction between wastes and products**

In Finland, there are no specific regulations concerning the distinction between wastes and by-products or the reclassification of waste as a product. So far, the classification has been made on a case-by-case basis within the process of environmental permitting.\(^{155}\)

A precedent of the Supreme Administrative Court (KHO 2005:90) concerning an environmental permit decision on a big steel factory stated that ferrochrome slag generated in the manufacturing process is not waste, but an exploitable by-product. After this precedent, some metallurgical slags, like blast furnace and ferrochrome slags, have mainly been considered to be products instead of wastes in Finland.\(^{155}\)

According to a legal ruling based on the precedent a material is by-product and not waste if\(^{155}\):

- It is generated in a continuous process;
- The recovery of the material is certain, taking into account among others the economical profitability;
- In an overall comparison, the benefits in terms of saving natural resources by the recovery are more significant than the environmental risks related to it.

**Government Decree concerning the recovery of certain wastes in earth construction (591/2006)**

In order to promote the recovery of certain wastes in earth construction, Government Decree 596/2006 has been laid down in Finland. The Decree is based on article 11 of the Waste Framework Directive (2006/12/EC). The draft decree was notified to the European Commission\(^{155}\).

According to the Decree, the use of concrete chippings, as well as of fly and bottom ashes from the combustion of coal and peat and wood-based material, in earth construction can, under certain conditions, be based on a notification to the environmental protection database instead of an environmental permit\(^{155}\).

The Decree is applicable to the institutional or commercial recovery of wastes for the following earth construction purposes\(^{158}\):

- Public roads, streets, bicycle lanes, pavements and areas directly connected to these, necessary for road maintenance or traffic, excluding noise barriers;
- Parking areas;
- Sports grounds and routes in recreational and sports areas;
- Railway yards as well as storage fields and roads in industrial areas, waste processing areas and air traffic areas.

\(^{158}\) MINISTRY OF THE ENVIRONMENT (2006A)
The Decree only applies to earth construction which is implemented in accordance with a street plan, a plan for implementing a public area, a permit or notification as referred to in the Land Use and Building Act (132/1999), or in accordance with a road plan as referred to in the Law on Public Roads (243/1954) or the Highways Act (503/2005). The Decree does not apply in important or other groundwater areas suitable for water supply.\textsuperscript{158}

The Decree sets out limit values on the content and leaching of harmful substances and defines the general principles for the quality control of waste. Specific limit values have been defined separately for concrete chippings and for fly and bottom ashes.\textsuperscript{158}

If the requirements of the Decree are not met (for instance the limit values are exceeded) a permit will be required for the recovery.\textsuperscript{158}

Limit values have been defined separately for covered and paved structures. Covering refers to protecting a structure containing waste with a layer of natural rock, the minimum thickness of which is 10 cm, in order to prevent the spread of waste. Paving refers to protecting a structure containing waste with asphalt with a maximum void of 5 per cent, or another material with which a corresponding level of protection can be achieved, in order to reduce the seepage of rainwater.\textsuperscript{158}

Moreover, limit values have been defined separately for basic characterisation and for quality control investigations. Basic characterisations are conducted to prove that the waste in question falls within the scope of the Decree. Through quality control investigations, waste quality shall be monitored for an adequate period.\textsuperscript{158}

The content limit values for inorganic substances are based on the results of waste type specific analyses. The content limit values for TOC, PCB and PAH are based on the limit values defined by the Landfill Directive (2003/33/EY) for inert waste to be accepted at inert landfill sites. As an exception, no limit value has been defined for the TOC content of ashes, due to the difficulties related to the measurement of it.\textsuperscript{159}

All leaching limit values have been derived from the limit values defined by the Landfill Directive (2003/33/EY) for inert waste to be accepted at inert landfill sites. Specific leaching limit values for both waste material groups have been defined based on the general limit values of the Landfill Directive\textsuperscript{155}:

- Some ashes have difficulties to comply with the general limit values. Their use in earth construction has however overall positive environmental impacts. Therefore, the Government Decree allows, with some exceptions, threefold limit values for ashes in paved structures in comparison to the limit values for covered structures. To prevent environmental risks, these increased values have been defined so that they do not exceed the leaching values created by modelling, which were used as a basis for the definition of the limit values of the Landfill Directive (2003/33/EY)\textsuperscript{160}.
- For crushed concrete, the limit values for paved structures are the same as for covered structure, except for sulphates, for which threefold values are allowed for paved structures in comparison to covered structures.\textsuperscript{155}

\textsuperscript{158} MINISTRY OF THE ENVIRONMENT (2006B)
\textsuperscript{159} VTT (2006A)
\textsuperscript{160} VTT (2006A)
7.6.1.1 Construction and demolition waste

**Government Decision on construction waste (259/1997)**

The purpose of the Government Decision on construction waste (259/1997) is to reduce the quantity and harmfulness of construction waste and increase its recovery. However, the Decision does not contain any special quality requirements. The overall aim of the Decision was to recover at least 50 per cent of all construction waste, except for soil, rock, and dredging waste, in the year 2000. The Decision does not apply to construction sites where the quantity of resulting construction waste other than soil, rock and dredging waste is not more than 5 tons, or where the quantity of soil, rock and dredging waste deriving from it is not more than 800 tons. 

According to the Decision (259/1997), construction must be planned and implemented and construction waste collected and transported in such a way that the recoverable waste and the following waste types are kept separate, or are separated from each other and other construction waste:

- Concrete, brick, mineral tile, ceramic and gypsum wastes;
- Metal wastes;
- Soil, rock and dredging wastes.

Limit values for concrete chippings in the Government Decree concerning the recovery of certain wastes in earth construction (591/2006)

Concrete chippings refer to waste made of dismantled concrete structures or concrete waste from new buildings and the concrete industry by crushing the material into grains with a maximum diameter of 150mm. Table 95 shows the limit values defined for concrete chippings in the Government Decree concerning the recovery of certain wastes in earth construction (591/2006).
Table 95: Limit values for concrete chippings (Waste codes 10 13 14, 17 01 01 and 19 12 12) (Finland)

<table>
<thead>
<tr>
<th>Harmful substance</th>
<th>Limit value, mg/kg of dry matter</th>
<th>Limit value, mg/kg of dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic characterisations</td>
<td>Quality control investigations</td>
</tr>
<tr>
<td></td>
<td>Content (L/S = 10l/kg)</td>
<td>Content (L/S = 10l/kg)</td>
</tr>
<tr>
<td></td>
<td>Covered structure</td>
<td>Leaching (L/S = 10l/kg)</td>
</tr>
<tr>
<td></td>
<td>Paved structure</td>
<td>Leaching (L/S = 10l/kg)</td>
</tr>
<tr>
<td>PCB</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>PAH</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>TOC</td>
<td>30,000</td>
<td></td>
</tr>
<tr>
<td>DOC</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Antimony (Sb)</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>50</td>
<td>0.5</td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>10</td>
<td>0.02</td>
</tr>
<tr>
<td>Chrome (Cr)</td>
<td>400</td>
<td>0.5</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>400</td>
<td>2.0</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>300</td>
<td>0.5</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Vanadium (V)</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>700</td>
<td>4.0</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Fluoride (F-)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Sulphate (SO42-)</td>
<td>1,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Chloride (Cl-)</td>
<td>800</td>
<td>800</td>
</tr>
</tbody>
</table>

163 Polyaromatic hydrocarbons, total amount of compounds (anthracene, acenaphthene, acenaphthylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, phenanthrene, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, naphthalene, pyrene, chrysene).
164 Total quantity of organic carbon.
165 Dissolved organic carbon.
7.6.1.2 Slags from ferrous metal production

There are no specific regulations concerning the recovery of slags from ferrous production.

7.6.1.3 Ashes from coal combustion processes

*Limit values for ashes from coal combustion in the Government Decree concerning the recovery of certain wastes in earth construction (591/2006)*

Fly and bottom ashes from the combustion of coal refer to waste separated mechanically or electrically from flue gases created in the combustion of coal, and extracted from the bottom of the combustion chamber of a coal combustion plant.\(^{158}\)

Fly and bottom ashes from the combustion of peat and wood-based material refer to waste separated mechanically or electrically from flue gases created in the combustion of peat, wood chips, bark residue, primary fibre pulp production, botanical waste including fibre material created in connection with the production of paper from pulp, unprocessed wood waste or any other comparable wood-based material or a mixture thereof, or extracted from the bottom of the combustion plant’s combustion chamber.\(^{158}\)
Table 96: Limit values for ashes from coal combustion (Waste codes 10 01 02, 10 01 03, 10 01 17, 10 01 01 and 10 01 15) (Finland)<sup>158</sup>.

<table>
<thead>
<tr>
<th>Harmful substance</th>
<th>Limit value, mg/kg of dry matter</th>
<th>Limit value, mg/kg of dry matter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic characterisations</td>
<td>Quality control investigations</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td>Leaching (L/S = 10l/kg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Covered structure</td>
</tr>
<tr>
<td>PCB</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>PAH</td>
<td>20/404</td>
<td></td>
</tr>
<tr>
<td>DOC</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Antimony (Sb)</td>
<td>0.06</td>
<td>0.18</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>50</td>
<td>0.5</td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td>3,000</td>
<td>20</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>15</td>
<td>0.04</td>
</tr>
<tr>
<td>Chrome (Cr)</td>
<td>400</td>
<td>0.5</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>400</td>
<td>2.0</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>300</td>
<td>0.5</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>50</td>
<td>0.5</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>0.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Vanadium (V)</td>
<td>400</td>
<td>2.0</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>2,000</td>
<td>4.0</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Fluoride (F--)</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Sulphate (SO₄²⁻)</td>
<td>1,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Chloride (Cl⁻)</td>
<td>800</td>
<td>2,400</td>
</tr>
</tbody>
</table>

Descriptions see Table 95.

### 7.6.2 Construction and demolition waste

In the year 2004 about 1.6 million tonnes of construction and demolition wastes were generated by house building activities in Finland. Excavated soils are excluded from this quantity. The quantity results from statistical estimations of Statistics Finland which are based on national surveys and registers. 56% of the waste generated by house building activities was generated in repair and rebuilding and 16% in the construction of new buildings. Figure 32 represents the composition of the construction and demolition waste arising from house building.<sup>155</sup>
In the latest waste statistics, the excavated soils which were recovered on the same building site where they were generated are not included in the quantities of wastes generated. In accordance with this interpretation, about 19.5 million tonnes of excavated soils were generated in construction activities (including house building as well as earth and water construction) in the year 2004.\textsuperscript{155}

In the year 2004, about 54\% of the construction and demolition wastes generated by house building activities (excavated soils are excluded) were recovered. Figure 33 shows the development of the recovery rate of construction and demolition wastes generated by house building activities in Finland (excavated soils are excluded). The rate of recovery has increased by 15\% since 2000.\textsuperscript{167}

\begin{figure}[h]
\centering
\includegraphics[width=0.6\textwidth]{composition_of_construction_and_demolition_waste_from_house_building_finland.png}
\caption{Composition of construction and demolition waste from house building (excavated soils are excluded) (Finland)\textsuperscript{166}.}
\end{figure}

\textsuperscript{155} VTT (2006B)
\textsuperscript{166} ENVIROMNENT ADMINISTRATION (2007A); CONTACT FINLAND 01 (2007)
Reclaimed concrete has been used in pavement construction on several construction sites since 1994 in Finland. It has been observed that the bearing capacity of pavements made of reclaimed concrete has been much better than that of the pavements made of crushed rock or gravel. One of the biggest reference projects is the motorway VT4 Helsinki-Lahti, where 20,000 tonnes of reclaimed concrete were used in 1998 in the base layer of the road. Also, crushed brick has been used in the sub-base layers of light traffic routes and yards in Finland. In addition, crushed brick as frost insulation has also been put to experimented use.\(^{168}\)

In Finland about 250,000 – 300,000 t of reclaimed asphalt is annually generated and recycled, which corresponds to about 12 % of the total production volume of the asphalt industry\(^{168}\).

\(^{168}\text{TEKES (2000B)}}
7.6.3 Slags from ferrous metal production

According to the statistics on industrial output compiled by Statistics Finland, about 1.5 – 3.0 million tonnes of slags are generated annually by the Finnish metal industry.\textsuperscript{169}

*Figure 34: Development of the quantities of slags generated in metal industry (Finland)\textsuperscript{155}.*

According to the Association of Finnish Steel and Metal Producers, about 1.3 million tonnes of “by-products” of the Finnish metal industry were utilized in the year 2006 (see Table 97)\textsuperscript{155}.

*Table 97: Utilization of ‘By-products’ of the Finnish Steel Industry 2006 (Finland)\textsuperscript{155}.*

<table>
<thead>
<tr>
<th>Type of use</th>
<th>tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of Cement</td>
<td>237.500</td>
</tr>
<tr>
<td>Land Reclamation</td>
<td>157.000</td>
</tr>
<tr>
<td>Earth and Road Construction</td>
<td>908.700</td>
</tr>
<tr>
<td>Total</td>
<td>1,303.200</td>
</tr>
</tbody>
</table>

\textsuperscript{169} PUUSTINEN (2003); CONTACT FINLAND 01 (2007)
Blast-furnace slags have been utilized in road construction in Finland since the end of the 1980s. Especially in Oulu and Raahe there are many structures made of blast-furnace slag. An example of the use of pulverized blast-furnace slag as a binder in bulk stabilization is a clay road project in Viikki in Helsinki. Air-cooled blast-furnace slag has been utilized in sub-base and base courses in road building projects of the Finnish National Road Administration (Finnra).\textsuperscript{168}

OKTO (OutoKumpu Tornio) -insulation is a by-product of Outokumpu Chrome Ltd ferrochromium production, which is located at the steel plant in Tornio. OKTO-insulation is used in road and house building as thermal insulation. The technical properties of OKTO-insulation are basically the same as blast-furnace slag, but OKTO-insulation is not a hydraulic binding material in comparison with blast-furnace slag.\textsuperscript{168}

OKTO-aggregate is produced by the same process as OKTO-insulation in the Outokumpu Chrome Ltd ferrochromium production in Tornio. OKTO-aggregate is made of air-cooled ferrochromium slag whereas OKTO-insulation is made of water-cooled, granulated ferrochromium slag. OKTO-aggregate may be utilized as an asphalt aggregate in different fractions in many kinds of asphalt types. All of the natural rock and stone aggregate, including the filler, may be replaced by products made of OKTO-aggregate.\textsuperscript{168}

\section*{7.6.4 Ashes from coal combustion processes}

According to the data reported to the Compliance Monitoring Data System of the Finnish Environmental Administration, about 380,000 tonnes of bottom ashes (100101) and 672,000 tonnes of fly ashes (100102) were generated in combustion processes in Finland in the year 2006.\textsuperscript{155}

The Finnish Energy Industries compile annual statistics on the generation, recovery and disposal of ashes and slags resulting from coal combustion processes. According to the statistics of the Finnish Energy Industries, about 50 – 60 percent of ashes and slags from coal combustion have been recovered in recent years in Finland (see Table 98 and Table 99).\textsuperscript{170}

\textsuperscript{170} FINNISH ENERGY INDUSTRIES (2004); FINNISH ENERGY INDUSTRIES (2006); FINNISH ENERGY INDUSTRIES (2007)
Fly ash has been used as an earth construction material in Finland since the 1960s and 1970s. The most common applications have been different filling and embankment structures. Wider utilisation and material development of fly ash mainly took place during the 1990s.170

Bottom ash has been used in Finland on several different sites since the 1970s. It has been utilised in road and street structures, in pipe and wire excavation structures of municipal engineering, in the structures of light traffic routes and in different embankment and field structures. Mostly bottom ash has been used in sub-base layers, but also in lightening structures and as filling material in pipe and wire excavations.170
7.7 France

In 2005 a total amount of 410.0 million tons of aggregates were produced in France. 10.0 million tons were recycled aggregates coming from construction and demolition waste used in the aggregates market. 7.0 million tons were secondary aggregates including blast-furnace slag, electric-arc-furnace slag, incinerator bottom ash (IBA), pulverised fuel ash (PFA) and other industrial and extraction by-products for construction and civil engineering.3

7.7.1 Existing standards and regulation

In France, there are no national environmental regulations for the use of C&D waste, coal ash or slags from iron and steel industry.171

Technical guides exist at national and sometimes the local scale to define the fields of application (including the limits) of each waste stream and the engineering properties (physical, geotechnical, and variability) required for their use:


These requirements have been completed in some regional areas where the use of these waste streams (and others) was historically important, by specific technical guidelines for each waste stream.171

For these three waste streams, European standards elaborated by CEN within the framework of the Construction Product Directive 89/106/CE apply also in France.

In France there are specific standards, in particular XP P 18-545 which specifies a classification system for the use of granular material (natural, artificial or recycled) in the road base and XP P 98-135 which specifies how to characterise reclaimed asphalt for recycling in bituminous material (hot process).171

In practice, each producer has its own Quality Assurance Plan in which the characteristics of the waste are gathered, especially variability and compliance with existing standards, guidelines or regulations (physical and/or mechanical). Concerning the environmental aspect, requirements are set locally by the local authority in the permit of the plant where the waste is produced. Those requirements are mainly based on national landfilling limit values or on the national guidelines for the use of incineration bottom ash from the thermal treatment of municipal solid waste.171

The ‘Loi du 13 juillet 1992’ provides that as of 1 July 2002 the landfills accept only ‘ultimate’ wastes. These are wastes that are not qualified for172: recycling, extracting the recycling parts (sorting plant), or treatments to reduce the contamination.

171 CONTACT FRANCE 01 (2008)
Landfill is the ultimate alternative in order to dispose of waste. Every other way of treatment is encouraged within the technical and economical limits. The traditional landfills were closed and replaced by controlled stocking centres for ultimate wastes that cannot be recycled or where the recycling costs are even higher than the costs of natural materials.

The ‘Circulaire du 15/02/00 relative à la planification de la gestion des déchets de chantier du bâtiment et des travaux publics (BTP) (BOMATE n° 2000-03 du 20/03/00)’ suggests an intention with the following aims:

- to install a network of treatment that offers to professionals in constructing and demolition a close-by service in order to reduce the transport routes of waste and the costs of their treatment,
- to favour the reduction of the production of waste at the source,
- to valorise the existing recycling network,
- to permit the use of recycling materials in the building and road construction industry,
- to involve the public constructor in the elimination of waste by the elaboration of recommendations.

The classification of landfills is as follows:

- ‘Class 1’ landfills are for special industrial wastes;
- ‘Class 2’ landfills are for household and similar wastes;
- ‘Class 3’ landfills are for inert wastes.

The following ministerial orders are relevant for disposal:

- The ministerial order of 2004-12-31 for disposal in landfills for inert waste: for industrial waste such as coal ash and slags.
- The ministerial order of 2006-03-15 for disposal in landfills for inert waste: for C&D waste.
- The ministerial order of 1997-09-09 (lastly revised in 2002-12-31) for disposal in landfills for non hazardous waste: for C&D waste, coal ash and slags.

These orders transpose the requirements of the European landfill directive 1999/31/EC and those of the Council Decision 2003/33/EC into national law.

In France there is no regulation for the valorisation (re-use, recycling) of recycled material.
7.7.2 Construction and demolition waste

C&D waste from the building sector are generally generated as a mix. Selective demolition is not widely practised on site, except for asbestos removal. Wastes go to grouping and sorting facilities to separate the different fractions (metals, plastics, wood, mineral, others). The mineral fraction is then consigned to recycling facilities to separate metals from the mineral phase by crushing and to produce from this last fraction aggregate by sieving.\textsuperscript{171}

The mineral fraction of C&D waste can be directly re-used (reclaimed asphalt) or can go to recycling facilities to be crushed and sieved to obtain the desired aggregate.\textsuperscript{171}

Table 100: Amounts of waste from construction and public works generated in France in 2004 in million tons (France).

<table>
<thead>
<tr>
<th>In Million tons</th>
<th>Civil works (e.g. roads and bridges)</th>
<th>Building construction and demolition waste (total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>demolition</td>
<td>renovation</td>
</tr>
<tr>
<td>Inert waste</td>
<td>292.8</td>
<td>29.2</td>
</tr>
<tr>
<td>Non inert waste</td>
<td>2.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Total</td>
<td>295.5</td>
<td>31.2</td>
</tr>
</tbody>
</table>

Table 100 shows the amount of the waste from construction and public works generated in 2004. More than 12 million tons of the construction and demolition waste were recycled as aggregates.\textsuperscript{171}

In 2000 280 million tons of waste from civil works were generated of which 34 % were reused on the same site, 11% were reused on other sites, 7% were recycled, 11 % were used in quarry backfilling and 34 % were landfilled.\textsuperscript{171}

Arising mostly from public works engineering, around two-thirds of the wastes are reused as filling material or are recycled for road building. Recovery of demolition wastes is hindered by the difficulty in separating the more or less polluting materials they contain. Only a maximum of about 50 % of the inert demolition waste is reused or recycled. An ample availability of natural aggregates in certain regions, low landfill fees, and a poorly developed network of recycling centres also keep low the recycling rate.

Construction and public works wastes also contain a small proportion of hazardous wastes, mainly treated woods.\textsuperscript{174}

In 2004, the construction sector used only few recycled aggregates. Only 4 % of the total amount of the produced aggregates were derived from the recycling of waste. The material used for the construction was mainly natural material. The production amount of aggregates in France was about 408 millions of tonnes in 2004.\textsuperscript{174}

\textsuperscript{174} CROSNIER, MOISETTE & LERAY, FREDERIC (2007)
It should be mentioned however that the quantification of recycled aggregates used in France is not thoroughly done. These figures have been given by the quarry federation and do not cover all the recycling plants or all waste streams used as aggregates (e.g. recovered asphalt, other recycled road aggregates, Municipal Solid Waste Incineration Bottom Ash, coal fly ash, foundry sand). So, the real recycled aggregate amount should be higher than 4% and probably around 10%.\textsuperscript{171}

The inert waste is used as earth walls or transformed into aggregates after crushing in road construction on another site where it is produced. The reused materials on the same construction site are not considered to be waste, although they are in the waste stream.

### 7.7.3 Slags from ferrous metal production

Blast furnace slags are currently used for cement production or for hydraulically bound mixes. Slags from the steel industry are less widely used. Before use, slags are always processed by scrap removal, crushing and sieving.\textsuperscript{171}

Table 101 shows the total production of slag; Figure 36 and Figure 37 show the uses of slag.

Table 101: Production of slags in 2004 (France)\textsuperscript{175}.

<table>
<thead>
<tr>
<th>Slag</th>
<th>Tons produced in 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast furnace slag (BF)</td>
<td>4,116,000</td>
</tr>
<tr>
<td>Steel slag</td>
<td>2,203,000</td>
</tr>
<tr>
<td>BOF steel slag</td>
<td>1,198,000</td>
</tr>
<tr>
<td>EAF carbon steel slag</td>
<td>698,000</td>
</tr>
<tr>
<td>EAF High Alloy steel slag</td>
<td>307,000</td>
</tr>
</tbody>
</table>

\textsuperscript{175} EUROSALG (2007)
Figure 36: Use of slags 1 (France)\textsuperscript{174}. 

\begin{itemize}
  \item BF slag (in Kt.)
  \begin{itemize}
    \item Aggregates (Civil and Construction Works): 1384, 34%
    \item Granulated (Cement and other Hydraulic Binders): 2572, 62%
    \item Granulated (in Slag Bound Road Mixes): 160, 4%
  \end{itemize}

  \item Steel Slags (in Kt.)
  \begin{itemize}
    \item Civil works: 1208, 55%
    \item Hydraulic works: 262, 12%
    \item Construction works: 34, 2%
    \item Temporary stock: 159, 7%
    \item Permanent dump: 9, 0%
    \item Agriculture: 52, 2%
    \item Internal Recycling: 479, 22%
  \end{itemize}

  \item EAF Carbon Steel Slags (in Kt.)
  \begin{itemize}
    \item Civil works: 548, 78%
    \item Hydraulic works: 123, 18%
    \item Construction works: 12, 2%
    \item Temporary stock: 10, 1%
    \item Permanent dump: 5, 1%
    \item Agriculture: 0, 0%
    \item Internal Recycling: 0, 0%
  \end{itemize}
\end{itemize}
Fly Ashes from coal combustion processes from current production are used for cement and concrete production. These ashes are not processed. Only ashes from old stocks, which are mainly disposed of in ponds, are dedicated to road construction or underground quarry backfilling. These two last applications are not currently used. Other ashes are not used.
7.8 Germany

Approximately 260 million tons of mineral wastes (60 % of total waste volume) are generated yearly\textsuperscript{184}.

7.8.1 Existing standards and regulation

In 1996 the ‘Circulating Economy and Waste Material Law’\textsuperscript{176} was introduced in Germany. In Paragraph 4 three alternatives for recycling are described. The first alternative describes the substitution of natural resources by production of secondary resources from waste, the second describes the utilisation of the material properties of waste for the original field of application, and the third describes the substitution of natural resources for fields other than the original field of application (energy recovery excluded)\textsuperscript{177}.

Besides the general legislation regarding soil protection and water protection several regulations were enacted to minimize environmental impacts from specific recovery operations (e.g. landfill recovery ordinance\textsuperscript{178}, ordinance on underground waste storage)\textsuperscript{179}.

For the recycling of mineral wastes the ‘Working Group of the German Länder on Waste Issues (LAGA)’ published a regulation paper\textsuperscript{180} which is not legally binding, but has been introduced and used by legal authorities in several federal states. Based on this paper LAGA worked out key points\textsuperscript{181} which should be considered for a legally binding regulation.

Among the key points a differentiation is made between the use of waste as a component in products and the use of waste as a bulk material, where waste is the main component of the material. Specific limit values are defined for specific intended fields of application for solid content and leaching, for e.g. blast furnace slags, granulated cinder, steel slags, bottom and fly ashes from hard coal firing as well as recycled construction and demolition waste. In general these limits are defined with regard to water protection and soil protection, but the requirements of the ‘Federal Ordinance on soil protection and brown fields’\textsuperscript{182} remain to be adequately considered confirmed by a judgement of the Federal Administrative Court\textsuperscript{183}.

\textsuperscript{176} LOWER HOUSE OF GERMAN PARLIAMENT (1994)  
\textsuperscript{177} VERSTEYL A. AND PRELLE R. (2007)  
\textsuperscript{178} FEDERAL MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY (2005)  
\textsuperscript{179} FEDERAL MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY (2002)  
\textsuperscript{180} WORKING GROUP OF THE GERMAN LÄNDER ON WASTE ISSUES (2003)  
\textsuperscript{181} WORKING GROUP OF THE GERMAN LÄNDER ON WASTE ISSUES (2004)  
\textsuperscript{182} FEDERAL MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY (1999)  
\textsuperscript{183} GERMAN FEDERAL ADMINISTRATIVE COURT (2005)
Based on the LAGA’s key points the ministry and the federal environment agency started a working progress to produce a binding legal ordinance to regulate the use of mineral recycled and secondary aggregates in building constructions. By the end of December 2007, a working draft\textsuperscript{184} was already available.

In the draft, in paragraph 4 to 6 requirements are defined for the use of recycled and secondary aggregates in building constructions. Paragraph 5 stipulates regulations for the quality and possible fields of application.

Concerning material quality, general leaching limits have been defined for different kinds of input materials (similar to the LAGA key points). For excavated soil material leaching limits regarding different background values are defined in addition to the general leaching limits. If excavated soil material is below the precautionary limits of the ‘Federal ordinance on soil protection and brown fields\textsuperscript{182}’ these materials need not to be tested with regard to the leaching limits at all. For spent railway ballast, leaching limits regarding different types of spent railway ballast are given in addition to the general leaching limits.

The possible uses for each input material are specified by combining different possibilities for technical application (more than 20; see Annex 2) and different site conditions. The site conditions outside the water protection areas are classified as advantageous or disadvantageous with regard to the ground water layer. Within the water protection areas the use of materials is limited to advantageous overlay conditions according to the ‘Guideline for the environmentally compatible use of industrial by-products and recycled construction materials in road construction’\textsuperscript{185}. For each possible combination of technical application and site condition there are specific values for the possible intended uses regarding soil protection and water protection. By comparing the leaching limits and quality of the input material with the specified values for the intended use the possibility for the intended use is defined as possible, not possible or possible under special conditions.

The specified values are defined by considering the principles of the GAP-Report\textsuperscript{186}, which details the precautionary principle for the protection of groundwater that has to be considered with the recycling of wastes or the use of products. Furthermore, concepts of insignificance thresholds for soil\textsuperscript{187} and groundwater\textsuperscript{188}, which define maximum concentrations to mark the threshold between minimal loading and limited pollution, were taken into consideration. Special emphasis was given to the impact of chlorides and sulphides on soil and groundwater.

In addition to limits, the draft ordinance stipulates in paragraph 8 and 9 requirements for analyses, documentation and information as well as standardized testing methods (see Annex 4).

\textsuperscript{184} \textsc{Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2007)}

\textsuperscript{185} FGSV (2001)

\textsuperscript{186} Working Group of the German Länder on Water Issues (2002)

\textsuperscript{187} See also Bannick C. (2006)

\textsuperscript{188} See also Böhme M. (2006)
7.8.1.1 Construction and demolition waste

Table 102 shows leaching limits for the use of recycled construction materials (recycled construction and demolition waste, recycled hydraulically bound road construction materials) in building constructions defined in the draft ordinance.

Table 102: Leaching limits for recycled construction materials (Germany)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Recycled construction material (type 1)</th>
<th>Recycled construction material (type 2)</th>
<th>Recycled construction material (type 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH value</td>
<td></td>
<td>7–12.5</td>
<td>7–12.5</td>
<td>7–12.5</td>
</tr>
<tr>
<td>Conductivity</td>
<td>µS/cm</td>
<td>2,000</td>
<td>2,500</td>
<td>10,000</td>
</tr>
<tr>
<td>Sulphate</td>
<td>mg/L</td>
<td>200</td>
<td>350</td>
<td>1,400</td>
</tr>
<tr>
<td>PAH&lt;sub&gt;15&lt;/sub&gt;</td>
<td>µg/L</td>
<td>3</td>
<td>4.5</td>
<td>15</td>
</tr>
<tr>
<td>Chromium total</td>
<td>µg/L</td>
<td>50</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Copper</td>
<td>µg/L</td>
<td>40</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>Vanadium</td>
<td>µg/L</td>
<td>30</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Parameter for analysis required for basic characterization:
- Recycled construction material: pH value; conductivity; chloride; sulphate; PAH<sub>15</sub>; antimony; arsenic; lead; cadmium; chromium total; copper; molybdenum; nickel; vanadium; zinc.
- The quality types of recycled construction material (1-3) are related to possible intended uses laid down in Annex 2-2 of the draft ordinance.

As comparisons with test results show the parameters sulphate, PAH and copper can be seen as the critical as well as the limiting ones.

The German ‘Federal Union of Recycling Building Materials’ published a guideline for construction recycled building materials. This guideline stipulates the position of the recycling industry and should provide technical requirements for the quality of recycled construction materials related to specified uses. Requirements for environmental compatibility are not defined in the guideline. Table 103 shows possible source materials for production and Table 2 product types and related uses of recycled construction materials as defined in the guideline.

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189 Limit of 350 mg/L with beginning of the year 2020.
190 Limit of 700 mg/L with beginning of the year 2020; exceeding values allowed for specific uses.
191 Alternative limits for RC-1: 5 mg/kg, RC-2: 15 mg/kg and RC-3: 30 mg/kg until end of 2019.
192 GERMAN FEDERAL UNION OF RECYCLING BUILDING MATERIALS (2006)
Table 103: Source materials for recycled construction materials (Germany)\textsuperscript{192}.

<table>
<thead>
<tr>
<th>Unbound</th>
<th>Hydraulically bound</th>
<th>Bituminous bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mansory, natural stones, gravel and sand, other mineral materials (e.g. dam construction materials, railway ballast, frost protection layers, bearing layers without binder, tiles and facade slabs of natural stone)</td>
<td>Concrete, mortar, lime-stone masonry, brick masonry, ceramics for construction (e.g. concrete road blankets, bearing layers with hydraulic binders, broken masonry, concrete pipes, concrete sleepers, concrete or reinforced concrete elements, curbs and plates, cement screed)</td>
<td>Asphalt, without tar (e.g. Asphalt milling granulate, broken asphalt from road construction, cast asphalt screed)</td>
</tr>
</tbody>
</table>

Table 104: Product types and related uses of recycled construction materials (Germany)\textsuperscript{192}.

<table>
<thead>
<tr>
<th>Type</th>
<th>Intended use</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC-Stra</td>
<td>Classified road constructions</td>
</tr>
<tr>
<td>RC-Wege</td>
<td>Traffic areas outside the classified road constructions</td>
</tr>
<tr>
<td>RC-Depo</td>
<td>Landfill constructions</td>
</tr>
<tr>
<td>RC-Asphalt</td>
<td>Asphalt road constructions</td>
</tr>
<tr>
<td>RC-Beton</td>
<td>Concrete constructions, concrete products</td>
</tr>
<tr>
<td>RC-Erd</td>
<td>Earth moving</td>
</tr>
<tr>
<td>RC-Vegtra</td>
<td>Vegetation-related use, etc.</td>
</tr>
</tbody>
</table>

7.8.1.2 Slags from ferrous metal production

Table 105 shows leaching limits for the use of blast furnace slag, granulated cinder and steel slag (recycled construction and demolition waste, recycled hydraulically bound road construction materials) in building constructions defined in the draft ordinance.
Table 105: Leaching limits for blast furnace slag, granulated cinder and steel slag (Germany).\(^\text{194}\)

<table>
<thead>
<tr>
<th>Parameter for analysis required for basic characterization:</th>
<th>Blast furnace slag: pH value; conductivity; chloride; sulphate; antimony; arsenic; lead; cadmium; chromium total; copper; molybdenum; nickel; vanadium; zinc.</th>
<th>Granulated cinder: pH value; conductivity; sulphate; antimony; arsenic; lead; cadmium; chromium total; copper; molybdenum; nickel; vanadium; zinc.</th>
<th>Steel slag: pH value; conductivity; chloride; sulphate; fluoride; antimony; arsenic; lead; cadmium; chromium total; copper; molybdenum; nickel; vanadium; zinc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH value</td>
<td>9-12</td>
<td>9-12</td>
<td>9-12</td>
</tr>
<tr>
<td>Conductivity</td>
<td>(\mu \text{S/cm})</td>
<td>5,000</td>
<td>7,000</td>
</tr>
<tr>
<td>Sulphate</td>
<td>mg/L</td>
<td>900(^\text{193})</td>
<td>2,500</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>(\mu \text{g/L})</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Vanadium</td>
<td>(\mu \text{g/L})</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

7.8.1.3 Ashes from coal combustion processes

Table 55 shows leaching limits for the use of ashes from hard coal firing (granulate from smelting process, bottom ash and fly ash from dry and smelting process) in building constructions defined in the draft ordinance.

\(^{193}\) Sulphur total, converted to sulphate.
### Table 106: Leaching limits for ashes from hard coal firing (Germany)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Granulate from smelting chamber</th>
<th>Bottom ash</th>
<th>Fly ash from dry and smelting process</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH value</td>
<td></td>
<td>6-9</td>
<td>10-12</td>
<td>8-13</td>
</tr>
<tr>
<td>Conductivity</td>
<td>µS/cm</td>
<td>200</td>
<td>2,000</td>
<td>13,000</td>
</tr>
<tr>
<td>Sulphate</td>
<td>mg/L</td>
<td>n.s.</td>
<td>500</td>
<td>5,000</td>
</tr>
<tr>
<td>Arsenic</td>
<td>µg/L</td>
<td>n.s.</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Cadmium</td>
<td>µg/L</td>
<td>n.s.</td>
<td>n.s.</td>
<td>35</td>
</tr>
<tr>
<td>Chromium total</td>
<td>µg/L</td>
<td>n.s.</td>
<td>n.s.</td>
<td>1,700</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>µg/L</td>
<td>n.s.</td>
<td>800</td>
<td>3,000</td>
</tr>
<tr>
<td>Vanadium</td>
<td>µg/L</td>
<td>n.s.</td>
<td>65</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Parameter for analysis required for basic characterization:

Granulate from smelting chamber and bottom ash: pH value; conductivity; chloride; sulphate; antimony; arsenic; lead; cadmium; chromium total; copper; molybdenum; nickel; vanadium; zinc.

Fly ash from dry and smelting process: pH value; conductivity; chloride; sulphate; fluoride, antimony; arsenic; lead; cadmium; chromium total; copper; molybdenum; nickel; vanadium; zinc.

### 7.8.2 Construction and demolition waste

Approximately 73 million tons of construction and demolition waste is generated yearly. 2/3 of this volume is recycled to construction material.

Construction and demolition waste includes mineral construction waste, construction site waste and road construction waste considering codes of the European Waste List (EWL) listed in Table 107. Table 108 shows the generation and uses of construction and demolition waste in the year 2002.

### Table 107: Codes of EWL for construction and demolition waste (Germany)

| Mineral construction waste | 17 01 01; 17 01 02; 17 01 03; 17 01 07 |
| Construction site waste   | 17 02 01; 17 02 02; 17 02 03; 17 04 01; 17 04 02; 17 04 03; 17 04 04; 17 04 05; 17 04 06; 17 04 07; 17 04 11; 17 06 04; 17 08 02; 17 09 04 |
| Road construction waste   | 17 03 02 |

---

Table 108: Generation and use of construction and demolition waste (Germany)\textsuperscript{197}.

<table>
<thead>
<tr>
<th>C&amp;D waste (Mio. tons) in 2002</th>
<th>Mineral construction waste</th>
<th>Construction site waste</th>
<th>Road construction waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>52.1</td>
<td>4.3</td>
<td>16.6</td>
</tr>
<tr>
<td>Recycled construction material</td>
<td>35.7</td>
<td>1.2</td>
<td>14.2</td>
</tr>
<tr>
<td>Open pit</td>
<td>7.0</td>
<td>n.s.</td>
<td>0.3</td>
</tr>
<tr>
<td>Landfill construction material</td>
<td>1.6</td>
<td>n.s.</td>
<td>0.1</td>
</tr>
<tr>
<td>Engineered Recovery</td>
<td>n.s.</td>
<td>0.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>Public authorities\textsuperscript{195}</td>
<td>3.8</td>
<td>n.s.</td>
<td>1.7</td>
</tr>
<tr>
<td>Landfill</td>
<td>4.0</td>
<td>2.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

About 2/3 of the totally generated volumes are recycled to construction materials. Table 109 shows the fields of application for the recycled construction materials.

Table 109: Use of recycled construction materials (Germany)\textsuperscript{197}.

<table>
<thead>
<tr>
<th>Type of application</th>
<th>Mio. Tons in 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road construction</td>
<td>35.5</td>
</tr>
<tr>
<td>Earth moving</td>
<td>9.9</td>
</tr>
<tr>
<td>Additive for concrete</td>
<td>0.8</td>
</tr>
<tr>
<td>Others</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Additionally to Table 108, hazardous waste is generated during construction and demolition (see Table 110).

Table 110: Hazardous waste from construction and demolition (Germany)\textsuperscript{197}.

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Tons in 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 01 06: Mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances</td>
<td>1,240,000</td>
</tr>
<tr>
<td>17 03 01: Bituminous mixtures containing coal tar</td>
<td>1,964,000</td>
</tr>
<tr>
<td>17 03 03: Coal tar and tarred products</td>
<td>162,000</td>
</tr>
<tr>
<td>17 08 01: Gypsum-based construction materials contaminated with dangerous substances</td>
<td>160</td>
</tr>
</tbody>
</table>

\textsuperscript{195} Data of the year 2003.
7.8.3 Slags from ferrous metal production

In 2000 7.6 million tons of blast furnace slag were reused, 68% in the cement industry and others, 30% in road construction, 1% for internal use and others and 1% in agriculture. Other uses such as the use as cobblestone, building stone and expanded blast furnace slag have been discontinued.\footnote{196}

In 2000, 5.8 million tons of converter-slag were treated or disposed of, 63% as building materials, 5% as fertilizers, 13% in metallurgy, 2% were stored and 4% were used otherwise. Because of its physical characteristics 13% have been land filled.\footnote{196}

Approximately 7 million tons of blast furnace slags and 6 million tons of steel slags are generated yearly. Table 111, Table 112 and show data on the generation and use of slags in Germany.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|c|}
\hline
Blast furnace slag & Slump blast furnace slag & Granulated cinder \\
\hline
Generation & 2.28 & 1.78 & 5.01 & 5.66 \\
Cement & 0 & 0 & 4.76 & 5.30 \\
Construction material & 2.04 & 2.12 & 0.11 & 0.20 \\
Fertiliser & 0.03 & 0.02 & 0 & 0 \\
Storage* & 0.21 & -0.36 & 0.14 & 0.16 \\
\hline
\end{tabular}
\caption{Generation and use of blast furnace slags from metal production (Germany).\footnote{197}}
\end{table}

\footnote{196} FEHS (2005)
\footnote{197} DEHOUST G. ET. AL (2007)
Table 112: Generation and use of steel slags from metal production (Germany)\(^\text{197}\).

<table>
<thead>
<tr>
<th>Steel slag (Mio. tons)</th>
<th>Basic oxygen furnace slag</th>
<th>Electric arc furnace slag</th>
<th>Non ferrous metallurgy slag(^\text{198})</th>
<th>Secondary slag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>3.39</td>
<td>3.46</td>
<td>1.52</td>
<td>1.60</td>
</tr>
<tr>
<td>Reuse</td>
<td>0.64</td>
<td>0.61</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>0.34</td>
<td>0.27</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Construction material</td>
<td>1.60</td>
<td>1.49</td>
<td>1.29</td>
<td>1.57</td>
</tr>
<tr>
<td>Landfill</td>
<td>0.56</td>
<td>0.73</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Storage*</td>
<td>0.25</td>
<td>0.35</td>
<td>0.17</td>
<td>-0.05</td>
</tr>
</tbody>
</table>

\(^*\) + in storage, - from storage

Table 113: Generation of slags from metal production in 2005 and 2006 (Germany)\(^\text{199}\).

<table>
<thead>
<tr>
<th>Slag (Mio. tons)</th>
<th>Blast furnace slag</th>
<th>Steel slag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>Generation</td>
<td>7.25</td>
<td>7.62</td>
</tr>
</tbody>
</table>

In 2006 the total amount of blast furnace slag was recovered and about 0.61 million tons of the steel slags were disposed of on landfill\(^\text{199}\).

7.8.4 Ashes from coal combustion processes

Approximately 6 million tonnes of coal ashes from hard coal firing and 10 million tonnes of coal ashes from brown coal firing are generated yearly (see Table 114 and Table 115).

\(^\text{197}\) Non ferrous metallurgy slag is not covered by the study, and not included in the summarized amounts in Table 113.

\(^\text{199}\) EUROPÄISCHER WIRTSCHAFTSDIENST GMBH (2007)
### Table 114: Generation and use of residues from hard coal combustion (Germany)\(^{197}\).

<table>
<thead>
<tr>
<th>Hard coal ashes (Mio. tons)</th>
<th>Ashes from smelting chamber</th>
<th>Bottom ash</th>
<th>Fly ash</th>
<th>Fluidized bed ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>2.065</td>
<td>2.112</td>
<td>1.954</td>
<td>0.517</td>
</tr>
<tr>
<td>Concrete / Cement</td>
<td>0.139</td>
<td>0.161</td>
<td>0.177</td>
<td>0.150</td>
</tr>
<tr>
<td>Bricks / Ceramics</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.020</td>
</tr>
<tr>
<td>Filling / Mining mortar</td>
<td>0.157</td>
<td>0.126</td>
<td>0.109</td>
<td>0.026</td>
</tr>
<tr>
<td>Backfilling</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Landfill construction</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Earth moving / structural and civil engineering / road construction</td>
<td>1.127</td>
<td>0.998</td>
<td>1.013</td>
<td>0.314</td>
</tr>
<tr>
<td>Steel strip</td>
<td>0.531</td>
<td>0.662</td>
<td>0.356</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>0.111</td>
<td>0.165</td>
<td>0.299</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 115: Generation and use of residues from brown coal combustion (Germany)\(^{197}\).

<table>
<thead>
<tr>
<th>Brown coal ashes (Mio. tons)</th>
<th>Bottom ash</th>
<th>Fly ash</th>
<th>Fluidized bed ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>1.890</td>
<td>1.846</td>
<td>1.723</td>
</tr>
<tr>
<td>Concrete / Cement</td>
<td>0.053</td>
<td>0.045</td>
<td>0.003</td>
</tr>
<tr>
<td>Filling</td>
<td>0.023</td>
<td>0.001</td>
<td>0.021</td>
</tr>
<tr>
<td>Backfilling</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Landfill construction</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Road construction</td>
<td>0</td>
<td>0</td>
<td>0.199</td>
</tr>
<tr>
<td>Structural and civil engineer</td>
<td>1.814</td>
<td>1.791</td>
<td>1.500</td>
</tr>
<tr>
<td>Soil Fertiliser</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
7.9 Ireland

7.9.1 Existing standards and regulation

The Waste Management Act 1996\textsuperscript{200} and amendments made to it (2001, 2003 and 2005) are the primary legislative instruments that govern the management of waste in Ireland. Specific aspects of the Waste Management Act and its amendments are enacted through various Waste Management Regulations issued by the Minister for Environment and Local Government. These individual Regulations define the roles of the regulatory authorities, establish conditions pertaining to the relevant aspects of waste management and apply a more detailed set of rules in specific areas.

A comprehensive policy framework for modernising the approach to waste management was put in place in 1998 in the form of the Policy Statement ‘Changing Our Ways’\textsuperscript{201}. The Policy Statement identifies waste management as a fundamental aspect of sustainable development and sets out a series of ambitious targets to be achieved over a fifteen-year time scale until 2013.

A levy of €15 per ton on the landfilling of waste was introduced on 1 June 2002 under the Waste Management (Landfill Levy) Regulations 2002. The levy is designed to encourage the diversion of waste away from landfills and generate revenues that can be applied in support of waste minimization and recycling initiatives. The Amendment of the Waste Management Regulations 2002\textsuperscript{202} in 2006 provides that the levy payable on waste disposed of at an unauthorised landfill shall be €20 per tonne after 28 July 2006. Currently the cost of landfilling unsegregated waste is higher than the cost of segregated waste. This is expected to provide a greater incentive for C&D waste segregation at source\textsuperscript{203}.

A position paper regarding the distinction between product/by-product and residue on a general level was worked out by the Environmental Protection Agency in 2006\textsuperscript{204}. Based on several rulings of the European Court of Justice the paper concentrates on the proofs necessary to promote a substance from being a residue=waste to being a by-product. The following proofs were proposed (all of them have to apply):

- Certainty of use (in the same or an other process, on or off-site);
- Financial advantage (savings or revenue);
- No further processing necessary (other than normal industrial treatment of products);
- No special environmental precautions required (over and above those normal for equivalent products/raw-materials, e.g., abatement, character of emissions);
- Used appropriately / suitable for use (in a manner equivalent to the material it is replacing or appropriate for the purpose proposed, e.g., low grade fuel – low calorific value; C&D derived material placed on a field to improve land - but no topsoil).

\textsuperscript{200} THE DEPARTMENT OF THE ENVIRONMENT AND LOCAL GOVERNMENT (1996)
\textsuperscript{201} THE DEPARTMENT OF THE ENVIRONMENT AND LOCAL GOVERNMENT (1998A)
\textsuperscript{203} NATIONAL CONSTRUCTION AND DEMOLITION WASTE COUNCIL NCWDC (2005)
\textsuperscript{204} DERHAM (2006)
7.9.1.1 Construction and demolition waste

The Policy Statement ‘Changing Our Ways’ sets targets on the recycling rate of C&D waste. At least 50 % of C&D waste should be recycled by 2003, with a progressive increase to at least 85 % by 2013.

In order to provide a framework to achieve compliance with the policy and targets as set out by the Policy Document mentioned above and such other policies set from time to time by the Minister, in 2002 the National Construction and Demolition Waste Council (NCDWC) was established by the Forum for the Construction Industry. The NCDWC is a voluntary producer responsibility initiative to oversee the implementation of a broad range of recommendations of Task Force B4 ‘Recycling of Construction and Demolition Waste’.

The implementation of C&D policy is generally through the voluntary industry initiative (developed by the NCDWC in 2004/2005) and the adoption and implementation of regional waste management plans. The country is divided into 10 regions for waste planning purposes and plans are prepared and adopted every five years by the local authorities in each of the 10 regions.

Furthermore, the Council shall carry out research, prepare action plans and make recommendations on the measures/_steps that might be taken to ensure compliance with statutory requirements. NCDWC published a ‘Guide to construction & demolition waste legislation’ in 2004, which aims at explaining in simple terms the current waste legislation and the various waste regulations relevant to contractors and site managers and at explaining the impact that these regulatory controls have on the construction industry.

In July 2006 ‘Best Practice Guidelines on the Preparation of Waste Management Plans for Construction and Demolition Waste Projects’ were published. The Guidelines promote an integrated approach to the management of this waste stream. They are designed to promote sustainable development, environmental protection and the optimum use of resources. The Guidelines introduce the concept of integrated waste management planning for construction above certain threshold limits; as follows:

- New residential development of 10 houses or more;
- New development other than above including institutional, educational, health and other public facilities with an aggregate floor area in excess of 1,250 m²;
- Demolition/renovation/refurbishment projects generating in excess of 100 m³ of C&D waste;
- Civil engineering projects producing in excess of 500 m³ of waste excluding waste materials used for development works on the site.

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205 NATIONAL CONSTRUCTION AND DEMOLITION WASTE COUNCIL (2004)
206 ANONYMOUS (2006)
They apply to both public and private sector projects. The Guidelines provide details on what should be in the Plan to address sustainable waste management throughout all phases in the life of a project and provide information on the following:

- Analysis of the waste arisings/material surpluses;
- Specific waste management objectives of the project;
- Methods proposed for prevention, reuse and recycling of wastes;
- Material handling procedures;
- Proposals for educations of workforce and plan dissemination programme.

Since 1998 - according to the Waste Management Permit Regulations\textsuperscript{207} - the use/recovery of C&D waste can only take place at a site which has obtained a permit from the local authority or the Environment Protection Agency. This includes the use of inert soil for quarry restoration as well as the production of secondary aggregates in any case. These regulations do not specify any upper limit on the volumes of such materials recovered/produced by such activities. In the course of the general review of permitting regulations presently undertaken by the Department of the Environment and Local Government permitting processes shall be simplified and turnaround times shall be reduced by amending the regulation.

The survey ‘Environmental Management in the Extractive Industry (Non-Scheduled Minerals)’\textsuperscript{208} published by the EPA in 2006 notes that Ireland has a substantially higher aggregate demand per head of population than any other EU state. Nevertheless, up to now a particular difficulty in the reuse of recycled aggregates has been reluctance in the construction industry to use recycled aggregates in construction projects due to the lack of an appropriate standard and/or experience in the use of such materials. As an example most concrete specifications so far referred to the British Standard BS 882, Specification for Aggregates from Natural Sources for Concrete, for guidance on the acceptable properties of aggregates for use in concrete. It is expected that employment of the new European Standard for aggregates in concrete BS EN 12620, Aggregates for Concrete\textsuperscript{209}, which permits the use of recycled aggregates in the making of concrete, will encourage the use of recycled aggregates in concrete.

The ‘National Roads Authority Design Manual for Roads and Bridges’ (NRA DMRB) is a modified version of the British ‘Design Manual for Roads and Bridges’, which was formally introduced for use in Ireland from 2001. The DMRB provides a comprehensive manual system which accommodates all current standards, advice notes and other published documents relating to the design, assessment and operation of trunk roads (including motorways) in the United Kingdom\textsuperscript{210}. Since 2004 the NRA DMRB permits recycled concrete to be used for certain road base and sub-base materials. Clause 308 ‘Granular Material Type A’ allows the use of recycled crushed mixed concrete aggregates as defined in Annex A of IS EN 13285\textsuperscript{211}.

\textsuperscript{207} THE DEPARTMENT OF THE ENVIRONMENT AND LOCAL GOVERNMENT IRELAND (1998B)

\textsuperscript{208} IRELAND ENVIRONMENTAL PROTECTION AGENCY EPA (2006)

\textsuperscript{209} BRITISH STANDARDS INSTITUTE (2002)

\textsuperscript{210} NATIONAL ROADS AUTHORITY: \url{http://www.nra.ie}

\textsuperscript{211} NATIONAL STANDARDS AUTHORITY OF IRELAND (2004)
This allows for the inclusion of masonry as a component of the mix. Crushed masonry may include crushed concrete brick or block, or cut natural stone or rubble. Recycled materials will need to demonstrate ongoing conformity to factory production controls per the relevant European Standard, in this case IS EN 13285.

7.9.1.2 Slags from ferrous metal production

Slags from ferrous metal production are subject to the same legislation as C&D waste. However, no specific quantitative targets were set in the Policy Statement ‘Changing Our Ways’\textsuperscript{201} regarding the recovery rate.

The slags are considered on a case-by-case basis in the context of the waste/IPPC licence applicable to the facility generating the waste.

7.9.1.3 Ashes from coal combustion processes

Ashes from coal combustion processes are subject to the same legislation as C&D waste. However, no specific quantitative targets were set in the Policy Statement ‘Changing Our Ways’\textsuperscript{201} regarding the recovery rate.

The ashes are considered on a case-by-case basis in the context of the waste/IPPC licence applicable to the facility generating the waste.

7.9.2 Construction and demolition waste

C&D waste is generated primarily from the many construction projects which have been carried out over the past 5 years. These consist of housing projects (70,000 built in 2003) and large infrastructure projects, mainly motorways currently under construction. Demolition activity is increasing in urban areas with increased brown field development.

Data on the arising of C&D waste and excavation waste in Ireland is available for the years 1998\textsuperscript{212}, 2001\textsuperscript{213}, 2004\textsuperscript{214} and 2005\textsuperscript{215} from the National Waste Reports published by the Environmental Protection Agency.

Table 116 summarizes the amounts collected by authorised waste collection permit holders as well as those reported to be recovered and disposed of. The remarkable increase in the generation of construction and demolition waste since 2001 is likely to be due to two main contributing factors: increased infrastructure and housing development and improved and more comprehensive reporting. The discrepancy between the amounts collected and the total volume of C&D waste recovered and disposed of highlights the lasting need for quality improvement of data recording and reporting by waste operators and local authorities.

\textsuperscript{212} IRELAND ENVIRONMENTAL PROTECTION AGENCY (EPA) (1998)
\textsuperscript{213} IRELAND ENVIRONMENTAL PROTECTION AGENCY (EPA) (2001)
\textsuperscript{214} IRELAND ENVIRONMENTAL PROTECTION AGENCY (EPA) (2004)
\textsuperscript{215} IRELAND ENVIRONMENTAL PROTECTION AGENCY (EPA) (2005)
Table 116: Development of C&D and excavation waste generation and management in Ireland (in tonnes) (Ireland)²¹²-²¹⁵.

<table>
<thead>
<tr>
<th></th>
<th>C&amp;D waste</th>
<th>Soil &amp; Stones</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection total</td>
<td>2,254,896</td>
<td>2,675,605</td>
<td>2,285,624</td>
</tr>
<tr>
<td>Recovery (as cover/landscaping material and other landfill engineering purposes) at EPA-licensed landfills</td>
<td>807,033</td>
<td>354,946</td>
<td>281,374</td>
</tr>
<tr>
<td>Recovery at local authority permitted sites</td>
<td>661,317</td>
<td>1,490,087</td>
<td>708,852</td>
</tr>
<tr>
<td>Rate of recovery</td>
<td>65.1 %</td>
<td>69 %</td>
<td>43.3 %</td>
</tr>
<tr>
<td>Disposal at EPA-licensed landfills</td>
<td>750,297</td>
<td>13,162</td>
<td>8,857</td>
</tr>
<tr>
<td>Rate of disposal</td>
<td>34.9 %</td>
<td>31 %</td>
<td>56.7 %</td>
</tr>
</tbody>
</table>

Excavation waste is referred to as “Soil & Stones”. “C&D waste” is mixed C&D waste (concrete and rubble, as well as wood glass, metal and plastics). Data on the composition of the C&D waste stream is provided by a survey carried out in 1996 only (see Figure 38)²¹².

In Ireland dredge spoils arise mainly from harbour development and maintenance operations. Information provided by the Marine Institute indicates that in 1996 1,388,734 tonnes in 2001 1,257,000 tonnes of dredging spoil were disposed of at sea. There is no noticeable trend in the annual tonnages of dredging materials being disposed of and only an upper estimate for dredge spoil can be made based on permits issued for sea disposal under the Dumping at Sea Act, 1996.
A total of 13 permits were granted during 1998 of which 11 related to dredge spoil. The quantities permitted were the maximum amount allowed to be disposed of.

Up to now no data on waste generation by the construction industry is available. However, with the introduction of waste management planning into construction projects, this data should in time become available.

Initialized by the Environmental Protection Agency (EPA) a review of the environmental management practice (and related issues) within the construction industry was published in 2006\textsuperscript{216}. The review provides an assessment of the historical and future aggregate demand in Ireland. Future supply of primary aggregates (land-based and marine) and secondary (recycled) aggregate is discussed in the context of the future demand. Furthermore, it provides an estimation of the future supply of primary and secondary aggregates. Referring to C&D waste generation reported in the EPA’s National Waste Reports, the study straightens out that not all of the recovered soil and stone material would have been suitable for use as construction aggregates, and a significant portion of this material is used in the restoration of poorly drained lands to beneficial agricultural use. The authors propose that if conservatively (from the aggregate supply perspective) 50\% of the recovered “soil & stones” waste stream of 9.5 million tonnes in 2004 is considered suitable for reuse as secondary aggregates (i.e. 4.75 million tonnes per year) this would represent less than 5\% of the projected demand for construction aggregates. The key limiting factor is the relatively small volume of C&D waste stream (concrete, rubble etc.) available for recycling into secondary aggregates.

The Policy Statement ‘Preventing and Recycling Waste’\textsuperscript{217} illustrates that two facilities with significant capacity have been established for the processing of the construction and demolition waste that is delivered to municipal landfill sites in Dublin and Cork. There has also been an increased trend towards the crushing of demolition concrete and masonry for beneficial re-use as recycled aggregates on individual construction sites. The document summarizes that the Regional Waste Management Plans provide for the development of around 18 C&D waste recycling facilities, to be located close to major raw material sources and potential product markets. However, no information on the state of implementation is available.

\subsection*{7.9.3 Slags from ferrous metal production}

Data on the generation of slags from the ferrous metal production can be found in the National Waste Report 1998\textsuperscript{212}. The generation of waste from the processing of slag (EWC-Code: 10 02 01) was 35,000 tonnes. The means of obtaining information on industrial waste in 1998 is described in 7.9.4.

Data on treatment options of slag from the ferrous metal production is not available.

\textsuperscript{216} IRELAND ENVIRONMENTAL PROTECTION AGENCY (EPA) (2006)

\textsuperscript{217} DEPARTMENT OF THE ENVIRONMENT AND LOCAL GOVERNMENT IRELAND (2002)
7.9.4 Ashes from coal combustion processes

Data on the generation of ashes from the coal combustion processes can be found in the national waste reports 2004\textsuperscript{214}, 2001\textsuperscript{213} and 1998\textsuperscript{212}. Table 117 shows the development of arising and management options.

Table 117: Development of arising and management of coal ashes and management in Ireland (in tonnes) (Ireland).

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Coal fly ash</th>
<th>Bottom ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWC-Code</td>
<td>10 01 02</td>
<td>10 01 01</td>
</tr>
<tr>
<td></td>
<td>1998\textsuperscript{a}</td>
<td>2001\textsuperscript{b}</td>
</tr>
<tr>
<td>Arising</td>
<td>194,301</td>
<td>202,950</td>
</tr>
<tr>
<td>Management options</td>
<td></td>
<td>148,781</td>
</tr>
</tbody>
</table>

a… The principal means of obtaining information on industrial waste in 1998 was through a questionnaire for all industries employing twenty five people or more in the industrial manufacturing sector. The questionnaire classified waste according to the European List of Waste (LoW) and the Hazardous Waste List (HWL). Numerical and statistical methods were used to extrapolate the data obtained from the questionnaire (response rate: 23.1 \%) responses to estimate national waste quantities.

b… 2001 an estimate was made of industrial waste generation and management based on information provided by 307 IPC-licensed companies and 159 non-IPC-licensed companies.

c… Industrial waste generation in 2004 is estimated from information provided by a total of 433 companies: 289 IPPC-licensed companies, from their annual environmental reports; and 144 non-IPPC licensed companies, by way of sample survey.


7.10 Italy

7.10.1 Existing standards and regulation

According to Decree 22/97\textsuperscript{218} the waste management system is based on: a) prevention of waste generation (to be developed in national and local waste plans); b) material and energy recovery from waste. The decree established that permits for incineration plants should be granted only if the plant had an energy recovery system and that waste disposal must be reduced as much as possible. The issuing of decree 22/97 gave input to many actions for waste prevention and recycling in Italy\textsuperscript{218}.

At local level several agreements have been signed in the field of agricultural waste and construction & demolition waste.

The Ministerial Decree of 5\textsuperscript{th} of February 1998\textsuperscript{219} stipulates the recovery of non-hazardous waste. Construction and demolition waste, ashes and slags are covered by the degree. Table 118 shows leaching limits defined for the recovery of waste.

*Table 118: Leaching limits obtained for different recovery activities (Italy)\textsuperscript{219}.*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit of measurement</th>
<th>Limit\textsuperscript{220}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrates NO\textsubscript{3}</td>
<td>mg/l</td>
<td>50</td>
</tr>
<tr>
<td>Fluoride F</td>
<td>mg/l</td>
<td>1.5</td>
</tr>
<tr>
<td>Sulphate SO\textsubscript{4}</td>
<td>mg/l</td>
<td>250</td>
</tr>
<tr>
<td>Chlorides Cl</td>
<td>mg/l</td>
<td>100</td>
</tr>
<tr>
<td>Cyanides Cn</td>
<td>µg/l</td>
<td>50</td>
</tr>
<tr>
<td>Barium Ba</td>
<td>mg/l</td>
<td>1</td>
</tr>
<tr>
<td>Copper Cu</td>
<td>mg/l</td>
<td>0.05</td>
</tr>
<tr>
<td>Zinc Zn</td>
<td>mg/l</td>
<td>3</td>
</tr>
<tr>
<td>Beryllium Be</td>
<td>µg/l</td>
<td>10</td>
</tr>
<tr>
<td>Cobalt Co</td>
<td>µg/l</td>
<td>250</td>
</tr>
<tr>
<td>Nickel Ni</td>
<td>µg/l</td>
<td>10</td>
</tr>
<tr>
<td>Vanadium V</td>
<td>µg/l</td>
<td>500</td>
</tr>
<tr>
<td>Arsenic As</td>
<td>µg/l</td>
<td>50</td>
</tr>
<tr>
<td>Cadmium Cd</td>
<td>µg/l</td>
<td>5</td>
</tr>
<tr>
<td>Chromium total Cr</td>
<td>µg/l</td>
<td>50</td>
</tr>
<tr>
<td>Lead Pb</td>
<td>µg/l</td>
<td>50</td>
</tr>
<tr>
<td>Selenium Se</td>
<td>µg/l</td>
<td>50</td>
</tr>
<tr>
<td>Mercury Hg</td>
<td>µg/l</td>
<td>1</td>
</tr>
<tr>
<td>Asbestos</td>
<td>mg/l</td>
<td>30</td>
</tr>
<tr>
<td>COD</td>
<td>mg/l</td>
<td>30</td>
</tr>
<tr>
<td>pH</td>
<td>-</td>
<td>5.5 – 12.0</td>
</tr>
</tbody>
</table>

\textsuperscript{218} MINISTRY OF ENVIRONMENT (1997)

\textsuperscript{219} MINISTRY OF ENVIRONMENT (1998)

\textsuperscript{220} Valid test method: BS EN 12457-2:2002: Characterisation of waste, Leaching, Compliance test for leaching of granular waste materials and sludges. One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 4 mm (without or with size reduction).
7.10.1.1 Construction and demolition waste

Construction and demolition wastes listed in Table 7 are covered by the Ministerial Decree for the recovery of non-hazardous waste. Table 120 shows possible recovery activities for the covered waste streams.

Table 119: Inert waste from construction and demolition activities suitable for recovery (Italy)

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 13 11</td>
<td>Wastes from cement-based composite materials other than those mentioned in 10 13 09 and 10 13 10</td>
</tr>
<tr>
<td>17 01 01</td>
<td>Concrete</td>
</tr>
<tr>
<td>17 01 02</td>
<td>Bricks</td>
</tr>
<tr>
<td>17 01 03</td>
<td>Tiles and ceramics</td>
</tr>
<tr>
<td>17 01 07</td>
<td>Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06</td>
</tr>
<tr>
<td>17 08 02</td>
<td>Gypsum-based construction materials other than those mentioned in 17 08 01</td>
</tr>
<tr>
<td>17 09 04</td>
<td>Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03</td>
</tr>
<tr>
<td>20 03 01</td>
<td>Mixed municipal waste</td>
</tr>
</tbody>
</table>

Table 120: Recovery activities for waste coming from construction and demolition (Italy)

<table>
<thead>
<tr>
<th>Code</th>
<th>Activities</th>
<th>Leaching limits obligatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>R5</td>
<td>Substrates for road, railway and airport construction</td>
<td>X</td>
</tr>
<tr>
<td>R5</td>
<td>Production of secondary raw materials (including mechanical treatment)</td>
<td>X</td>
</tr>
<tr>
<td>R10</td>
<td>Environmental recovery - Land treatment resulting in benefit to agriculture or ecological improvement</td>
<td>X</td>
</tr>
<tr>
<td>R13</td>
<td>Storage</td>
<td>X</td>
</tr>
</tbody>
</table>

7.10.1.2 Slags from ferrous metal production

Wastes from ferrous metal production listed in Table 121 are covered by the Ministerial Decree for the recovery of non-hazardous waste. Table 122 shows possible recovery activities for the covered waste streams.

Table 121: Waste from ferrous metal production suitable for recovery (Italy)

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 02 01</td>
<td>wastes from the processing of slag</td>
</tr>
<tr>
<td>10 02 02</td>
<td>unprocessed slag</td>
</tr>
<tr>
<td>10 09 03</td>
<td>furnace slag</td>
</tr>
</tbody>
</table>
Table 122: Recovery activities for waste coming from ferrous metal production (Italy)\(^{219}\).

<table>
<thead>
<tr>
<th>Code</th>
<th>Activities</th>
<th>Leaching limits obligatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>R4</td>
<td>Steel mills and foundries with recovery of ferrous and non-ferrous metals</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>Cement industry</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>Production of concrete and bituminous conglomerates</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>Glass industry</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>Substrates for road and railway construction</td>
<td>X</td>
</tr>
<tr>
<td>R5</td>
<td>Covering landfills with a maximum of 30% of waste (by weight) mixed to the covering layer</td>
<td>X</td>
</tr>
<tr>
<td>R10</td>
<td>Environmental utilization - Land treatment resulting in benefit to agriculture or ecological improvement</td>
<td>X</td>
</tr>
</tbody>
</table>

Concrete, bituminous conglomerates and cement for construction and brick can be marketed\(^{219}\).

7.10.1.3 Ashes from coal combustion processes

Wastes from burning of coal and lignite listed in Table 123 are covered by the Ministerial Decree for the recovery of non-hazardous waste. Table 124 shows possible recovery activities for the covered waste streams. In general in PCDD concentration must not exceed 2.5 ppb; PCB and PCT must not exceed 25 ppm.

Table 123: Ash from burning of coal and lignite suitable for recovery (Italy)\(^{219}\).

<table>
<thead>
<tr>
<th>Code</th>
<th>Waste type</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10 01 01</td>
<td>Bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)</td>
<td></td>
</tr>
<tr>
<td>10 01 02</td>
<td>Coal fly ash</td>
<td></td>
</tr>
<tr>
<td>10 01 03</td>
<td>Fly ash from peat and untreated wood</td>
<td></td>
</tr>
<tr>
<td>10 01 15</td>
<td>Bottom ash, slag and boiler dust from co-incineration other than those mentioned in 10 01 14</td>
<td></td>
</tr>
<tr>
<td>10 01 17</td>
<td>Fly ash from co-incineration other than those mentioned in 10 01 16</td>
<td></td>
</tr>
</tbody>
</table>

Table 124: Recovery activities for ash from burning of coal and lignite (Italy)\(^{219}\).

<table>
<thead>
<tr>
<th>Code</th>
<th>Activities</th>
<th>Leaching limits obligatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>R5</td>
<td>Cement industry</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>Production of cement conglomerates</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>Brick industry and expanded clay production industry</td>
<td></td>
</tr>
</tbody>
</table>

Concrete, cement conglomerates, clay bricks and expanded forms usually can be marketed\(^{219}\).
7.10.2 Construction and demolition waste

In 2004, approximately 46.5 million tons of waste from construction and demolition were generated, the percentages recorded in the North, the Centre and the South of the country were respectively, 61.5%, 20.5%, and 18%\textsuperscript{221}.

A particularly significant growth is observed for the operation identified by code ‘R5’ (recycling / recovery of other inorganic materials) caused by a high percentage of waste resulting from construction activities and demolition as well as construction or reconstruction works of the road.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|}
\hline
Waste (in million tons) & 2002 & 2003 & 2003 \\
\hline
Waste from construction and demolition & 37.3 & 42.5 & 46.5 \\
\hline
\end{tabular}
\caption{Table 125: Generation of construction and demolition waste 2002-2004\textsuperscript{221}.}
\end{table}

7.10.3 Slags from ferrous metal production

No results and no feedback.

7.10.4 Ashes from coal combustion processes

No results and no feedback.

\textsuperscript{221} AGENCY FOR ENVIRONMENTAL PROTECTION AND TECHNICAL SERVICES – APAT (2005)
7.11 Luxembourg

7.11.1 Existing standards and regulation

Complying with article 20 of the ‘Loi du 17 juin 1994 relative à la prévention et à la gestion des déchets’ the reuse of the inert materials is obligatory according to accompanying documentation on public applications for road construction or other works.  

Apart from this, there are no existing standards or legislation (laws, ordinances, guidelines, agreements, etc.) concerning recovery of certain waste streams.


7.11.2 Construction and demolition waste

Table 126: Construction and demolition waste in Luxembourg

<table>
<thead>
<tr>
<th>Tons</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generated</td>
<td>6,306,543</td>
<td>5,545,630</td>
<td>6,901,572</td>
<td>7,802,118</td>
</tr>
<tr>
<td>Recycled</td>
<td>3,096,000</td>
<td>1,714,423</td>
<td>2,291,912</td>
<td>3,583,400</td>
</tr>
<tr>
<td>Disposed</td>
<td>3,210,000</td>
<td>3,827,496</td>
<td>4,599,457</td>
<td>4,216,470</td>
</tr>
<tr>
<td>Sorted</td>
<td>543</td>
<td>2,687</td>
<td>2,977</td>
<td>2,147</td>
</tr>
<tr>
<td>Incinerated</td>
<td>0</td>
<td>1,025</td>
<td>7,226</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 126 shows the generated, recycled, incinerated and disposed of amounts of construction and demolition waste in Luxembourg for 2002-2005.

7.11.3 Slags from ferrous metal production

Table 127: Slags from ferrous metal production in Luxembourg

<table>
<thead>
<tr>
<th>Tons</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generated</td>
<td>220,875</td>
<td>320,351</td>
<td>280,142</td>
<td>434,620</td>
</tr>
<tr>
<td>Recycled</td>
<td>99.996%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Disposed (Germany)</td>
<td>0.004%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 127 shows the generated, recycled and disposed amounts of slags from ferrous metal production in Luxembourg for 2002-2005. The slags were mainly recycled in Luxembourg. Only in 2002 were disposed of small amounts in Germany.

222 ADMINISTRATION DE L’ENVIRONNEMENT (2000)
223 CONTACT LUXEMBOURG 01 (2007)
7.11.4 Ashes from coal combustion processes

Table 128: Bottom ash, slag and boiler dust from coal combustion processes in Luxembourg.

<table>
<thead>
<tr>
<th>Tons</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generated</td>
<td>40</td>
<td>49,775</td>
<td>60,878</td>
<td>71,515</td>
</tr>
<tr>
<td>CP treatment (in Luxembourg)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lime works (in Germany)</td>
<td>40</td>
<td>425</td>
<td>-</td>
<td>92</td>
</tr>
<tr>
<td>Cement kiln production (in Luxembourg)</td>
<td>-</td>
<td>49,350</td>
<td>60,878</td>
<td>71,147</td>
</tr>
<tr>
<td>Disposal (in Germany)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>277</td>
</tr>
</tbody>
</table>

Table 128 shows the generated amounts of bottom ash, slag and boiler dust (EWC 100101) from coal combustion processes in Luxembourg for 2002-2005.
7.12 Malta

Construction and demolition waste in Malta is composed of basic inert materials like soft stone, hard stone, concrete and other materials such as timber, metals, especially iron, plastics and textiles and additional materials for surface treatment, like chemicals for timber, colours and paints. During the last 40 years, the construction industry has increasingly made use of concrete, thus the amount of concrete from the demolishing activities becomes more and more important.

Construction and demolition waste is not yet recycled in Malta. It has been estimated that for Malta there could be up to 34 years of soft stone reserves available and 38 years of hard stone reserves. From the point of view of national raw materials reserves one key element of policy approach is the need to maximise the contribution of alternative supplies, particularly through recycling. As the revised “Solid Waste Management Strategy, Draft 2006” has not been published until now it can only be guessed that legislation in favour of the separation of C & D wastes is in development.

After 1995 no coal was imported for power generation in Malta\textsuperscript{82} which means that nowadays no ashes from coal combustion processes are generated in Malta.

Ferrous metal production does not exist in Malta and therefore no slags from this production are generated.

7.12.1 Existing standards and regulation

No specific national standards or regulation until now.

7.12.2 Construction and demolition waste

The available information on the quantities of construction and demolition waste in Malta is not very consistent. There are four different sources for information on these wastes.

There are weigh bridge data on inert waste that stem from the disposal facilities which are operating as contractors for WasteServ Malta Ltd. These facilities received:

\begin{itemize}
  \item 761,883 to in the year 2003
  \item 2,177,861 to in the year 2004
  \item 1,185,174 to in the year 2005 and
  \item 865,713 to in the year 2006
\end{itemize}

The 'State of the Construction Industry Report 2005\textsuperscript{224} published by the Maltese Building Industry Consultative Council (BICC) highlights the sectors generating construction and demolition waste and the amounts in tons (see Table 129).

\textsuperscript{224} MALTESE BUILDING INDUSTRY CONSULTATIVE COUNCIL BICC (2005)

<table>
<thead>
<tr>
<th>Sector</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining and Quarrying</td>
<td>1,094,850</td>
<td>1,167,130</td>
<td>2,187,780</td>
<td>1,196,310</td>
</tr>
<tr>
<td>Construction</td>
<td>247,970</td>
<td>171,810</td>
<td>28,170</td>
<td>9,360</td>
</tr>
<tr>
<td>Total</td>
<td>1,342,820</td>
<td>1,338,940</td>
<td>2,215,950</td>
<td>1,205,670</td>
</tr>
</tbody>
</table>

The drop in construction waste since 2002 is not the result of a lack of production of waste from this sector but a result of a change in disposal patterns. In fact, disused quarries are being used for the disposal of construction related waste, and therefore all the waste from the industry that is disposed in these quarries is recorded under the mining and quarrying sector.

Data are also available from the Malta Environment Planning Authority (MEPA) on construction and demolition waste that is dumped at sea. The estimated amount of excavated rock deposited at sea would be as follows:

- 513,628 tons from March 2003 until January 2006
- 299,000 tons from March 2006 until October 2006
- 35,567 tons from November 2006 until March 2007

Another reliable data source is the MEPA ‘Updated reporting on disused quarries 2006’ (May 2007) which estimates the void space for refilling in disused quarries and quarries under operation. Following this report there should be the following void quarry space (operating and disused quarries):

- 37,712,433 m³ in Malta and
- 2,520,960 m³ in Gozo

The report also states that not all of the void space can be used for infilling of construction and demolition waste because the quarries are also used for other purposes. The lifespan for infilling could be estimated by (a) assuming future amounts of construction and demolition/excavation waste, (b) assuming the percentage of the void space to be really available for infilling and (c) assuming future quarrying activities.

Concluding it can be said that for the years 2004 and 2005 the weighed amounts are very similar to the reported amounts from the NSO. Adding the amounts of construction and demolition waste dumped at sea the entire quantity is estimated to be between 1.4 Mio tons/year and 2.4 Mio tons/year; of this, 80 % is soil excavation waste and 100,000 to 200,000 to/year concrete from the demolishing activities.

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225 MALTA ENVIRONMENT PLANNING AUTHORITY MEPA (2007)
7.13 Netherlands

In 2005 a total amount of 48.2 million tons of aggregates were produced in the Netherlands. 20.2 million tons were recycled aggregates coming from construction and demolition waste used in aggregates market. The amount of the secondary aggregates including blast-furnace slag, electric-arc-furnace slag, incinerator bottom ash (IBA), pulverised fuel ash (PFA) and other industrial and extraction by-products for construction and civil engineering is unknown.

7.13.1 Existing standards and regulation

Relevant policy documents and laws are\textsuperscript{226}.

\textit{The Building Materials Decree (Bouwstoffenbesluit')}:

The aim of the Building Materials Decree is to prevent pollution of the soil and surface water. The standards with which building materials are required to comply therefore relate to the chemical composition and leaching behaviour of materials. On the basis of these, building materials are grouped into categories and conditions are attached to the categories for use of these materials.

Basic Elements of the Building Material Decree are\textsuperscript{227}:

- Applicable to all primary and alternative materials such as those derived from mineral by-products;
- Leaching considered as main release process to assess environmental impact;
- No mixing of construction materials and soil;
- Distinction between granular (percolation) and monolithic materials (diffusion);
- Distinction between a free-use category and a category with restricted use i.e. isolation measures needed and requirement for use at least 0.5 meter above groundwater level.

The Decree divides materials in four applicable categories (clean soil, category 1 building materials, category 2 building materials and a 'special category'). It states that especially category 2 materials need insulation measures and have to meet additional requirements.

Category 1 building materials are building materials whose composition and immission values for the various substances do not exceed those stipulated in the Building Materials Decree when the materials are used. Use of these building materials is permitted without measures, or additional measures, being required to protect the environment.

Category 2 building materials are building materials whose composition values do not exceed those stipulated in the Building Materials Decree but whose immission values would if additional isolation measures were not taken. Materials that do not fall into category 1 or category 2 may not be used as a building material.

\textsuperscript{226} MINISTRY OF TRANSPORT, PUBLIC WORKS AND WATER MANAGEMENT (2003)
\textsuperscript{227} VAN DER SLOOT & EIKELBOOM (2007)
The principle grouping is into category 1 and category 2 building materials. Besides this main grouping there are another three special categories of building materials, viz. earth, bottom ash from waste incineration plants and tarry asphalt aggregate.

The quality requirements of the Building Materials Decree have resulted in improved construction and demolition waste acceptance and processing. Also it has resulted in certifications and batch inspections, and companies specialised in these fields.

It includes criteria for leaching of contaminants from these materials, which are used to determine whether materials are applicable or not, and whether isolation measures are required. The Building Materials Decree has resulted in improved construction and demolition waste acceptance and processing.  

Table 130: Composition and immission standards for building materials, not being clean earth (Netherlands).

<table>
<thead>
<tr>
<th>Substance</th>
<th>Immission standards (mg/m² per 100 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals</strong></td>
<td></td>
</tr>
<tr>
<td>Sb</td>
<td>39</td>
</tr>
<tr>
<td>As</td>
<td>435</td>
</tr>
<tr>
<td>Ba</td>
<td>6,300</td>
</tr>
<tr>
<td>Cd</td>
<td>12</td>
</tr>
<tr>
<td>Cr</td>
<td>1,500</td>
</tr>
<tr>
<td>Co</td>
<td>300</td>
</tr>
<tr>
<td>Cu</td>
<td>540</td>
</tr>
<tr>
<td>Hg</td>
<td>4.5</td>
</tr>
<tr>
<td>Pb</td>
<td>1,275</td>
</tr>
<tr>
<td>Mo</td>
<td>150</td>
</tr>
<tr>
<td>Ni</td>
<td>525</td>
</tr>
<tr>
<td>Se</td>
<td>15</td>
</tr>
<tr>
<td>Sn</td>
<td>300</td>
</tr>
<tr>
<td>V</td>
<td>2,400</td>
</tr>
<tr>
<td>Zn</td>
<td>2,100</td>
</tr>
<tr>
<td><strong>Other inorganic compounds</strong></td>
<td></td>
</tr>
<tr>
<td>Bromide</td>
<td>300</td>
</tr>
<tr>
<td>Chloride</td>
<td>30,000</td>
</tr>
<tr>
<td>Cyanide (free)</td>
<td>15</td>
</tr>
<tr>
<td>Cyanide (complex)</td>
<td>75</td>
</tr>
<tr>
<td>Fluoride</td>
<td>14,000</td>
</tr>
<tr>
<td>Thiocyanates (sum)</td>
<td>-</td>
</tr>
<tr>
<td>Sulphate</td>
<td>45,000</td>
</tr>
</tbody>
</table>

The category into which a building material falls determines what is or is not permitted or required with a building material and what conditions must be complied with for its use. The category also determines the procedural requirements the owner or principal has to comply with.  

---

The Soil Quality Decree ('Besluit Bodemkwaliteit'):

Following an evaluation, it was decided to simplify the Building Materials Decree and reduce the administrative burden it entails. The critical loads in the Building Materials Decree were replaced by emission limit values in the Soil Quality Decree which went into effect in 2007. New critical loads have been computed for the Soil Quality Decree which is protective for soil, groundwater and surface water.

The new decree simplifies the use of building materials and simplifies the burden of proof for a number of building materials through the use of the declaration of conformity for a great many of them. This means that production is no longer externally supervised, so that compulsory inspections are eliminated as well. It also means there is a clear-cut link between the standards for the maximum allowable quantity of certain substances to be introduced into soil and groundwater and for environmental risks. The standard primarily focuses on the product and does not differentiate several situations in its use. The decree is based on the principle: the smaller the risks, the more limited the rules. 229

The Soil Quality Regulation (Preliminary draft, Version 6.0 – 10 October 2006):

Under the Soil Quality Decree, building materials must meet the requirements laid down in Annex A of the Soil Quality Regulation. The list of requirements in this ministerial regulation distinguishes between moulded building materials, such as concrete and bricks, and non-moulded building materials, such as ash and granules. This distinction is made because the leaching process differs for materials of both types and must therefore also be measured differently. The ministerial regulation sets out how it can be established when a building material is moulded or not. Besides the requirement concerning the minimum volume, this involves sustainable non-deformability and diffusion-controlled leaching.

Un-moulded building materials that cannot meet the emission requirements, but which can meet the emission requirements for IBC building materials, may only be used as IBC building material under insulating facilities. The compositional requirements in Annex A are the same for all types of building materials.

The Building Decree ('Bouwbesluit'):

The Building Decree ('Bouwbesluit') contains the minimum technical requirements for all buildings like houses, offices and shops. The requirements relate to security, health, usefulness, effective use of energy and the environment. The Building Decree was effectuated in 1992 establishing similar requirements for the entire country. On 1 January 2003 a new version of the Building Decree was effectuated. 226

The Construction and Demolition Waste Dumping Ban:

On 1 January 1997 the Waste Substances (Prohibition of Landfill) Decree banned the landfilling of recyclable building and demolition waste. The ban was subsequently extended to include combustible building and demolition waste.

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229 MINISTRY OF FINANCE – INTERMINISTERIAL PROJECT UNIT FOR ADMINISTRATIVE BURDENS (2006)
Since April 2000, most landfill sites have obtained an exemption from the ban on the landfilling of building and demolition waste, however. As long as the exemption remains valid, building and demolition waste can be dumped there. These exemptions were granted because for the moment there is insufficient capacity for recovery or incineration of the combustible fraction of building and demolition waste. Landfilling this fraction is unattractive, however, because of the high landfill tax.

This Dumping Ban forbids dumping of reusable construction and demolition waste (like the residual sieve sand from the processing of construction and demolition waste), non-re-usable flammable construction and demolition waste (that often can be burned due to the overcapacity of waste incinerators) and the use of construction and demolition waste without processing. The Dumping Ban has also led to issuing certificates to sorting companies, as dumping sites may only accept residue from certified companies that give a label to the supplied residue if it contains less than 12% re-usable material. In this way the Dumping Ban also promotes improvement of separation and purification techniques, which leads to an increased quality of re-usable material.

**Provincial Environmental Regulations:**

As waste removal is primarily organised at regional (provincial) level, the provincial authorities are important in creating Provincial Environmental Regulations that are executed in the Provincial Environmental Policy Plan. According to these rules, quantities of waste materials received by the collectors and processing contractors must be reported quarterly, and transport of corporate waste between provinces without prior permission is prohibited. In this way unnecessary waste transport and non-use of the capacity of provincial processing plants and dumping sites is prevented.

Four instruments are presently under preparation to stimulate the sustainable use of secondary and recycled raw materials:

- **The draft decree amending the dumping ban on waste substances decree:**
  A dumping ban is imposed on a further six categories of waste substances in the draft decree amending the dumping of waste substances decree. The original decree has been amended and supplemented on a number of points. The description of the ‘soil’ category, for instance, has been amended in such a way that the dumping ban also applies to the categories clean soil, category 1 and category 2 soil.

- **The fifth pillar of the Building Decree:**
  The ‘fifth pillar’ of the Building Decree is expected to embed a minimum level of sustainable material usage in law.

- **The National Waste Management Plan:**
  The National Waste Management Plan of the Ministry of Housing, Spatial Planning and the Environment will comprise policy for waste management, partly aimed at the provision of secondary building materials.

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\[226^M\text{INISTRY OF THE ENVIRONMENT AND SPATIAL PLANNING OF THE NETHERLANDS (2001)}\]
The National Waste Management Plan came into effect in late 2002. In this plan, the government describes the waste policy for the next four years, giving an outlook until 2012.

The Waste Management theme replaces the “Disposal” theme. Waste management includes the entire chain of waste segregation at source, collection, transport, storage, processing, recovery and removal. The prevention of waste precedes waste management and is therefore not formally covered by the term. The policy for this area is discussed as part of this theme.

The Ministry uses new terms and definitions in the National Waste Management Plan for dealing with waste. They are better adapted to European regulations than the old terms. Important changes include:

- the term ‘disposal’ (the total chain) has been replaced by ‘management’ or ‘waste management’;
- the term ‘final disposal’, mainly incineration in a waste incinerator and landfill, has been replaced by ‘disposal’;
- the term ‘recovery’ is now the umbrella term for reuse, recycling and the use of waste principally as fuel. This is justified by an amendment to the Environmental Management Act in May 2002.

The definition above means that recovery is broader than reuse. Alongside reuse (for example returnable glass) and recycling (such as one-way glass, paper, metals), recovery now also includes the use of waste principally as fuel. This involves, for example, use as fuel in cement kilns and in power plants and the incineration in their own facilities by industrial and manufacturing companies in the industry target sector (in so far as that includes energy extraction). To date, such applications have been classified as ‘incineration’.

The concept of discharging waste to surface water will also apply to the discharge of treated water separated during the processing of liquid waste streams (such as ship-generated waste). Until now, the Ministry used the term ‘discharge’ to describe the actual discharge of a waste substance into surface water. At the end of the 1990s, incidentally, this was confined exclusively to phosphor-gypsum, a waste stream from the fertiliser industry, discharges of which stopped in 2000.

The waste policy follows a hierarchy in waste management, which corresponds broadly to ‘Lansink’s Ladder’ (named after the proposer of the motion passed unanimously by the Dutch Lower House in 1979). The hierarchy is as follows:

- waste prevention (highest priority);
- the highest possible quality of recovery. In so far as recovery in the form of reuse or recycling is not possible, high priority is given to using the energy content of waste by using it (after post-separation) as fuel in installations with high energy yields;
- incineration as a form of disposal, using the energy generated;
- landfill (the least desirable processing method).
The National Waste Management Plan states, as the objectives for 2012:

- increasing the relative decoupling that has already been achieved of the gross domestic product and the total waste supply by continuing and intensifying the prevention policy;
- increasing the level of waste recovery to 83% by 2012;
- limiting the amount of waste for disposal to 9.5 billion kg, of which 2 billion kg will be waste destined for landfilling.

**The incentive scheme for the processing of contaminated dredging material:**

The Ministry of Transport, Public Works and Water Management has also decided to financially support the processing of contaminated dredging material into a material that can be used in the building industry with a sum of 41 million Euro over a period of four years.

The Designation of Hazardous Wastes Decree (BAGA) specifically states that building and demolition waste is not hazardous waste if, following selective disposal, it is free of lead, asphalt and contaminated packaging materials for a number of named products.

### 7.13.2 Construction and demolition waste

Table 131 shows the amount of the generation and disposal of construction and demolition waste in the Netherlands for the period 1985-2001.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Reuse</td>
<td>6.1</td>
<td>9.3</td>
<td>12.8</td>
<td>14.9</td>
<td>15.8</td>
<td>16.6</td>
<td>18.0</td>
<td>18.4</td>
</tr>
<tr>
<td>Incineration</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Landfill</td>
<td>6.1</td>
<td>3.2</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

The increase in the amount of construction and demolition waste by more than half since 1990 has outstripped the growth of the economy. There has been a major increase in the reuse of construction and demolition waste. In 1990, this was still between 70 and 75%. Estimated recovery in recent years has been almost 95%. Almost all the stony construction and demolition waste is transformed in crushing plants into granulate for recovery (mainly in road construction). Large quantities of wood are also recovered. The substantial rise in the landfill charges has been a powerful moving force in this respect.

Around 1995, the quantity of construction and demolition waste sent to landfill stabilised at approximately 1 billion kg. In early 2000, landfilling was banned for construction and demolition waste which could be incinerated or reused.

In 2000, 94% of the construction and demolition waste were reused or recycled and about 20% of all building materials consisted of secondary materials.

---

231 ENVIRONMENTAL DATA COMPENDIUM: [http://www.mnp.nl](http://www.mnp.nl)
The composition of the construction and demolition waste is as follows:

Table 132: Composition of Construction and demolition waste (Netherlands)\textsuperscript{230}.

<table>
<thead>
<tr>
<th>Composite</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>40</td>
</tr>
<tr>
<td>Asphalt</td>
<td>26</td>
</tr>
<tr>
<td>Masonry</td>
<td>25</td>
</tr>
<tr>
<td>Gravel</td>
<td>2</td>
</tr>
<tr>
<td>Timber</td>
<td>1,5</td>
</tr>
<tr>
<td>Packaging</td>
<td>1</td>
</tr>
<tr>
<td>Metal</td>
<td>1</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>5,5</td>
</tr>
</tbody>
</table>

In 2005 25.8 million tons construction and demolition waste were generated in the Netherlands. 24.6 million tons were recovered and only 0.9 million tons were landfilled. Thus the total recovery rate is 95%.

The export of construction and demolition waste (CDW) has risen sharply in the last two years. In 2002, 940 kilotons were exported, mainly to Germany. There are various reasons for the increase in exports of this waste in the last two years.

- The Netherlands has no facilities for firing the high-calorific fractions, especially the ones which are produced after sorting/treatment.
- The requirements for using waste as a building material are not as strict in Germany.
- A high rate has to be paid in the Netherlands to dispose of combustible waste at landfill sites, in part due to the high landfill tax. It is cheaper in Germany to dispose of the post-sorting non-recoverable waste in landfills than it is in the Netherlands.

There are also financial and other incentives that invite illegal operations. Landfilling is cheaper in Germany than in the Netherlands. Also, the managers of German waste disposal sites have every interest in filling their sites as quickly as possible on account of the impending landfill ban. This provides an incentive not to sort imported waste, as is required, but to dispose of it immediately in landfills.

\textbf{Quality control measures for secondary and recycled raw materials:}

Technical specifications for secondary aggregates in road construction have primarily been developed to standardize the load-bearing capacity. The so called RAW Standards (Rationalization and Automation in Road Construction), developed by the CROW includes minimum shares of high-strength particles (i.e. of crushed concrete and stone fragments with a minimum dry density of 16 t/m\textsuperscript{3}), and maximum shares of low strength particles (e.g. asphalt fragments or porous stone fragments; see Table 133).
Table 133: Quality parameters for secondary aggregates in road construction (Netherlands).

<table>
<thead>
<tr>
<th>Aggregate Type</th>
<th>Main Component</th>
<th>Side Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled concrete aggregate</td>
<td>min. 80% crushed concrete with dry density &gt; 2100 kg/m³</td>
<td>max. 10% different stone and max. 5% asphalt</td>
</tr>
<tr>
<td>Recycled masonry aggregate</td>
<td>min. 85% crushed stone with dry density &gt; 1600 kg/m³</td>
<td>max. 15% different stone and max. 10% asphalt</td>
</tr>
<tr>
<td>Recycled mixed aggregate</td>
<td>min. 50% crushed concrete with dry density &gt; 2100 kg/m³ and max. 85% crushed stone with dry density &gt; 1600 kg/m³</td>
<td>max. 10% different stone and max. 5% asphalt</td>
</tr>
</tbody>
</table>

Technical requirements of secondary aggregates for use in concrete have been defined to prevent damaging effects arising from the physical and chemical properties of individual particles (e.g. the effect on cement hardening and concrete strength, or post-hardening reactivity).
Table 134 Requirements for secondary aggregates in concrete. The NEN standards referred to can be obtained from Dutch Normalization Institute (NNI/NEN, Delft) (Netherlands).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Requirement</th>
<th>Determination method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading</td>
<td></td>
<td>Comparable to natural aggregate</td>
<td>NEN 5916</td>
</tr>
<tr>
<td>Particle shape</td>
<td></td>
<td>Critical shape recommended</td>
<td></td>
</tr>
<tr>
<td>Flat components</td>
<td>m/m</td>
<td>&lt;40%</td>
<td>NEN 5935</td>
</tr>
<tr>
<td>Round components</td>
<td></td>
<td>limited share when used in concrete for (road) pavements</td>
<td></td>
</tr>
<tr>
<td>Shell content</td>
<td>m/m</td>
<td>&lt;10% of carbonates in coarse aggregates</td>
<td>NEN 5922</td>
</tr>
<tr>
<td>% fines</td>
<td>m/m</td>
<td>grade 0-1 mm: &lt;10% grades 0-2 and 0-4 mm: &lt; 4.0% coarser grades: &lt; 3.0%</td>
<td>NEN 5917</td>
</tr>
<tr>
<td>Aggregate composition</td>
<td>m/m</td>
<td>Recycled concrete aggregate: concrete content &gt;90%, LA-value &lt;40. Recycled coarse aggregates: concrete content &gt;50%, LA-value &lt;50. Bitumen, rubber, metals, glass, etc. &lt;1.0%</td>
<td>NEN 1079</td>
</tr>
<tr>
<td>Non-stony admixtures</td>
<td>V/V</td>
<td>Bitumen, rubber, metals, glass, etc. &lt;1%</td>
<td></td>
</tr>
<tr>
<td>Chlorides</td>
<td>m/m</td>
<td>Grades 0-4 mm non reinforced: &lt;1.0% reinforced: &lt;0.1% pre-stressed: &lt;0.03%</td>
<td>NEN 5921</td>
</tr>
<tr>
<td>Sulphates</td>
<td>m/m</td>
<td>&lt;1.0%</td>
<td>NEN 5930</td>
</tr>
<tr>
<td>Sulphur compounds</td>
<td></td>
<td>&lt;2% if dry aggregate consists of slag</td>
<td></td>
</tr>
<tr>
<td>Iron and vanadium compounds</td>
<td>-</td>
<td>spot index &lt; 20</td>
<td>NEN 5923</td>
</tr>
<tr>
<td>Fine organic compound material</td>
<td>-</td>
<td>discoloration not darker than standard picture A, or satisfying standard picture B</td>
<td>NEN 5919 NEN 5920</td>
</tr>
<tr>
<td>Soft components</td>
<td>m/m</td>
<td>&lt;0.5%</td>
<td>NEN 5919</td>
</tr>
<tr>
<td>low-density material</td>
<td>m/m</td>
<td>&lt;0.1%</td>
<td>NEN 5933</td>
</tr>
</tbody>
</table>

There are still a number of problem substances, however: asbestos, gypsum and PAHs (polycyclic aromatic hydrocarbons). Before a building can be demolished, an inventory must be made as to whether it contains asbestos. If asbestos is present, it must be removed separately. Gypsum must be demolished selectively to ensure that the granulated rubble complies with the Building Materials Decree. The PAH content of granulated rubble can be limited by selective demolition and pre-sieving at a sorting plant. Tar-bearing asphalt must also be removed from the chain since it no longer complies with the Building Materials Decree because of its PAH content.

Certification of the final product gives consumers confidence that the products meet all the engineering and environmental specifications.

One crucial element in the management of building and demolition waste is the market for secondary building materials produced from waste. The main product is granulated rubble, which is sold as a material for the construction of road foundations and (to a small extent) as a substitute for gravel in concrete.
Especially the stony fraction is crushed and reused as a road base material. Nearly all the material that is reused goes into one segment of the market (road construction).\(^{232}\)

A survey for the period of 2002 to 2003 shows that aggregates from C&D waste and other similar products are used for:

*Table 135: Uses of C&D waste aggregates and other similar products.*\(^3\)

<table>
<thead>
<tr>
<th>Use</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation and filling</td>
<td>84</td>
</tr>
<tr>
<td>Asphalt</td>
<td>8</td>
</tr>
<tr>
<td>Concrete</td>
<td>3</td>
</tr>
<tr>
<td>Dumping</td>
<td>1</td>
</tr>
<tr>
<td>Metals</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>2</td>
</tr>
</tbody>
</table>

Thermal techniques have recently become available for treating tar-bearing asphalt so that the PAHs are destroyed and the inorganic material can be recycled.

For concrete, this technology involves a rotary kiln in which the uncontaminated concrete rubble is thermally treated at a temperature of about 700 °C to dehydrate the cement stone. The concrete rubble pieces disintegrate and the original components (gravel, sand and cement stone) are set free and can be reused for the production of new concrete.

For masonry debris, the new technology consists of a three-step process. In the first step, the large pieces of debris are thermally treated at a temperature of about 500 °C to set free the majority of the original ceramic bricks. These whole bricks can be used for restoration purposes or for the construction of buildings in an old fashioned appearance. Subsequently, the remaining pieces of brick and mortar are physically separated. In the third step, the remaining ceramic fraction is crushed and reused as one of the raw materials for the production of new ceramic bricks. To be able to process the entire supply of C&D waste, the above mentioned processes have to be implemented in an overall process. This overall process also includes process steps for the treatment of mixed C&D waste. The mixed C&D waste streams are separated and decontaminated. For this purpose several dry density separation techniques are being developed. The quality of the stony fraction is improved to a level that it can be re-used as an aggregate in concrete.

For unsorted demolition waste advanced detection and separation techniques are being developed, to sort out contaminants like gypsum and hazardous materials. The remaining material is divided into a heavy (stony) fraction and a light (combustible) fraction. The combustible fraction (wood, plastic, paper, bituminous roofing material) is cleaned up and prepared as a fuel for the thermal process steps.\(^{232}\)

The business company BENTUM invested 50 million Euro in the installation of a thermo regeneration factory for polluted bituminous mix, where an amount of 800 kilotons per year were regenerated.\(^3\)

\(^{232}\) TNO SCIENCE AND INDUSTRY (2007)
7.13.3 Slags from ferrous metal production

Table 136 shows the amount of slags in the Netherlands for the year 2000.

Table 136: Figures for slags from ferrous metal production for the Netherlands for 2000 (Netherlands).

<table>
<thead>
<tr>
<th>Million tons</th>
<th>Production</th>
<th>Usage</th>
<th>Land filled</th>
<th>Storage / Supplies</th>
<th>Import from</th>
<th>Export to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast furnace slag</td>
<td>1.2</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
<td>1.3</td>
<td>(Germany)</td>
</tr>
<tr>
<td>Steel Slag</td>
<td>0.5</td>
<td>0.69</td>
<td>-</td>
<td>-0.19</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Currently about 600,000 tons of basic oxygen furnace slag are generated each year. Depending on the quality these are used for:

- building material in roads;
- part of it is used on site in the own steelmaking process.

In the future Corus wants to change the slag making process, with the purpose that the quality can be better controlled.

Currently each year about 1.5 to 1.7 million tons blast furnace slag are produced as slag sand and used in the cement industry. Part of it is used as building material in roads. About 60,000 tons per year are 'stukslak', a specific slag used as building material in roads.233

7.13.4 Ashes from coal combustion processes

Table 137 shows the amount of ashes from coal combustion processes in the Netherlands for the year 2000.

Table 137: Figures for ashes from coal combustion processes for the Netherlands for 2000 (Netherlands).

<table>
<thead>
<tr>
<th>Kilo tons</th>
<th>Production</th>
<th>Usage</th>
<th>Land filled</th>
<th>Storage / Supplies</th>
<th>Import from</th>
<th>Export to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal bottom ash</td>
<td>153</td>
<td>125</td>
<td>-</td>
<td>28</td>
<td>-</td>
<td>(UK, BE)</td>
</tr>
<tr>
<td>Coal fly ash</td>
<td>961</td>
<td>622</td>
<td>-</td>
<td>little</td>
<td>-</td>
<td>330</td>
</tr>
</tbody>
</table>

233 CONTACT NETHERLANDS 01 (2007)
In 2004 the following amounts of coal combustion residues were generated in the Netherlands:

Table 138: Generation of coal combustion residues in the Netherlands\textsuperscript{234}.

<table>
<thead>
<tr>
<th>Residue</th>
<th>Tonnes / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash</td>
<td>1,017</td>
</tr>
<tr>
<td>Bottom ash</td>
<td>183</td>
</tr>
<tr>
<td>Boiler slag</td>
<td>0</td>
</tr>
<tr>
<td>Flue gas desulphurisation gypsum</td>
<td>307</td>
</tr>
<tr>
<td>Spray dry absorption residue</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,507</strong></td>
</tr>
</tbody>
</table>

\textsuperscript{234} BERG (2006)
7.14 Poland

7.14.1 Existing standards and regulation

In Poland the rules dealing with waste are laid down in the Act of 27 April 2001 on waste\textsuperscript{235}. Article 5 defines the rules for waste management.

7.14.2 Construction and demolition waste

Waste generated in the construction and demolition industry is classified as waste from construction, repairs and disassembly of building structures and road infrastructure\textsuperscript{236}.

It is difficult to estimate the overall volume of construction and demolition waste forced due to the fact that this waste is generated by many companies representing the repair and construction industry, road industry and industrial construction industry. Large amounts can be assumed for excavated soil and waste from the railway industry\textsuperscript{236}.

The quality of waste differs depending on its source. Waste resulting from construction, repair and demolition work in the industrial construction industry may be polluted, e.g. with heavy metals, substances deriving from crude oil, PCB, impregnating agents (railway sleepers), oils and smears or other dangerous substances and heavy metals (broken stone) and PCB (soil, including stones and condensers). Waste including asbestos is generally defined as hazardous waste\textsuperscript{236}.

In 2000, 2,185.8 thousand tons of waste were generated in the construction and repair industry. This volume includes the waste types iron and steel, soil from excavations and deepening works, waste concrete and concrete debris coming from demolition and repair works, mixed debris and materials coming from demolition works, waste construction materials based on gypsum, soil and stones. These types of waste constituted 98.39% of all waste coming from the construction and repair industry\textsuperscript{236}.

About 1,636.1 thousand tons (74.85%) of the total generated wastes were recovered in 2000, including 778.5 thousand tons that were recovered for industrial purposes. 314.9 thousand tons of the total generated wastes were disposed of. 234.8 thousand tons were stored. A total amount of 24,950.6 thousand tons of waste was in storage at the storage yards in the year 2000\textsuperscript{236}.

\textsuperscript{235} POLISH PARLIAMENT (2001)
Wood, plastics, asphalt including pitch, lead and zinc are fully recovered. The best developed market is the market of recovery of waste and scrap of metal and metal alloys. This waste is processed by the iron and steel industry and non-ferrous metal industry as a raw material to produce steel and non-ferrous metals. In Poland, a system for the recovery of metals has already been implemented. Moreover, many companies where metals are post-production waste deliver these wastes directly to iron/steelworks Poland also has also got an accurate processing base for waste wood (excluding impregnated wood), glass and plastics. Waste plastics may be recovered or disposed of thorough material recycling, chemical recycling or power recycling. Waste glass may be managed mainly at glass works during glass melting processes. Waste wood may be used to produce chipboards (after removing all iron ferrule and thick nails are removed) or to produce wood power briquettes. Wood not including preservatives and impregnating agents may be also used for power generation. Around 70% of construction debris is recovered. The remaining quantity is deposited at municipal storage yards and at special yards for construction debris. Moreover, many companies store debris on their premises. Construction debris may be mainly reutilised by the construction and road industry (as road aggregate). Waste such as mixed debris and materials coming from demolition works, waste concrete and concrete debris from demolition and repair works and soil from excavations and deepening works as well as mineral wool are difficult to recover.

7.14.3 Slags from ferrous metal production

In 2000, Poland generated around 4,900 thousand tons of waste from the iron and steel industry in 18 plants. In the iron and steel industry, the following types of waste prevail: slag from the iron metallurgical industry – 3,333.7 thousand tons, scale – 616.1 thousand tons, dusts and sludges from smelter gas cleaning – 445.0 thousand tons, melting loss – 285.8 thousand tons. The biggest share of these wastes is made up of slags coming from steelmaking and other processes, constituting 69% of the total quantity of waste. Figure 39 presents the structure of waste management in the iron and steel industry.
Residues with high recovery rates are waste copperas, melting loss from the iron industry and dusts from gas cleaning. Around 4.7% of metallurgical waste is disposed of. Wastes that are mostly disposed of are: slags from steelmaking processes, slags from other processes, sludges from smelter gas cleaning, used inflammable materials, scales. Wastes from the iron and steel industry are mostly subject to recovery processes. Metallurgical slags (as iron-bearing waste) are mostly recycled in pig iron processes in the iron industry. In addition, they are also utilised in the non-metallurgical sectors, e. g. like the road construction industry as secondary aggregates (metallurgical slags), construction industry as secondary aggregate for concrete, production of bricks as a correction addition (steel dusts), hard coal mining as backfilling sand substitute (furnace granulated slag), production of cement clinker (steel dusts and sludge, furnace granulated slag), production of colour glass (steel dusts).

In 2000 the utilisation of finished metallurgical products in Poland reached 7.3 million tons and it was 17.1% higher than in 1999 (6.26 million tons). In 2006, a consumption of finished products is expected to grow by 13% in relation to 2000, and in 2014 by 28.4%. It is forecasted that the share of the import of finished metallurgical products, including results of the restructuring programme (including limited investment programme) will drop and in 2006 it will constitute around 36%, not exceeding 3.3 million tons. The quantity of waste from the iron and steel industry is expected to grow to 5.5 million tons in 2006, and to 6.7 million tons in 2014.

In Poland there are technical and technological possibilities to recover post-production waste, except for fine oiled up iron-bearing waste. The recovery of sludges is limited due to their high hydration.

### 7.14.4 Ashes from coal combustion processes

Waste generated in the power industry is classified as waste from thermal processes, waste from power plants and other fuel combustion companies, which is resulting from the combustion of hard and brown coal and from smelter gas cleaning processes. Basic solid wastes resulting from the production of electrical and thermal energy from the combustion of solid fuels are so called furnace waste and waste from smelter gas desulphurisation (including slag and fly ashes from the combustion of hard and brown coal).

In the year 2000, 19,740 thousand tons of waste were generated in the power industry. Of that, 74.62% (14,731 thousand tons) were recovered, including 8,264.1 thousand tons for industrial purposes (e.g. production of construction materials, cement, concrete). Table 109 shows waste types with high recovery rates. It appears that fly ashes and slag are broadly utilised in various branches of industry, mainly in the production of construction materials to produce cement, concrete, aggregates, bricks, special ceramic materials, etc. In the hard coal mining industry, dusts are used to backfill underground headings, protect abandoned workings against gas and water penetration, reinforce rock mass and insulate fire fields.
Table 139: Waste types with high recovery rates, generated in the power industry (Poland).

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Recovery rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid waste from calcium methods of smelter gas desulphurisation</td>
<td>97.68</td>
</tr>
<tr>
<td>Fly ash from hard coal</td>
<td>93.45</td>
</tr>
<tr>
<td>Slag</td>
<td>85.97</td>
</tr>
<tr>
<td>Ash and slag mixes from wet disposal of furnace waste</td>
<td>53.20</td>
</tr>
</tbody>
</table>

In 2000 about 4,509.7 thousand tons of waste were disposed of. At the end of 2000, approximately 323,037.5 thousand tons were stored at the storage yards.

In Poland, dusts and slag from brown coal are commonly used to backfill headings of brown coal, natural aggregates, clay and sulphur. Dust and slag mix from the storage yards is used to construct embankments for storage yards of furnace and other waste. In the road construction industry, dusts and slag may be used as secondary aggregates, additional sources of grains, additions to binders, binders or fillers. They are also used to construct road embankments.

Under consideration of existing and planed power plants for coal no changes are expected in the quality and quantity of classic furnace waste. For 2003 to 2014 a generation of dusts and classic slags of approximately 14 to 15 million tons per annum is expected.

By implementation of subsequent systems for smelter gas desulphurisation the quantities of mixes of dusts and waste from desulphurisation will increase. Desulphurisation processes according to the wet lime and gypsum method will generate post-reaction gypsum. In 2003-2006 and then to 2014 the quantity of post-reaction gypsum will remain at the level of 2.3 to 2.5 million tons per annum.

It is expected that professional power plants and power and heating plants will maintain their demand for hard coal as a result of the increased demand for electrical energy and the stable power production from brown coal. Therefore, it is expected that the production of waste will reach about 20.8 to 22.3 million tons p.a.
7.15 Spain

7.15.1 Existing standards and regulation

7.15.1.1 Construction and demolition waste

*Draft Royal Decree for the Regulation of Generation and Management of Construction and Demolition Wastes*[^37]

The Draft Royal Decree for the Regulation of Generation and Management of Construction and Demolition Wastes was published on 25th October 2007. The objective of the decree is to establish a legal regime for the production and management of construction and demolition waste. It aims at promoting the prevention, reuse, recycling and other forms of recovery of construction and demolition wastes, ensuring the correct disposal of the construction and demolition wastes which are not recovered and contributing to the sustainable development of the construction sector.

Among others, the Draft Royal Decree puts an obligation on the generator[^238] of construction and demolition waste to include in the construction plan a study on the management of the construction and demolition waste generated on the construction site concerned. The Study should include inter alia an estimation of the quantities which will be generated, measures of prevention which will be taken, the intended destination for the wastes and an estimation of waste management costs.

The waste holder[^239], for his part, is obliged to present to the owner of the construction site a plan for the management of construction and demolition waste which concretises the implementation of the waste management study.

The Draft Royal Decree defines thresholds above which construction and demolition wastes have to be sorted on site in order to facilitate their subsequent recovery (see Table 140).

*Table 140: Thresholds for the sorting on site according to the Draft Royal Decree for the Regulation of Generation and Management of Construction and Demolition Wastes (Spain).*

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Threshold (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete and stones</td>
<td>20</td>
</tr>
<tr>
<td>Bricks, tiles, ceramic</td>
<td>40</td>
</tr>
<tr>
<td>Bituminous mixtures</td>
<td>5</td>
</tr>
<tr>
<td>Metal</td>
<td>2</td>
</tr>
<tr>
<td>Wood</td>
<td>1</td>
</tr>
<tr>
<td>Glass</td>
<td>1</td>
</tr>
<tr>
<td>Plastic</td>
<td>0.5</td>
</tr>
<tr>
<td>Paper and cardboard</td>
<td>0.5</td>
</tr>
</tbody>
</table>

[^37]: PROYECTO DE REAL DECRETO (2007)

[^238]: The owner of the property with whom the ultimate decision to build or demolish lays.

[^239]: The one who executes the construction and has the physical control of the wastes generated.
Furthermore, the Draft Royal Decree prohibits the disposal of construction and demolition wastes without pretreatment and demands the establishment of tariff systems which discourage the disposal of recoverable wastes or such wastes which have been pretreated only by means of sorting. The Draft Royal Decree also establishes the minimum criteria for the definition, when the use of inert waste for restoration, filling or conditioning purposes can be regarded as recovery rather than disposal.

Finally, the Draft Royal Decree requires that on public construction sites, measures of waste prevention and use of secondary aggregates and other recovered products have be to encouraged.

**Regulations of Autonomous Communities**

In Spain some Autonomous Communities have implemented regional legislation related to the generation and management of construction and demolition wastes.

In the following some of these regulations are listed without making a thorough review of the extensive regional legislation which in one way or another affect the generation and management of construction and demolition waste:

- Balearic: Decree 10/2000 laying down temporarily and as a matter of extreme urgency rules on the sorting and disposal of construction and demolition waste.
- Balearic: Order of the Ministry of the Environment, of 28th February 2000, on the transitional measures for the licensing of facilities for recovery and disposal of construction and demolition waste and Resolution of the Ministry of the Environment, of 26th February 2001, on the implementation of additional provisions to the Order of 28th February 2000.
- Valencia: Decree 200/2004 of the Government regulating the use of inert waste for restoration, filling or conditioning or other construction purposes.
- Basque: Decree 423/1994 on the management of inert or stabilized waste.
- Aragon: Preliminary draft decree on the rules on generation, possession and management of the construction and demolition waste in the Autonomous Community of Aragon.

**National Plan for Construction and Demolition Waste**

The first National Plan for Construction and Demolition Waste in Spain came into force in 2001 and set among others the following objectives for the generation and management of construction and demolition wastes:

- Reaching the rate of correct management of construction and demolition wastes of 90% by the year 2006;
- Reduction of the generation of construction and demolition wastes by 10% by the year 2006;
- Reaching the rate of recycling and reuse of 60% by the year 2006.

---

240 THE GENERAL SECRETARIAT OF THE ENVIRONMENT (2001)
The Draft of a new National Plan for Construction and Demolition Waste was published in 2006 as a part of the draft of a National Integrated Waste Plan. It will set objectives for the generation and management of construction and demolition wastes until the year 2015. The main objectives proposed in the draft version of the plan are:

- Reaching the rate of correct management of construction and demolition wastes of 95% by the year 2011;
- Reduction of the generation or increase of the reuse of construction and demolition wastes by a total of 15% by the year 2011;
- Reaching the recycling rate of 40% by the year 2011.

### 7.15.1.2 Slags from ferrous metal production

**Regulations of Autonomous Communities**

In Spain some Autonomous Communities have developed specific regulations in order to increase the recovery of slag from thermo metallurgic processes. Catalonia was in 1996 the first Spanish region to adopt a regulation on the recovery of slag[^242]. The Basque Country[^243] approved its own Decree in 2003 and Cantabria in 2006[^244].

Although these three regional regulations differ to some extent from each other, the main points stipulated are very similar:

- All three regulations set out limit values which recoverable slags have to meet. The regulations also define the methods and general principles for the analysis of these parameters;
- All three regulations define the acceptable uses specific for each type of recoverable slag. In addition, they also set some detailed requirements for the use of slags;
- All three regulations specify the authorization of recovery activities and set down rules concerning record keeping, documentation and reporting.

The limit values in the three regional Decrees above mentioned differ from each other. Table 141, Table 142 and Table 143 represent the limit values of each of these Decrees.

[^241]: MINISTRY OF ENVIRONMENT (2006)
[^242]: GOVERNMENT OF CATALONIA (1996)
[^244]: GOVERNMENT COUNCIL OF CANTABRIA (2006)
Table 141: Leaching limit values according to the Decree 104/2006 of the Autonomous Community of Cantabria (Spain).

<table>
<thead>
<tr>
<th>Harmful substance</th>
<th>Limit value, mg/kg of dry matter$^{247}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium</td>
<td>20</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.5</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.04</td>
</tr>
<tr>
<td>Copper</td>
<td>2</td>
</tr>
<tr>
<td>Chromium total</td>
<td>0.5</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.01</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.4</td>
</tr>
<tr>
<td>Lead</td>
<td>0.5</td>
</tr>
<tr>
<td>Zinc</td>
<td>4</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.5</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.1</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.06</td>
</tr>
<tr>
<td>Chloride</td>
<td>800</td>
</tr>
<tr>
<td>Fluoride</td>
<td>10</td>
</tr>
<tr>
<td>Sulphate</td>
<td>1,000</td>
</tr>
<tr>
<td>Phenol index</td>
<td>1</td>
</tr>
<tr>
<td>DOC (Dissolved Organic Carbon)</td>
<td>500</td>
</tr>
<tr>
<td>TDS (Total Dissolved Solids)$^{248}$</td>
<td>4,000</td>
</tr>
</tbody>
</table>

$^{245}$ Supernatant layer which is combined with impurities from molten metal in the process of melting of scrap and which is separated from the liquid charge based on density differences.

$^{246}$ Supernatant layer which is generated during the operation of refining molten steel and which is separated from the liquid charge based on density differences.

$^{247}$ Leaching analyses have to be carried out according to the standard EN 12457-4. The limit values are not binding in case the slag is recovered as raw material in the production of cement or aggregate concrete.

$^{248}$ Can be used alternatively to the values of Sulphate and Chloride.
Table 142: Leaching limit values according to the Decree 34/2003 of the Autonomous Community of the Basque Country (Spain).

Uses which may be applied:
Black slags:
- specific foundation structures, bituminous surface coatings of roads or private or public paths
- urbanization projects of industrial areas
- as covering material in landfills or for the construction of temporary roads in landfill areas
- manufacture of cement or concrete
White slags:
- manufacture of cement
- under specific preconditions, the competent environmental authorities may also permit other uses

<table>
<thead>
<tr>
<th>Harmful substance</th>
<th>Limit value, mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium</td>
<td>17</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.009</td>
</tr>
<tr>
<td>Chromium</td>
<td>2.6</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>1.3</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.8</td>
</tr>
<tr>
<td>Lead</td>
<td>0.8</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.007</td>
</tr>
<tr>
<td>Vanadium</td>
<td>1.3</td>
</tr>
<tr>
<td>Zinc</td>
<td>1.2</td>
</tr>
<tr>
<td>Fluoride (F)</td>
<td>18</td>
</tr>
<tr>
<td>SO$_4^-$</td>
<td>377</td>
</tr>
</tbody>
</table>

b) Limit values for the use of slags in bituminous surface coatings of roads or private or public paths

<table>
<thead>
<tr>
<th>Harmful substance</th>
<th>Limit value, mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium</td>
<td>0.6</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.2</td>
</tr>
</tbody>
</table>

$^{249}$ Leaching analyses have to be carried out according to standard EN 12457.
Table 143: Limit values for the recovery of thermo metallurgic slags in Catalonia according to the Decree of February 15, 1996, on the recovery of slags (Spain).

<table>
<thead>
<tr>
<th>Uses which may be applied:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Foundation structures of roads</td>
</tr>
<tr>
<td>- Earth fillings</td>
</tr>
<tr>
<td>- Restoration or conditioning of areas used for extraction purposes</td>
</tr>
<tr>
<td>- Other purposes permitted by the competent environmental authorities</td>
</tr>
</tbody>
</table>

a) Limit values for the parameters which are to be analysed directly from the slags

<table>
<thead>
<tr>
<th>Dissoluble fraction</th>
<th>3%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmful substance</td>
<td>Limit value, mg/kg</td>
</tr>
<tr>
<td>Arsenic</td>
<td>250</td>
</tr>
<tr>
<td>Cadmium</td>
<td>50</td>
</tr>
<tr>
<td>Copper</td>
<td>6,000</td>
</tr>
<tr>
<td>Chromium</td>
<td>3,000</td>
</tr>
<tr>
<td>Mercury</td>
<td>25</td>
</tr>
<tr>
<td>Nickel</td>
<td>2,000</td>
</tr>
<tr>
<td>Lead</td>
<td>2,000</td>
</tr>
<tr>
<td>Zinc</td>
<td>8,000</td>
</tr>
</tbody>
</table>

b) Limit values for the parameters which are to be analysed from a leachate generated according to standard DIN 38414-S4

<table>
<thead>
<tr>
<th>Conductivity</th>
<th>6,000 μS/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmful substance</td>
<td>Limit value, mg/l</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.1</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.1</td>
</tr>
<tr>
<td>Copper</td>
<td>2</td>
</tr>
<tr>
<td>Chromium VI</td>
<td>0.1</td>
</tr>
<tr>
<td>Chromium total</td>
<td>0.5</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.02</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.5</td>
</tr>
<tr>
<td>Lead</td>
<td>0.5</td>
</tr>
<tr>
<td>Zinc</td>
<td>2</td>
</tr>
</tbody>
</table>

7.15.1.3 Ashes from coal combustion processes

No results.

7.15.2 Construction and demolition waste

For the National Plan for Construction and Demolition Waste 2007-2015, data was collected on the quantities generated in the Autonomous Communities of Spain. However, this data is not complete, as for some Autonomous Communities no data was available.\textsuperscript{241}

\textsuperscript{250} To be analysed from the sample as it is.

\textsuperscript{251} To be analysed from a dry sample.
Table 144: Generation of construction and demolition waste in the Autonomous Communities of Spain in the year 2005 (Spain)\textsuperscript{241}.

<table>
<thead>
<tr>
<th>Autonomous Community</th>
<th>Generation of Construction and Demolition Waste in 2005 (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andalucía</td>
<td></td>
</tr>
<tr>
<td>Aragón</td>
<td>3,000,000</td>
</tr>
<tr>
<td>Asturias</td>
<td>250,439</td>
</tr>
<tr>
<td>Baleares</td>
<td></td>
</tr>
<tr>
<td>Canarias</td>
<td></td>
</tr>
<tr>
<td>Cantabria</td>
<td>112,113</td>
</tr>
<tr>
<td>Castilla – La Mancha</td>
<td>1,894,667</td>
</tr>
<tr>
<td>Castilla y León</td>
<td>1,895,977</td>
</tr>
<tr>
<td>Cataluña</td>
<td>8,761,719</td>
</tr>
<tr>
<td>Comunidad Valenciana</td>
<td></td>
</tr>
<tr>
<td>Extremadura</td>
<td>872,480</td>
</tr>
<tr>
<td>Galicia</td>
<td></td>
</tr>
<tr>
<td>Madrid</td>
<td>5,231,966</td>
</tr>
<tr>
<td>Murcia</td>
<td>529,806</td>
</tr>
<tr>
<td>Navarra</td>
<td></td>
</tr>
<tr>
<td>País Vasco</td>
<td>1,228,000</td>
</tr>
<tr>
<td>Rioja (La)</td>
<td></td>
</tr>
<tr>
<td>Ceuta</td>
<td>19,187</td>
</tr>
<tr>
<td>Melilla</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22,568,354</strong></td>
</tr>
</tbody>
</table>

According to a statistical estimate made for the National Plan for Construction and Demolition Waste 2007-2015, the generation of construction and demolition wastes increased on average by 8.7% annually during the years 2001-2005 (see Figure 40). The statistical estimation was based on waste factors and statistical data on construction and demolition activities. This increase reflects the intensive growth of the construction sector in Spain.\textsuperscript{241}
According to a study carried out in 2004 by the Institute for the Sustainability of Resources (ISR) for the Ministry of Environment, approximately 10 million tonnes of total amount of about 35 million tons of construction and demolition waste was disposed of in landfills which were adapted to the existing landfill regulations. Over 60% of the construction and demolition waste generated is disposed of in an uncontrolled way. Table 145 shows data on the recycling and disposal of construction and demolition waste in Spain in 2005.\textsuperscript{541}
Table 145: Management of construction and demolition waste in Spain in 2005 (Spain)\textsuperscript{241}.

<table>
<thead>
<tr>
<th>Autonomous Community</th>
<th>Recycling (tons)</th>
<th>Disposal (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andalucía</td>
<td>83,070</td>
<td></td>
</tr>
<tr>
<td>Aragón</td>
<td>15,383</td>
<td>250,439</td>
</tr>
<tr>
<td>Asturias</td>
<td>250,439</td>
<td></td>
</tr>
<tr>
<td>Baleares</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canarias</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cantabria</td>
<td>7,597</td>
<td>104,533</td>
</tr>
<tr>
<td>Castilla – La Mancha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castilla y León</td>
<td>194,120</td>
<td></td>
</tr>
<tr>
<td>Cataluña</td>
<td>465,124</td>
<td>7,248,881</td>
</tr>
<tr>
<td>Comunidad Valenciana</td>
<td>353,874</td>
<td></td>
</tr>
<tr>
<td>Extremadura</td>
<td>3,750</td>
<td>868,730</td>
</tr>
<tr>
<td>Galicia</td>
<td>12,285</td>
<td></td>
</tr>
<tr>
<td>Madrid</td>
<td>436,616</td>
<td></td>
</tr>
<tr>
<td>Murcia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navarra</td>
<td></td>
<td></td>
</tr>
<tr>
<td>País Vasco</td>
<td>195,645</td>
<td></td>
</tr>
<tr>
<td>Rioja (La)</td>
<td>2,390</td>
<td>52,233</td>
</tr>
<tr>
<td>Ceuta</td>
<td>19,762</td>
<td></td>
</tr>
<tr>
<td>Melilla</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,769,836</strong></td>
<td><strong>8,544,578</strong></td>
</tr>
</tbody>
</table>

7.15.3 Slags from ferrous metal production

No results.

7.15.4 Ashes from coal combustion processes

No results.
7.16 Sweden

7.16.1 Existing standards and regulation

**General policies for increased recycling**

In Sweden there are 16 national environmental objectives (1998:145). Two of them are more closely related to the Swedish waste management:

- The environmental objective A Non-Toxic Environment states: 'The environment must be free from man-made or extracted compounds and metals that represent a threat to human health or biological diversity.'
- The environmental objective A Good Built Environment calls for buildings and amenities to be located and designed in accordance with sound environmental principles and in a manner to promote the sustainable management of land, water and other resources. One of the targets under this objective speaks of making the maximum use of the resource potential of waste while minimising health and environmental risks and impacts. This means we must increase the fraction of recycled material without placing human health or the environment at risk.

The Environmental Code (1998:808), which is the new legislative framework in the environmental field, imposes resource conservation standards as part of its general ‘rules of consideration’. All activities must take advantage of opportunities to save materials and energy. The effects of this resource conservation requirement have not yet been analysed.


According to the Landfill Tax Act (1999:673), all material entering landfill facilities is taxed, while material removed from the facility qualifies for a deduction. The current rate is SEK 435 per tonne. The aim of the tax is to discourage landfill as a waste disposal method and increase the economic incentives for treating and recycling waste in a more environmentally friendly and resource-efficient way.

The impact of the tax in terms of increased recycling and reduced landfilling has been considerable. The quantity of landfilled wastes more than halved between 1994 and 2004. Approximately 2.1 million tonnes of waste other than household waste was landfilled outside of industrial sites in 2004, whereas the figure for 1994 was 4.7 million tonnes. The waste which is not landfilled anymore is now recovered in the form of materials or energy.

Sweden’s Waste Plan ‘A Strategy for Sustainable Waste Management’ sets out the desired course of the waste management to be followed over the next few years.

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252 CONTACT SWEDEN 01 (2007)
253 SWEDISH ENVIRONMENTAL PROTECTION AGENCY (2005)
254 SWEDISH ENVIRONMENTAL PROTECTION AGENCY: [http://www.naturvardsverket.se/sv/](http://www.naturvardsverket.se/sv/)
According to the Strategy, an impetus is needed for increased recycling of waste on land. Examples of applications are construction of roads, golf courses, noise screens and use as material for covering landfill sites.\(^\text{253}\)

One of the national environmental objectives (1998:145) implies that natural gravel should only be used for construction purposes when there are no possible substitutes in specific applications. The Interim Targets and Action Strategies for the environmental objectives (2001:130) state that by 2010 the extraction of natural gravel in Sweden should not exceed 12 million tonnes per year.\(^\text{255}\)

**Criteria for the recovery of waste as construction material**

At present there is no national framework for sustainable recycling for construction purposes and practices vary throughout the country.\(^\text{253}\)

The use of waste for construction purposes is an environmentally hazardous activity under the Ordinance on Environmentally Hazardous Activities and Public Health (1998:899).\(^\text{254}\) Depending on the risk, the activity must be reported to the municipal council or licensed by the county administrative board. If the activity does not entail any risk for environment or health it is not necessary to report the activity to the municipal council.\(^\text{252}\)

The Swedish Environmental Protection Agency is currently developing a guideline for the recovery of waste as construction material on assignment of the Swedish government.\(^\text{252}\) The guideline includes definitions, general preconditions and limit values for the recovery of waste as construction material. The guideline is primarily directed at authorities responsible for controlling and permitting.\(^\text{256}\) The national environmental targets together with the existing legislation are important when the guideline is developed.\(^\text{252}\)

The draft version of the guideline provides maximum values of content and leaching for 10 substances (e.g. lead, cadmium, mercury) for two categories of uses (‘general uses’ and ‘use as covering material above the sealing layer in landfills for non-hazardous or hazardous wastes’). However, the guideline points out that, also in the future, case by case assessments have to be carried out in order to decide if a specific waste is suitable to be recovered as construction material, taking into account also such substances for which no maximum value has been defined in the guideline. Organic substances are an example of such additionally relevant substances. The assessment as regards additional relevant substances can be carried out based on the general principles defined by the guideline.\(^\text{256}\)

The maximum values are based on the principles of minimisation of health risks and protection of soil and ground and surface water. For the category ‘general uses’, the maximum values for the phasing out of substances of very high concern are based on the natural background levels. Phase-out substances of very high concern are substances that are classified as persistent and bioaccumulating, carcinogenic, mutagenic and reprotoxic. Lead, cadmium and mercury are classified as phase-out substances. Levels for the other substances are calculated by means of a risk assessment.\(^\text{256}\)

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\(^{255}\) ARM (2003)

\(^{256}\) **SWEDISH ENVIRONMENTAL PROTECTION AGENCY** (2007)
The maximum values are based on the assumption that it is possible that the wastes recovered as construction material can spread in an uncontrolled manner or move to another place. An essential reason for this is that there is no system in Sweden for keeping a record of sites where waste has been utilised.

The guideline identifies three categories of use for which the limit values are not suitable and for which specific assessments are needed:

- Use of waste in a contaminated area which is being treated
- Use of waste in landfill structures under the sealing layer of landfill cover
- Use of waste in bigger industrial areas

Examples of the uses covered by the guideline are:

- Roads, railways (category 1)
- Noise barriers (category 1)
- Yards or fields like e.g. parking sites (category 1)
- Earth fillings (category 1)
- Landfill cover structures, above the sealing layer (category 2)

The Swedish Environmental Protection Agency proposes that the wastes which do not exceed the limit values for the use category 1 could be used as construction material without the need to report about the activity to the municipal council. For waste that does not exceed the maximum levels it is assumed that the use will not pose any risk to the environment or human health. The proposed maximum levels are the levels for ‘free use’ of the waste. For utilising waste that exceeds the maximum levels a permit from or report to the authority is necessary.

Table 146 and Table 147 represent the limit values defined in the draft version of the guideline on the recovery of waste as construction material.

*Table 146: The limit values for the first category of use ‘general application’.*

<table>
<thead>
<tr>
<th>Substance</th>
<th>Content [mg / kg dry]</th>
<th>Leaching Co LS 0,1 l/kg [mg/l]</th>
<th>Leaching l/s= 10 l/kg [mg/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>20</td>
<td>0.09</td>
<td>0.31</td>
</tr>
<tr>
<td>Cd</td>
<td>0.2</td>
<td>0.004</td>
<td>0.01</td>
</tr>
<tr>
<td>Hg</td>
<td>0.1</td>
<td>0.001</td>
<td>0.004</td>
</tr>
<tr>
<td>As</td>
<td>10</td>
<td>0.016</td>
<td>0.13</td>
</tr>
<tr>
<td>Cu</td>
<td>40</td>
<td>0.09</td>
<td>0.31</td>
</tr>
<tr>
<td>Zn</td>
<td>120</td>
<td>0.64</td>
<td>2.2</td>
</tr>
<tr>
<td>Cr total</td>
<td>40</td>
<td>0.09</td>
<td>0.42</td>
</tr>
<tr>
<td>Ni</td>
<td>35</td>
<td>0.18</td>
<td>0.6</td>
</tr>
<tr>
<td>Cl</td>
<td>-</td>
<td>84</td>
<td>147</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>-</td>
<td>78</td>
<td>227</td>
</tr>
</tbody>
</table>
Table 147: The limit values for the second category of use ‘use in landfills as covering material above the sealing layer’.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Content [mg / kg dry]</th>
<th>Leaching Co LS 0,1 I/kg [mg/l]</th>
<th>Leaching I/s= 10 I/kg [mg/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>200</td>
<td>0.095</td>
<td>0.33</td>
</tr>
<tr>
<td>Cd</td>
<td>1.5</td>
<td>0.004</td>
<td>0.01</td>
</tr>
<tr>
<td>Hg</td>
<td>1.8</td>
<td>0.001</td>
<td>0.01</td>
</tr>
<tr>
<td>As</td>
<td>10</td>
<td>0.051</td>
<td>0.44</td>
</tr>
<tr>
<td>Cu</td>
<td>80</td>
<td>0.19</td>
<td>0.64</td>
</tr>
<tr>
<td>Zn</td>
<td>250</td>
<td>0.76</td>
<td>2.6</td>
</tr>
<tr>
<td>Cr total</td>
<td>80</td>
<td>0.055</td>
<td>0.26</td>
</tr>
<tr>
<td>Ni</td>
<td>70</td>
<td>0.19</td>
<td>0.62</td>
</tr>
<tr>
<td>Cl</td>
<td>-</td>
<td>6,200</td>
<td>11,000</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>-</td>
<td>2,900</td>
<td>8,500</td>
</tr>
</tbody>
</table>

**Technical Regulations**

The Swedish National Road Administration’s technical specifications for roads, ATB VÄG, are an example of technical specifications relevant as regards the use of secondary aggregates. According to these regulations, evidence is required that the alternative aggregate is equivalent to the material it replaces in a standard construction. Another possibility is to propose an alternative design whose strength must also be demonstrated.

Technical specifications for road construction are very relevant from the point of view of aggregates recycling as the road construction industry is responsible for about half of the aggregate consumption in Sweden. As in other sectors, sustainable management of resources has commenced in road construction. This has resulted in the introduction of alternative aggregate materials, such as recycled aggregates or industrial residues of different kinds.

**7.16.1.1 Construction and demolition waste**

According to the Planning and Building Law (1987:10), a waste plan/demolition plan must be appended to the Notification of Demolition provided to the local authority. This should specify the intended disposal route for the demolition products, focusing on the handling of hazardous substances. Furthermore, a certain level of education and experience of selective demolition and waste treatment is demanded for the responsible person at the demolition site.

Voluntary commitments by the construction industry concerning the construction and demolition waste have been made but have not yet been translated into action. The Ecocycle Council for the Construction Sector has set as an objective that the quantity of construction waste which is landfilled in Sweden will be halved until the year 2010 in comparison with the quantities which were landfilled in the year 2004.

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256 SNRA (2003)
As a voluntary system for conveying environmental information about building products, the system of building product declarations (BPDs) has been in existence for more than 10 years. The BPD is an industry-wide format for the way information about the environmental impact of building products should be communicated. The building product declarations include inter alia information on the type and quantity of the recycled material used in the manufacture of the product.259

7.16.1.2 Slags from ferrous metal production

No specific regulations.

7.16.1.3 Ashes from coal combustion processes

No specific regulations.

7.16.2 Construction and demolition waste

At the national level, there is no exact data available on the quantities of construction waste generated and recovered in Sweden. The reduction in quantities of construction and demolition waste going to landfill suggests that increasing quantities are recovered as materials (see Table 148).253

Table 148: Quantities (Mt/year) of landfilled construction and demolition waste.253

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction and demolition waste</td>
<td>0,9</td>
<td>0,74</td>
<td>0,53</td>
<td>0,37</td>
</tr>
</tbody>
</table>

A rough estimation of the generated amount of construction and demolition waste is 11 Mt per year252. The Swedish Geotechnical Institute has carried out an inventory of the wastes which potentially can be recovered as construction materials as substitutes of natural gravel. The inventory also contains an estimation of the quantities of construction wastes which can potentially be recovered as construction materials as well as data on the recovered quantities (see Table 149).260

259 THE ECO-CYCLE COUNCIL FOR THE CONSTRUCTION SECTOR (2007)
Table 149: Construction wastes, which could potentially be used as construction material, in the year 2005 (including rock materials).

<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Generation</th>
<th>Recovery</th>
<th>Types of use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure excavated soils</td>
<td>1,390,000</td>
<td>1,730,000</td>
<td>embankments, earth levelling, noise barriers, earth fillings, landfill covering, parking sites, consolidation of earth</td>
</tr>
<tr>
<td>Contaminated soils</td>
<td>516,000</td>
<td>426,000</td>
<td>embankments, earth levelling, noise barriers</td>
</tr>
<tr>
<td>Crushed concrete</td>
<td>20,000</td>
<td>16,000</td>
<td>embankments, earth levelling, noise barriers</td>
</tr>
<tr>
<td>Crushed stone from road works etc.</td>
<td>6,939,000</td>
<td>6,939,000</td>
<td>streets and railways</td>
</tr>
<tr>
<td>Diverse waste, e.g. asphalt</td>
<td>730,000</td>
<td>730,000</td>
<td>streets and railways</td>
</tr>
<tr>
<td>Powdered stone</td>
<td>550,000</td>
<td>550,000</td>
<td>earth fillings, construction material in landfills, noise barriers, trenches, additives for concrete and asphalt</td>
</tr>
<tr>
<td>pure asphalt</td>
<td>5,000</td>
<td>5,000</td>
<td>road and field constructions in landfills</td>
</tr>
<tr>
<td>Tarred asphalt</td>
<td>170,000</td>
<td></td>
<td>sub-base layers of roads</td>
</tr>
<tr>
<td>Total</td>
<td>10,320,000</td>
<td>10,396,000</td>
<td></td>
</tr>
</tbody>
</table>

7.16.3 Slags from ferrous metal production

According to the inventory carried out by the Swedish Geotechnical Institute, Swedish metal industry generated in the year 2005 about 1.6 million tonnes of slags which could potentially be recovered as construction materials (see Table 150).260

261 The table represents the situation of one specific year. The reasons why recycling exceeds generation are unknown. A probable reason is that waste that had been stored over years was recovered.
Table 150: Wastes which could potentially be used as construction material generated by the metal industry in the years 2001 and 2005.

<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>2001</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD-slag (Linz-Donawitz)</td>
<td>302,000</td>
<td>374,000</td>
</tr>
<tr>
<td>Arc furnace slag</td>
<td>113,000</td>
<td>311,000</td>
</tr>
<tr>
<td>Ferrochrome slag</td>
<td>124,000</td>
<td>125,000</td>
</tr>
<tr>
<td>Ferrous sand</td>
<td>233,000</td>
<td>260,000-270,000</td>
</tr>
<tr>
<td>Blast furnace slag</td>
<td>580,000</td>
<td>575,000</td>
</tr>
</tbody>
</table>

7.16.4 Ashes from coal combustion processes

The inventory of the Swedish Geotechnical Institute includes data on the combustion wastes which potentially can be recovered as construction materials as substitutes of natural gravel. (see Table 151)

Table 151: Ashes which could potentially be used as construction material, from coal combustion in the year 2005.

<table>
<thead>
<tr>
<th>Ashes from coal combustion processes (t/a) in the year 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Waste</td>
</tr>
<tr>
<td>Waste from flue gas cleaning</td>
</tr>
<tr>
<td>Bottom ashes</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
7.17 United Kingdom

7.17.1 Existing standards and legislation

The Waste Framework Directive (2006/12/EC) states that any establishment or undertaking carrying out waste recovery or disposal must obtain a permit from the competent authority. This requirement has been generally transposed into UK Law through the waste management licensing system under Part II of the Environmental Protection Act 1990\(^{262}\) and the Waste Management Licensing Regulations 1994 (as amended)\(^{263}\). The competent authority for permitting for England and Wales is the Environment Agency (EA). The Waste Management Licensing System shall be replaced by the new Environmental Permitting Regulations, which is due to come into force in April 2008. This will provide a single, simplified permitting system to replace also the Pollution Prevention and Control permits. With regard to recovery operations (and disposal operations at the place of production) the Waste Framework Directive gives Member States the discretion to provide exemptions from the requirement for a permit. The Department for Environment, Food and Rural Affairs (DEFRA) has exercised this discretion in order to encourage low risk waste recovery operations. The current schemes of exemptions are provided under Regulation 17 of and Schedule 3 to the Waste Management Licensing Regulations 1994 (as amended)\(^{263}\). Current exemptions which are of importance to the construction industry are paragraphs 9A (Land Reclamation or Improvement), 13 (Manufacture and Treatment of Waste), 19A (Storage and Use of Building Waste) and 24 (Crushing, Grinding or Size Reduction of Bricks, Tiles or Concrete). DEFRA, the EA and the Welsh Assembly Government are currently undertaking a review of the whole scheme of exemptions. The aim of the review is to provide a more risk-based and proportionate approach to the regulation of waste recovery and disposal operations. The majority of the current exemptions from waste management licensing have been in place with little amendment since 1994. Some have become increasingly complex, creating anomalies around who benefits from an exemption and who does not. There is also a need to develop new exemptions that take account of technical innovations and clarification of the definition of waste as a result of European case law. A new scheme of exemptions is due to be introduced in April 2009.

The Landfill Regulations\(^{264}\) implements the Landfill Directive. The Waste and Emissions Trading Act provides the basis for establishing Landfill Allowances. The system revolves around transferable allowances which will enable the greatest amount of waste diversion to occur in areas where it is cheapest, and most practicable to do so. The standard rate of Landfill Tax is £ 24 per ton for non-hazardous (and non-inert) wastes for 2007/08. From 1 April 2008 and until at least 2010–11, the standard rate of Landfill Tax will increase by £ 8 per ton each year. A lower rate of £ 2 per ton applies to inactive (or inert) wastes listed in the Landfill Tax (Qualifying Material) Order 1996. From 1 April 2008 this will increase to £ 2.50 per ton\(^{265}\).

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\(^{262}\) DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT (1991)

\(^{263}\) DEPARTMENT FOR ENVIRONMENT FOOD AND RURAL AFFAIRS (1994)

\(^{264}\) DEPARTMENT FOR ENVIRONMENT FOOD AND RURAL AFFAIRS DEFRA (2002A)

\(^{265}\) DEPARTMENT FOR ENVIRONMENT FOOD AND RURAL AFFAIRS DEFRA (2007)
The Aggregates Levy\(^{266}\) was introduced in 2002 to ensure that the environmental impact of extracting primary aggregate is more fully reflected in the price, thereby encouraging the use of recycled and secondary aggregates. It is currently set at £1.60 per ton of virgin aggregate. From 1 April 2008 this rate will increase to £1.95 per ton.

Under the UK Environmental Protection (Duty of Care) Regulations\(^{262}\), decisions as to whether residues are not waste any more are made by the Environment Agency on a case-by-case basis. To provide more certainty, to stop materials being landfilled unnecessarily and to increase the use of waste as a resource, the Waste Protocols Project\(^{267}\) has been set up and is conducted mainly by the EA and the Waste and Resources Action Programme (WRAP). Material streams usable for aggregate supply considered in the project are: blast furnace slag, steel slag, uncontaminated topsoil, contaminated soils (washed/stabilised), pulverised fuel ash, wood (not packaging), plastics not packaging.

The project aims at:

- The production of Quality Protocols defining the point at which waste may become a non-waste product or material that can be either reused by business or industry, or supplied into other markets, enabling recovered products to be used without the need for waste regulation controls;
- The production of statements, in accordance with the Environment Agency’s low risk regulatory policy, indicating that the use of the waste is considered to be such low risk that it would not normally be in the public interest to take enforcement action for failure to obtain a waste management licence;
- The production of statements that confirm to the business community what legal obligations they must comply with to use the treated waste material.

### 7.17.1.1 Construction and demolition waste

Information on the waste management intended for construction, demolition and excavation waste (CDEW) is provided by the ‘Waste Strategy for England, 2007’\(^{265}\). Policies on resource efficiency act at various levels in the construction supply chain, from the client level down. The Government can most effectively influence the sector by applying leverage at the top of the chain, targeting the major players and large public sector projects using measures.

The following precise targets were consulted on in the Consultation on the Sustainable Construction Strategy (SCS):

- A reduction of 50% of the waste going to landfill by 2012 compared with 2005 to be achieved by the construction industry. Further objectives are zero net waste (at construction level) by 2015 and zero waste to landfill by 2020. This target refers to reduction in the amount of waste going to licensed landfill where landfill tax is paid. The target aims at waste reduction and not just recycling/diversion of waste. The target would not count diversion of waste from landfill to exempt sites, backfilling quarry voids, site restoration and landfill engineering.

\(^{266}\) DEPARTMENT FOR ENVIRONMENT FOOD AND RURAL AFFAIRS DEFRA (2002b)

\(^{267}\) THE ENVIRONMENTAL AGENCY: [http://www.environment-agency.gov.uk](http://www.environment-agency.gov.uk)
For construction clients to include contractual requirements for measurement and improvement of materials resource efficiency in one-half of construction projects in England over £1 million in value by 2009. The £1 million threshold would capture around 10% of projects by number, 60–70% by value.

The SCS Consultation finished at the end of November 2007, and a summary of responses is due to be published at the end of February 2008.

Among the key policies proposed within the ‘Waste Strategy for England, 2007’ is the development and application of Site Waste Management Plans (SWMPs). SWMPs aim to reduce illegal waste activity, including fly-tipping, and will also encourage reduction in the amount of waste produced and improved resource efficiency. In 2004 there was a voluntary code of practice on SWMPs intended for use by companies engaged in projects of £200,000 or more in value. The Government is currently laying down regulations for SWMPs, which will make it mandatory for those responsible for projects above a certain threshold to prepare plans before work begins on site. The regulations will take effect from 6 April 2008 for all projects over £300,000 in value, and will be accompanied by non-statutory guidance.

In order to enhance market development and sector support the ‘WRAP Aggregates Programme’ was funded by DEFRA from the Aggregates Levy Sustainability Fund and was launched in 2002. WRAP is also funded by the Scottish Executive for an Aggregates Programme in Scotland. The programme’s aim is to promote sustainable aggregates use through encouraging greater use of recycled and secondary aggregates. It is addressing:

- The lack of effective reprocessing infrastructure to supply high quality products to local markets;
- The need for robust and readily available information to assist those involved in the specification, procurement, use and supply of recycled and secondary aggregates;
- Low end-user confidence and awareness of the cost effectiveness and performance specifications of recycled and secondary aggregates;
- Barriers in the supply chain, both real and perceived, that arise through legislation and regulations;
- Need for more uses for recycled, and particularly secondary, materials.

In connection with the review of the scheme of exemptions mentioned above two regulatory position statements were published by the EA.

- ‘The restoration of shallow quarries with inert wastes’ specifies the conditions under which no permit or licence for the restoration of shallow quarries using inert waste is required:
  - The quantity of inert waste used to restore the quarry must not be more than 20,000 m³ per hectare.
  - The depth of the waste must be no more than 2 m. The deposit of waste must achieve the final restoration levels at the quarry.

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269 The Environmental Agency (2007)
The waste used must be only those types: Bricks (EWC Code: 17 01 02), Tiles and ceramics (EWC Code: 17 01 03), Mixture of concrete, bricks, tiles and ceramics (EWC Code: 17 01 07); Soil and stones other than those containing dangerous substances (EWC Code: 17 05 04). Soil and stones from contaminated sites must not be accepted.

- 'The use of small quantities of road planings on tracks and roads under a Paragraph 19A exemption\(^{270}\).

In 2005 a ‘Quality protocol for the production of aggregates from inert waste’ was prepared by WRAP to provide a uniform control process for producers so that they can reasonably state and demonstrate that their product has been fully recovered\(^{271}\). The EA considered the protocol to be suitable for use in decisions on when a waste ceases to be a waste by its staff. Although the WRAP Quality Protocol was intended primarily for recycling of materials in association with road pavement construction, the principles should be adopted where RCA (recycled aggregate; principally comprising crushed concrete) is to be considered for use in structural concrete. The protocol covers factory production control, product descriptions, acceptance criteria, testing, recording and the producer’s duties of information. The following Table 152 (Annex C) lists the (inert) waste types allowed for the production of recycled aggregates - provided that there is no suspicion of contamination. The list represents substantially those inert waste types allowed to be disposed of at landfills for inert waste without testing\(^{272}\).

**Table 152: Waste types to be accepted for the production of recycled aggregates (United Kingdom)\(^{271}\).**

<table>
<thead>
<tr>
<th>EWC-Code</th>
<th>Description</th>
<th>Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 11 03</td>
<td>Waste glass based fibrous materials</td>
<td>Only without organic binders</td>
</tr>
<tr>
<td>15 01 07</td>
<td>Glass packaging</td>
<td></td>
</tr>
<tr>
<td>17 01 01</td>
<td>Concrete including solid dewatered concrete process waste</td>
<td>Selected C&amp;D waste acceptable only with low content of other types of material (like metals, plastics, organics, wood, rubber, etc.) The origin of the waste must be known.</td>
</tr>
<tr>
<td>17 01 02</td>
<td>Bricks</td>
<td></td>
</tr>
<tr>
<td>17 01 03</td>
<td>Tiles and ceramics</td>
<td></td>
</tr>
<tr>
<td>17 01 07</td>
<td>Mixtures of concrete, bricks, tiles and ceramics</td>
<td></td>
</tr>
<tr>
<td>17 02 02</td>
<td>Glass</td>
<td></td>
</tr>
<tr>
<td>17 05 04</td>
<td>Soils and stones including gravel, crushed rock, sand, clay, road base and planings, and track ballast</td>
<td>Excluding topsoil, peat.; excluding soil and stones from contaminated sites</td>
</tr>
<tr>
<td>17 05 08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 12 05</td>
<td>Glass</td>
<td></td>
</tr>
<tr>
<td>20 01 02</td>
<td>Glass</td>
<td>Separately collected glass only</td>
</tr>
<tr>
<td>20 02 02</td>
<td>Soil and stones restricted to parks waste</td>
<td>Only from garden and parks waste; excluding topsoil, peat</td>
</tr>
</tbody>
</table>

\(^{270}\) **The ENVIRONMENTAL AGENCY (2006)**  
\(^{271}\) **WASTE & RESOURCES ACTION PROGRAM (2005)**  
\(^{272}\) **THE ENVIRONMENT AGENCY (2001)**
Included information on the testing regime regarding frequency and methods of test for finished products are given in Table 153.

Table 153: Waste types to be accepted for the production of recycled aggregates (United Kingdom)\textsuperscript{271}.

<table>
<thead>
<tr>
<th>Property Description</th>
<th>BSEN test method</th>
<th>Minimum test frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>General description</td>
<td>-</td>
<td>Every incoming load by visual inspection</td>
</tr>
<tr>
<td>Aggregate composition including organics</td>
<td>Visual sorting of the plus 8 mm fraction</td>
<td>1 per week</td>
</tr>
<tr>
<td>Grading</td>
<td>933-1</td>
<td>1 per week</td>
</tr>
<tr>
<td>Fines content</td>
<td>933-1</td>
<td>1 per week</td>
</tr>
<tr>
<td>Particle size</td>
<td>933-3</td>
<td>1 per month</td>
</tr>
</tbody>
</table>

Annex B gives an overview of the test methods which may be used as a means of either deciding or illustrating suitability for a particular end use, including the categories:

- All end uses
- Use in concrete/hydraulically bound materials
- Uses as filling material
- Use as unbound, pipe bedding
- Use in asphalt

The `Manual of Contract Documents for Highway Works, Volume 1 (MCHW 1): Specification for Highway Works`\textsuperscript{273} permits the use of different C&D waste materials to be used in place of primary aggregates for the following applications listed in Table 154.

\textsuperscript{271} Highways Agency, Welsh Assembly, Scottish Executive and the Department of the Environment for Northern Ireland (2007)
Table 154: Specification for Highway Works (MCHW 1): Application of Secondary and Recycled Aggregates (United Kingdom)

<table>
<thead>
<tr>
<th>Application</th>
<th>Pipe bedding</th>
<th>Embankments and Fill</th>
<th>Capping</th>
<th>Unbound mixtures for sub-base</th>
<th>Hydraulically bound mixtures for sub-base and base</th>
<th>Bitumen bound layers</th>
<th>PQ Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled concrete aggregate</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Recycled aggregate</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Recycled asphalt</td>
<td>Where permitted, up to 100% recycled asphalt may be used</td>
<td>where permitted, up to 100% recycled asphalt may be used</td>
<td>100% Recycled asphalt can be used in sub-base</td>
<td>50% recycled asphalt can be used in sub-base or 100% if permitted by the contract specification</td>
<td>up to 100% recycled asphalt</td>
<td>up to 10% by mass recycled asphalt may be used in surface courses and up to 50% in all other layers</td>
<td>up to 5% asphalt as a foreign material, but recycled asphalt is generally not viewed as a concreting aggregate</td>
</tr>
</tbody>
</table>

The document refers to the following definitions of recycled aggregates:

- Recycled aggregate (RA) is defined in BS 8500-1 (2006) as the generic term for aggregate resulting from the reprocessing of inorganic material previously used in construction. In addition to significant quantities of natural aggregates, recycled aggregates are likely to contain impurities such as wood, metal, asphalt and plastic; these need to be controlled to acceptable levels dependent on the proposed use of the recycled aggregate. Where the composition of the recycled aggregate is principally crushed concrete, the material is defined in BS 8500-1 (2006) as RCA. BRE (1998) subdivided recycled aggregates into three classes, dependent on the brick content (BRE Digest 433).

- RCA (I) defines the lowest quality material. It could have relatively low strength and high levels of impurities. It might contain up to 100% brick or block masonry, or could comprise mainly concrete but with high levels of impurities.

- RCA (II) defines a relatively high quality material comprising mainly crushed concrete with up to 10% brick by weight but low levels of impurities, less than 1.5% by weight (wood, asphalt, glass, plastics, and metals). In some cases it could contain an appreciable amount of natural aggregate.

- RCA (III) defines a mixed material with up to 50% brick and high levels of impurities. The document refers only to RCA (II) type material, and materials conforming to RCA (I) and (III) are not permitted.

Table 155 shows the definitions of RCA according to BS 8500-2: 2002 and BRE Digest 433.

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274 BRITISH STANDARDS INSTITUTE (2006)
275 See Building Research Establishment BRE: Digest 433.
276 BRITISH STANDARDS INSTITUTE (2002A)
Table 155: Acceptable quality for recycled aggregates (RCA) (United Kingdom).

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>BS 8500</th>
<th>BRE Digest 433 RCA (II)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry</td>
<td>&lt; 5%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt; 10%</td>
</tr>
<tr>
<td>Lightweight material &lt; 1000kg/m&lt;sup&gt;2&lt;/sup&gt;</td>
<td>&lt; 0.5%&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Included in other foreign material</td>
</tr>
<tr>
<td>Asphalt</td>
<td>&lt; 5%&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Included in other foreign material</td>
</tr>
<tr>
<td>Other impurities (e.g. glass, plastic and metals)</td>
<td>&lt; 1%</td>
<td>Included in other foreign material</td>
</tr>
<tr>
<td>Other foreign material</td>
<td>Included in other impurities</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Wood</td>
<td>Not quoted but should be less than 0.1% as per EN 12620</td>
<td>&lt; 0.5%</td>
</tr>
<tr>
<td>Total</td>
<td>&lt; 11.5%</td>
<td>&lt; 11.5%</td>
</tr>
</tbody>
</table>

<sup>a</sup> Limit may be increased to < 10% for exposed concrete when asphalt limit reduced to < 0.5%.

<sup>b</sup> Limit set to < 0.1% for exposed concrete.

<sup>c</sup> “Floating stone” materials only.

<sup>d</sup> Limit set to < 0.5% for exposed concrete.

Regulation concerning the environmental performance of recycled aggregates is given in ‘BS 6920-1, Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water’<sup>277</sup>. The BS 6920 prescribes test methods for materials in contact with drinking water. Limit values are given for the material’s effects on odour and flavour, on appearance, on the growth of aquatic micro-organisms, on cytotoxicity and on extraction of metals (see Table 158).

7.17.1.2 Slags from ferrous metal production

In 2006, blast furnace slag (BFS) was put forward for consideration by the Waste Protocols Project mentioned above, aiming at establishing the point at which BFS ceases to be waste. A technical advisory group comprised of industry, EA and WRAP representatives, prepared a technical report<sup>278</sup> on this subject. Based on this, in August 2007 the EA came to the conclusion that BFS produced in the UK as Air Cooled Blast Furnace Slag (ACBFS) or Ground Granulated Blast Furnace Slag (GGBFS) is not a waste any more. The decision refers also to the Interpretative Communication on waste and by-products published by the European Commission<sup>23</sup>, which gave blast furnace slag (BFS) as a possible example of a by-product.

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<sup>277</sup> British Standards Institute (2000)

<sup>278</sup> Waste Resources & Action Programme WRAP (2007)
The following environmental impacts were taken into account when deciding BFS not to be waste any more:

- **CO₂-reduction**
  The production of cementitious products from BFS contributes towards the reduction in CO₂ emissions derived from traditional cement manufacturing. WRAP refers to a position paper of EUROSLAG\(^{279}\), which says that 50% of the CO₂ emissions associated with concrete production can be avoided by partially replacing ordinary Portland cement with GGBS – when comparing the life cycle assessment (LCA) of GGBS with that of Portland cement.

- **H₂S-production**
  Granulation releases lower levels of H₂S compared with conventional ‘air cooling’ and associated water quenching practices. In recent years the BFS industry has invested heavily in BFS granulation plants to reduce its airborne emissions and thus its environmental impact.

- **Water quality effects**
  Information on the leaching behaviour of BFS was taken from CIRIA Report 167\(^{280}\). For BFS it was shown that chloride, sulphate, alkali earth metals and ammoniacal nitrogen can be elevated relative to water quality standards (drinking water standards and/or Environmental Quality Standards). Heavy metals were generally below detection limits. Based on this data it was concluded that weathered BFS can be used as a limestone substitute in most settings. But in sensitive locations (e.g. within Source Protection Zone I of abstraction boreholes or water bodies within ecologically sensitive areas), the Environment Agency may require site-specific risk assessments to show that concentrations of chloride, sulphate, alkali earth metals and ammoniacal nitrogen are not likely to exceed relevant local statutory water objectives. Although the use of BFS as an unbound aggregate is known to present a potential environmental hazard (groundwater: pH increase and oxygen depletion) under specific ground conditions (e.g. poorly drained soils) it is stated that all construction materials that utilise BFS (i.e. concrete, asphalt and unbound materials) are typically compacted well when placed in-situ to sufficiently reduce the likelihood of water ingress and the risk of any leaching.

- **Possible effects on human health**
  Evidence was obtained from an US study\(^{281}\) of the potential human health risks associated with the environmental applications (e.g. fill, road base, landscaping) of iron and steel making slags. The study examined characterisation data for 73 samples of slags collected from blast furnaces, basic oxygen furnaces and electric arc furnaces. These data were compared with US regulatory health-based ‘screening’ benchmarks to determine constituents of interest. Sb, Be, Cd, Cr(III) and Cr(VI), Mn, T, and V were measured above screening levels and were assessed in an application-specific exposure assessment using standard US Environmental Protection Agency risk assessment methods. A stochastic analysis was conducted to evaluate the variability and uncertainty in the inhalation exposure and risk estimates, and the oral bio-accessibility of certain metals in the slags was quantified.

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\(^{279}\) EUROSLAG (2006)
\(^{280}\) BALDWIN ET AL. (1997)
\(^{281}\) PROCTOR ET AL. (2002)
This risk assessment found no significant hazards to human health as a result of the environmental applications of steel industry slag. However, the study indicated that site-specific ecological risk assessments may be required for slag applications in and around small water bodies with limited dilution volumes. This was due to high pH and Al levels, which were found to be at levels that might be harmful to aquatic life. However, the abstract did not distinguish between BFS and other steel making slags when discussing the potential effects on aquatic life.

The main item of the technical report is a table (see Table 156) illustrating the results of an overall risk assessment carried out by the technical advisory group for the use of BFS. The original data for the assessment is not part of the report.

Table 156: Risk assessment of BFS: production storage and use phases (United Kingdom).

<table>
<thead>
<tr>
<th>Hazardous event and potential pathway</th>
<th>Receptor(s)</th>
<th>Risk before mitigation</th>
<th>Issues and possible mitigation measures required at each phase (production, storage, use)</th>
<th>Risk after mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td>People and the local environment</td>
<td>✓</td>
<td>1. No issues identified but local authority planning permission controls should be adhered to.</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓ 2. No issues identified.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓ 3. No issues identified.</td>
<td></td>
</tr>
<tr>
<td>Odour</td>
<td>People and the local environment</td>
<td>✓</td>
<td>1. Production of hydrogen sulphide from quenching and cooling processes can generate complaints from the general public. In-line granulation significantly reduces such odour and the potential for these types of complaints.</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓ 2. Once BFS has solidified and been processed into aggregates, there are no odour release issues.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓</td>
<td>3. If BFS is not applied correctly, it is theoretically possible for such odour releases (from leachate generation) - though they are likely to be very minor. No direct evidence in relation to odour emerged during this study.</td>
<td></td>
</tr>
<tr>
<td>Spillage</td>
<td>People and the local environment</td>
<td>✓</td>
<td>1. Good housekeeping required at handling and processing facilities in line with PPC permit conditions.</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Good housekeeping at storage facilities required.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Good housekeeping required during usage/application stage.</td>
<td></td>
</tr>
</tbody>
</table>
A list of additional references, whose findings on further potential environmental impacts supported the decision, is given (see literature in Chapter 8).

Furthermore, the report summarizes specific environmental protection guidance for BFS usage. Production quality control and quality controlled natural weathering regime requires the following:

- The material selection stage of the construction project must include a review of the environmental implications related to the use of any proposed aggregate source. The contractor must produce a method statement identifying all recognised measures to protect the aquatic environment;
- Unbound BFS should not be used in water logged or poorly drained areas (lime, sulphur → pH increase, oxygen depletion);
- Wherever possible, BFS should not come into contact with the water table to avoid similar conditions developing as outlined above;

### Hazardous event and potential pathway

<table>
<thead>
<tr>
<th>Hazardous event and potential pathway</th>
<th>Receptor(s)</th>
<th>Risk before mitigation</th>
<th>Issues and possible mitigation measures required at each phase (production, storage, use)</th>
<th>Risk after mitigation</th>
</tr>
</thead>
</table>
| Contaminated run-off/release of contaminated site drainage to the environment | Properties, Ecosystems, Surface water, Groundwater | ✓ | 1. Possible run-off issues from all BFS production activities are subject to PPC permit conditions. Reference should be made to BACMI/Environment Agency guidance.  
2. All BFS stockpiles (pre-sales) are located within an integrated works complex and regulated via PPC permit conditions; refer to BACMI/Environment Agency guidance. Stockpiles must be within contained areas or similar with controlled/enclosed gaseous drainage systems. Control and clean-up spillages of material required.  
3. BFS delivered to construction sites for use in unbound applications should be stored according to BACMI/Environment Agency guidance. BFS used in asphalt or concrete poses no environmental risk because the slag is fully bound by bitumen or cement | ✓ |
| Wind-borne litter | People, Properties, Ecosystems | ✓ | 1. Good housekeeping required to prevent possibility of becoming airborne.  
2. As above.  
3. As above. | ✓ |
| Airborne dust, powders or particulates | People, Properties, Ecosystems | ✓ | 1. Course grain>2mm material.  
2. As above.  
3. As above. | ✓ ✓ ✓ |
| Combustion potential of BFS | People, Properties, Ecosystems, Atmosphere, Surface water, Groundwater | ✓ | Not applicable as melting point of BFS is >1,600°C. | ✓ |
| BFS storage | People, Properties, Ecosystems | ✓ | BFS delivered to construction sites for use in unbound applications should be stored according to BACMI/Environmental Agency guidance. BFS used in asphalt or concrete poses no environmental risk because the slag is fully bound by bitumen or cement. | ✓ |
| BFS disposal | People, Properties, Ecosystems | ✓ | Not applicable – full usage of material during all phases of production, storage and use. | ✓ |
Where unbound BFS is used in the construction of large exposed areas such as vehicle parks and major carriage ways, good practice should be followed to minimise the time the slag surface is exposed prior to overlay.

Based upon the Specification for Highway Works [MCHW Volume 1]\(^{273}\) and the Design Manual for Roads and Bridges [HD 35/04]\(^{282}\), steel slag can be recycled for the following applications (see Table 157): It is stressed that in most applications, steel slag will need to have undergone weathering to ensure volumetric stability in use.

**Table 157: Specification for Highway Works (MCHW 1): Application of Secondary and Recycled Aggregates (United Kingdom)\(^{273, 282}\):**

<table>
<thead>
<tr>
<th>Application</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe bedding</td>
<td>If meeting the appropriate grading and material requirements</td>
</tr>
<tr>
<td>Embankments and Fill</td>
<td>BFS can comply as selected granular fill and is specified by name, but this would be a wasteful re-use of a premium material. Slag is specifically excluded from granular fill overlying buried steel structures.</td>
</tr>
<tr>
<td>Capping</td>
<td>Weathered steel slags can comply as selected granular fill</td>
</tr>
<tr>
<td>Unbound mixtures for sub-base</td>
<td>Steel slag, well weathered and conforming to the requirements of BS 4987-1 is specified</td>
</tr>
<tr>
<td>Hydraulically bound mixtures for sub-base and base</td>
<td>No specific or general provision due to the potential for volume instability. The use may be permitted by the overseeing organisation if sufficient assurance of volume stability is provided.</td>
</tr>
<tr>
<td>Bitumen bound layers</td>
<td>May be used in base course, binder course, surface course. Of particular note is the use of steel slag aggregate within thin asphalt surfacing due to its beneficial high polishing resistance and aggregate shape. A degree of weathering is required to volumetrically stabilize the material prior to use.</td>
</tr>
<tr>
<td>PQ Concrete</td>
<td>No specific or general provision due to the potential for volume instability. The use may be permitted by the overseeing organisation if sufficient assurance of volume stability is provided.</td>
</tr>
</tbody>
</table>

### 7.17.1.3 Ashes from coal combustion processes

In the UK the Environment Agency (EA) as well as the Scottish Environmental Protection Agency (SEPA) considers coal fired power station products, such as pulverized fuel ash (PFA) and furnace bottom ash (FBA) to be waste. Thus contractors or producers of these residues have to apply for exemptions or waste management licenses under the UK regulation. Although many applications of coal fly ash have been exempt from Waste Management Licensing under Circular 11/94\(^{283}\) still in many cases ashes are handled as ‘waste’. The decision as to whether ashes can be utilised are made by the Environment Agency on a case-by-case basis.

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\(^{273}\) HIGHWAYS AGENCY (2004)

\(^{282}\) DEPARTMENT OF THE ENVIRONMENT (1994)
Contractors wishing to use ashes have to submit their proposals for approval, which should include an Environmental Risk Assessment. A considerable proportion of European standards to characterize waste materials can be called upon by the EA to form part of this document.

The EA have concluded that for the following applications the following courses of action are required:

- **PFA for use in the manufacture of aerated concrete blocks**
  
  § 13 of the 1994 Waste Management Licensing Regulations (WMLR) permits the manufacture of blocks from waste ash, provided that the waste is stored at the place where the activity is to be carried out; and the total quantity of waste stored at that place does not exceed 20,000 tonnes. The PFA is likely to cease to be waste at the point that it is incorporated into a block and therefore the blocks can be stored and sold as products with no waste management controls.

- **PFA/fly ash for the use in cement manufacture of blended cement or as raw kiln feed material**
  
  All cement blending and manufacturing plants are required to be registered under IPPC Part B for control of emissions to air. Provided all the requirements are met by the IPPC Part B recovery process, the PFA is likely to cease to be waste at the point that it is blended into the cement mix or used as a raw feed material. The resulting cement can be stored and sold as products with no waste management controls.

- **PFA/fly ash for the use in concrete as a Type II addition**
  
  Blending the cement in bulk or using cement in bulk other than at a construction site, including the bagging of cement and cement mixtures, the batching of ready mixed concrete and the manufacture of concrete blocks and other cement products are covered IPPC Part B. Provided all the WFD requirements are met by the Part B recovery process, the PFA is likely to cease to be waste at the point that it is blended into the concrete mix or used as a raw feed material. The resulting concrete can be stored and sold as products with no waste management controls.

- **PFA/fly ash for use as a fill material**
  
  § 19 of the 1994 Waste Management Regulation with the 2005 revisions permits the use of ash as a construction material under an exemption for relevant works. The PFA is likely to cease to be waste at the point that it is incorporated into the structure. There is a registration charge for applying for an exemption which is £546 per annum per contract.

- **PFA/fly ash for the use in grouting**
  
  The mixing plant;
  
  1. Where the mixing or batching of the grout is carried out on the site where the relevant works will be undertaken in accordance with a § 19 exemption then the batching will be covered by the exemption.
  2. Where the batching is carried on at a location separate from the final grouting or use, then the batching plant would require a Local Authority permit issued under Section 3.1 Part B.
  3. Where the use of the grout is not considered to be relevant work within the meaning of paragraph 19 then a waste management licence would be required. It is the Agency's view that the use of grout is not generally "relevant work" but must be considered on a case by case basis.
Furnace Bottom Ash (FBA) for the manufacture of lightweight concrete blocks
This activity is covered by § 13 of Schedule 3 to the Waste Management Licensing Regulations as detailed above. The FBA ceases to be waste at the point it is incorporated into a block and therefore the blocks can be stored and sold as products with no waste management controls.

A position paper ‘Waste Framework Directive and the UK Environment Agency – PFA and FBA’ was published by the United Kingdom Quality Ash Association (UKQAA) in 2006. The association aims at supporting the use of PFA/fly ash for all applications, e.g. for concrete, filling material, grouting, block manufacture, etc. and of bottom ash and cenospheres. The paper outlines the power industry’s position over coal ashes not being waste. They deduce their position about coal ashes being environmentally sound by:

- The fact, that there was not any environmental incident reported caused by the application of coal ashes;
- The fact, that the residues comply with the non hazardous category as defined in the Waste Acceptance Criteria;
- The positive outcomes of a generic environmental risk assessment.

As an example for a generic risk assessment the use of PFA to construct an embankment adjacent to a stream or river was considered. This was chosen as being the potentially worst case situation in which pollution is likely to occur, e.g. in an unbound application potentially exposed to rainfall, flooding, etc. The industry does not recommend the use of unbound PFA below the water table, for such applications cement/PFA grout or concrete is required.

Since there are no environmental standards or regulatory limits against which ash leachate values can be directly compared the following three documents were used for the environmental assessment of coal ashes, respectively:

- BS 6920-1, Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water. Specification is frequently used for the assessment of metals and inorganic determinants.
Table 158: Maximum allowable metals from BS 6920-1 (United Kingdom).[^274]

<table>
<thead>
<tr>
<th>Metal</th>
<th>Maximum allowable concentration</th>
<th>Reporting limits[^274]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µg l^-1</td>
<td>µg l^-1</td>
</tr>
<tr>
<td>Al</td>
<td>200</td>
<td>20</td>
</tr>
<tr>
<td>Sb</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>As</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Ba</td>
<td>1000</td>
<td>100</td>
</tr>
<tr>
<td>Cd</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>Cr</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>Fe</td>
<td>200</td>
<td>20</td>
</tr>
<tr>
<td>Pb</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Mn</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>Hg</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Ni</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>Se</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Ag</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

*...The reporting limits required by the National Regulator for some metals are based upon the new lower requirements specified in EC Directive on the quality of water intended for human consumption (98/83/EC).*

- The criteria for inert waste under the Landfill Directive.

To reflect the requirements of the European Landfill Directive the UK Environment Agency has produced the ‘Regulatory Guidance Note, Interim Waste Acceptance Criteria and Procedures’ (RGN2)[^288]. Table 159 shows the limit values for waste to be accepted at landfills for inert waste at L/S = 10/1 (determined by draft CEN standard two part batch test for inorganic constituents PrEN12457-3).

Table 159: Limit values for inert waste at L/S = 10/1 from RGN2 (United Kingdom).[^288]

<table>
<thead>
<tr>
<th>Component</th>
<th>Limit value</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>0.5</td>
</tr>
<tr>
<td>Cd</td>
<td>0.04</td>
</tr>
<tr>
<td>Cr\text{total}</td>
<td>0.5</td>
</tr>
<tr>
<td>Cu</td>
<td>2.0</td>
</tr>
<tr>
<td>Hg</td>
<td>0.01</td>
</tr>
<tr>
<td>Ni</td>
<td>0.4</td>
</tr>
<tr>
<td>Pb</td>
<td>0.5</td>
</tr>
<tr>
<td>Sb</td>
<td>0.06</td>
</tr>
<tr>
<td>Se</td>
<td>0.1</td>
</tr>
<tr>
<td>Zn</td>
<td>4.0</td>
</tr>
<tr>
<td>Cl</td>
<td>800</td>
</tr>
<tr>
<td>F</td>
<td>10</td>
</tr>
<tr>
<td>SO4^-</td>
<td>1,000</td>
</tr>
<tr>
<td>Phenol index</td>
<td>1.0</td>
</tr>
<tr>
<td>Dissolved organic carbon</td>
<td>500</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>4,000</td>
</tr>
</tbody>
</table>

[^274]: THE ENVIRONMENT AGENCY (2002)
[^288]: THE ENVIRONMENT AGENCY (2002)
Soil guideline values for assessing contaminated soils from the CLEA-software provided by the Department for Environment, Food and Rural Affairs and the Environment Agency.

Table 160: Soil guidelines values as a function of land use from CLEA (United Kingdom).

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Residential – with plant uptake</th>
<th>Allotment</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg kg(^{-1})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>20</td>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>Pb</td>
<td>450</td>
<td>450</td>
<td>750</td>
</tr>
<tr>
<td>As</td>
<td>1</td>
<td>1</td>
<td>1,400</td>
</tr>
<tr>
<td>Cr</td>
<td>130</td>
<td>130</td>
<td>5,000</td>
</tr>
<tr>
<td>Hg</td>
<td>8</td>
<td>8</td>
<td>480</td>
</tr>
<tr>
<td>Ni</td>
<td>50</td>
<td>50</td>
<td>5,000</td>
</tr>
<tr>
<td>Se</td>
<td>35</td>
<td>35</td>
<td>8,000</td>
</tr>
</tbody>
</table>

Based upon the Specification for Highway Works [MCHW Volume 1] and the Design Manual for Roads and Bridges [HD 35/04], PFA and FBA can be recycled for the following applications (see Table 161).

Table 161: Overview of possible applications of coal ash (United Kingdom).

<table>
<thead>
<tr>
<th>Pipe bedding</th>
<th>may contain FBA and PFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankments and Filling</td>
<td>Coal Fly Ash/Pulverised Fuel Ash is specified by name as PFA in both general cohesive fill containing not more than 20% Furnace Bottom Ash, and as conditioned ash in selected cohesive fill to structures and for reinforced earth. Furnace Bottom Ash (FBA) can comply as bulk fill and as selected granular fill that is to be stabilised with cement. However, it is not a named selected granular fill since it would generally fail the strength requirement.</td>
</tr>
<tr>
<td>Capping</td>
<td>Selected conditioned PFA for stabilisation with cement to form capping is specified</td>
</tr>
<tr>
<td>Unbound mixtures for sub-base</td>
<td>not to be used</td>
</tr>
<tr>
<td>Hydraulically bound mixtures for sub-base and base</td>
<td>Alternative binders include Fly Ashes (including PFA) to form Fly Ash Bound Mixtures (FABM). Cementitious binders in this application can include a number of alternatives to Portland cement with well established properties. These include Portland Fly Ash Cement and various combinations including GGBS and PFA.</td>
</tr>
<tr>
<td>Bitumen bound layers</td>
<td>PFA can comply as components of recycled aggregates within bitumen bound layers</td>
</tr>
<tr>
<td>PQ Concrete</td>
<td>PFA is capable of complying with the specification, but excluding exposed aggregate surfacing</td>
</tr>
</tbody>
</table>

\(^{289}\) DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS AND THE ENVIRONMENT AGENCY (2002)
Plenty of information on individual applications of coal ashes is available from the United Kingdom Quality Ash Association. The following technical datasheets are published online:

- PFA / fly ash for concrete - Explains why fly ash is beneficial in concrete
- Specifying PFA / fly ash in concrete to EN206/BS8500 - Explains how to specify fly ash in your concrete using the current UK standard
- The relative performance of EN450 fly ashes to Category S and N
- Applications for fly ash to EN450-1:2005
- PFA / fly ash as a fill material - Describes how PFA is used as a general and structural fill material
- PFA / fly ash for grouting applications - How PFA is used for grouting caverns, mines, redundant pipe work, etc.
- Sintered PFA Lightweight aggregates - Describes how lightweight aggregate is made and the applications its is used for
- Cenospheres - a unique filler - Describes what they are and some of the many applications for the material
- Fly Ash in Highways Construction - An overview of the use of FABM and ESC
- Fly Ash in Highways Construction - Describes FABMs and ESC in detail
- Fly Ash in Highways Construction - Laboratory mix design for FABMs
- Fly Ash in Highways Construction - Structural Design aspects
- Fly Ash in Highways Construction - Specification for FABM 1 & 2 - clauses you can use in your own specification
- Fly Ash in Highways Construction - Specification for FABM 5 - clauses you can use in your own specification
- Fly Ash in Highways Construction - Specification for Enhanced Stabilised Capping - clauses you can use in your own specification
- Furnace Bottom Ash in Light Weight Aggregate (LWA) Concrete Blocks.
- PFA in Aerated Concrete Blocks
- COSHH information about PFA (Health and Safety Information)

Furthermore, a large number of case studies on various applications of ashes are available.

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[290] UNITED KINGDOM QUALITY ASH ASSOCIATION: [http://www.ukqaa.org.uk](http://www.ukqaa.org.uk)
7.17.2 Construction and demolition waste

Data on arising and use of C&D waste for England is reported in 4 surveys carried out by the Department for Communities and Local Government in 1999\(^{291}\), 2001\(^{292}\), 2003\(^{293}\) and 2005\(^{294}\). These however only look at inert C&D waste i.e. construction, demolition and excavation waste that is suitable for reprocessing into recycled aggregates. There is no reasonable data for the non-inert fraction in terms of how much there is and what happens to it. WRAP estimates the amount of non-inert fraction accounting for approximately 15–20 million tonnes in 2005. This would include site construction and refurbishment waste\(^{265}\).

The objective of the surveys was to generate estimates for C&D waste including excavation waste (CDEW) recycled, used and disposed of at licensed landfills, as well as on CDEW spread on § 9A (Land Reclamation and Improvement) and § 19A (Storage and Use of Building Waste) registered exempt sites. These surveys cover operators of crushers and screens, and of licensed landfills. Data on registered exempt sites were also analysed.

The surveys made a clear distinction between ‘hard’ construction and demolition (C&D) waste and excavation waste in order to identify not just the current rate of aggregate recycling, but also the future potential rate. Administrative changes between 2003 and 2005, which mean that the data collection methods had to be changed, have to be taken into account when interpreting estimates for CDEW sent to licensed landfills and registered exempt sites. Landfills were then classified and authorised in a different way, and operators of registered exempt sites then had to pay a fee as well as going through a much more formal application procedure than was previously the case.

In all surveys very little evidence was found of hard C&D waste which could be recycled into aggregate being landfilled as waste, and only very modest tonnages were identified being used within landfills in an unprocessed form (and then it was mainly for site engineering).

The surveys suggest that the population of recycling crushers has continued to grow, but that the annual throughput of the average crusher has fallen with time pointing to greater competition between recyclers. It furthermore became obvious that the recyclers who are most successful at ‘pushing’ recycled aggregate up the value chain tend to be those operators who mix working on demolition sites with having access to a fixed recycling site of their own.

A similar survey was carried out in Scotland for the year 2003\(^{295}\).

Table 162 shows an overview of arisings and use of C&D waste and excavation waste from 1999 until 2005 in England and data obtained for Scotland in 2003.

\(^{291}\) DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT (1999)
\(^{292}\) DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT (2001)
\(^{293}\) DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT (2003)
\(^{294}\) DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT (2005)
\(^{295}\) WASTE & RESOURCES ACTION PROGRAM WRAP (2004)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled by crushers/screeners</td>
<td>24.4</td>
<td>43.3</td>
<td>45.5</td>
<td>4.9</td>
<td>46.4</td>
</tr>
<tr>
<td>for use as aggregate</td>
<td>-</td>
<td>38.0</td>
<td>39.5</td>
<td>4.3</td>
<td>42.1</td>
</tr>
<tr>
<td>for use as soil</td>
<td>-</td>
<td>7.1</td>
<td>5.9</td>
<td>0.6</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Used or disposed in landfill</strong></td>
<td><strong>25.8</strong></td>
<td><strong>23.2</strong></td>
<td><strong>29.1</strong></td>
<td><strong>2.4</strong></td>
<td><strong>27.8</strong></td>
</tr>
<tr>
<td>Disposed as waste</td>
<td>-</td>
<td>-</td>
<td>9.2</td>
<td>0.4</td>
<td>18.14</td>
</tr>
<tr>
<td>Cappinga</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.41</td>
</tr>
<tr>
<td>Engineeringb</td>
<td>-</td>
<td>-</td>
<td>6.5</td>
<td>0.3</td>
<td>4.2</td>
</tr>
<tr>
<td>used to backfill quarry voids</td>
<td>-</td>
<td>-</td>
<td>13.4</td>
<td>1.7</td>
<td>-</td>
</tr>
<tr>
<td><strong>Spread on exempt sites</strong></td>
<td><strong>19.0</strong></td>
<td><strong>22.4</strong></td>
<td><strong>16.4</strong></td>
<td><strong>3.5</strong></td>
<td><strong>15.4</strong></td>
</tr>
<tr>
<td>Total</td>
<td>69.2</td>
<td>88.89</td>
<td>90.93</td>
<td>10.8</td>
<td>89.6</td>
</tr>
</tbody>
</table>

a used in capping and restoration

b used in landfill engineering (roads, binding, drainage, daily cover etc).

c during 2003 operators of landfills were deciding whether to adapt or close their facilities in response to the Landfill (England & Wales) Regulations 2002 (which in turn were driven by the Landfill Directive). However, the growth in landfilled CDEW (9.19 million tonnes in 2003) compared to 2001 (3.87 million tonnes) appears to have come almost entirely from material landfilled as waste rather than material used for site closure and restoration.

d the drop in material used on registered exempt sites may be linked to a change in the way that the Environment Agency has interpreted the need for construction sites to register for exemptions under Paragraph 19. Whereas most such sites were previously registered with the Agency, some sites which are carrying out simple ‘cut and fill’ activities using clean site-won excavation waste now appear to be less likely to be required to register an exemption.

Table 163 shows the fractions of CDEW types spread on § 9&19 registered exempt sites in 2003.
Table 163: Composition of material spread on § 9 &19 registered exempt sites in England and Scotland (2003) (United Kingdom).

<table>
<thead>
<tr>
<th>Material</th>
<th>England</th>
<th>Scotland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean excavation waste</td>
<td>6.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Utility trench waste</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>Mixed excavation waste</td>
<td>3.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Uncrushed hard C&amp;D waste</td>
<td>1.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Road planings</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>Processed aggregate</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>Ash, slag, clinker</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>Dredged, other, unknown material</td>
<td>1.7</td>
<td>0</td>
</tr>
<tr>
<td>All materials</td>
<td>15.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

In the UK, secondary aggregates contribute approximately 23% (50 million tonnes) to the overall supply of construction aggregates (WRAP, 2002). It is anticipated that this would increase to ca. 57 million tonnes per annum over the period 2001 to 2016 according to the revised guidance prepared by the UK Office of the Deputy Prime Minister (ODPM, 2003).

For bituminous pavements methods and equipment for recycling are well developed and established; this can be done in situ or ex situ. Asphalt can be recycled back into hot asphalt, a process which gains the benefit from the original bitumen and high quality aggregate; or into cold lay foamed bitumen, which is growing in popularity. It is estimated that 5% of asphalt is recycled back into new asphalt and the remaining 95% is used as fill material296.

C&D waste including asbestos is the largest component of hazardous waste in England and Wales, constituting 32%, nearly 1.7 million tonnes. Nearly all of this goes to landfill, but although arisings increased sharply in 2004 as developers sought to beat the co-disposal ban, the trend is downwards.

CDEW is a major component of fly-tipped waste. CDEW formed over 31% of fly-tipping incidents dealt with by the Environment Agency in 2005/06. Nearly 60,000 incidents involving construction-related waste were reported to English local authorities, resulting in significant clean-up costs.

296 BARRITT (2003)
7.17.3 Slags from ferrous metal production

Data on arisings and use of slag from ferrous metal production for England and Wales were extracted from 2 surveys published in 2002\textsuperscript{297} and 2007\textsuperscript{298} by the Department for Communities and Local Government (see Table 164). There is no production of slags in Scotland.

Table 164: Arisings and use of steel slags in the UK (in million tonnes) (United Kingdom)\textsuperscript{297, 298}.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>0.28</td>
<td>2.7</td>
</tr>
<tr>
<td>Aggregate use</td>
<td>1.05</td>
<td>0.5</td>
<td>0.98</td>
<td>0.25</td>
<td>0</td>
<td>2.7</td>
</tr>
<tr>
<td>Non aggregate use</td>
<td>1.95</td>
<td>1.5</td>
<td>0.02</td>
<td>0</td>
<td>0.28</td>
<td>0</td>
</tr>
<tr>
<td>Potentially available</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Usable stockpiles</td>
<td>no data</td>
<td>no data</td>
<td>no data</td>
<td>no data</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Another source for the generation of slags from the ferrous metal production is the English Pollution Inventory\textsuperscript{299} (see Table 165). However, there is no separation in individual types of slag. Data on the waste management option is available for the year 2006 only.

Table 165: Arisings and waste management options for steel slag in England (in million tonnes) (United Kingdom)\textsuperscript{299}.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>3.66</td>
<td>3.00</td>
<td>1.08*</td>
</tr>
<tr>
<td>Waste Management Option</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1, Deposition in or under the terrain level (landfilling)</td>
<td>-</td>
<td>-</td>
<td>0.81</td>
</tr>
<tr>
<td>D5, Specially engineered landfill</td>
<td>-</td>
<td>-</td>
<td>0.15</td>
</tr>
<tr>
<td>R3, Recycling/reclamation of organic substances which are not used as solvents</td>
<td>-</td>
<td>-</td>
<td>0.01</td>
</tr>
<tr>
<td>R4, Recycling/reclamation of metals and metal compounds</td>
<td>-</td>
<td>-</td>
<td>0.09</td>
</tr>
<tr>
<td>others</td>
<td>-</td>
<td>-</td>
<td>negligible</td>
</tr>
</tbody>
</table>

\textsuperscript{a} the obvious decline compared to the previous years can be explained by the fact, that in 2006 a large part of slag was already considered a by-product and thus was not reported as waste.

\textsuperscript{297} DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT (2002)
\textsuperscript{298} DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT (2007)
\textsuperscript{299} POLLUTION INVENTORY: \url{http://www.environment-agency.gov.uk}
BFS is produced by the three remaining integrated steelmaking facilities in the UK. These are plants owned by Corus UK Ltd at Teesside, Scunthorpe and Port Talbot. Weathering of steel slag is commonly undertaken as part of the aggregate production process:

- Approximately 75% of BFS production in the UK is converted into ground granulated BFS (GGBFS). To produce GGBFS molten BFS is allowed to flow from the blast furnace down launders (runner beds) into a purpose-built granulation plant where the BFS is quenched rapidly with high volumes of warm water. This results in vitrified (glassy) material with a sand-like appearance, with particles typically 1–3 mm in size. The granulated BFS (GBFS) is then transported to a grinding mill for conversion into GGBFS.

- The remainder is converted into air-cooled BFS (ACBFS). To produce ACBFS molten BFS is allowed to flow from the blast furnace into open air pits located beside the furnaces. There the material is quenched with water applied by sprays to facilitate cooling and BFS crystallisation (this handling method enhances the properties by reducing the BFS density). Once sufficiently cooled, ACBFS is dug from the open air pits and transported to a nearby crushing and screening (aggregate) plant, where it is processed into aggregates.

Virtually all GGBFS produced is for sale to the UK concrete market, whereas ACBFS is crushed and screened for UK aggregate sales. Compared to the BFS production of 4.2 million tonnes in 2002, 4.55 million tonnes of BFS was used in the UK in 2002. Thus consumption exceeded production, with the shortfall being made up by UK stock movements to bridge the imbalance.

Effectively, on average, all the arisings of BOF are used in road construction, in asphalt or in sub-base. Very small quantities go for no aggregate uses elsewhere. There is continuing demand for this material for road construction purposes.

EAF steel slag is originating from electric arc furnace steel plants in Yorkshire and the Humber, and the South East. EAF slag is effectively all used as a high quality aggregate material in road surfacings.
7.17.4 Ashes from coal combustion processes

Information on the chemical composition of pulverised fuel ash from UK coal fired power plants was gained from a technical datasheet and the environmental risk assessment, mentioned above, published by the United Kingdom Quality Ash Association. Element concentrations in the solid phase as well as water leachable concentrations are illustrated in Table 166 and Table 167. The latter are the outcome of routine analyses.

Table 166: Element contents of the solid phase (typical ranges of oxides and trace elements from UK pulverised fuel ash) (United Kingdom). 

<table>
<thead>
<tr>
<th>Element</th>
<th>Unit</th>
<th>MIN</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>% as Al2O3</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Calcium</td>
<td>% as CaO</td>
<td>1.8</td>
<td>10</td>
</tr>
<tr>
<td>Chloride</td>
<td>% as Cl</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Free calcium oxide</td>
<td>%</td>
<td>&lt;0.1</td>
<td>1</td>
</tr>
<tr>
<td>Iron</td>
<td>% as Fe2O3</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>%</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Magnesium</td>
<td>% as MgO</td>
<td>1.0</td>
<td>3.5</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Potassium</td>
<td>% as K2O</td>
<td>2.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Silicon</td>
<td>% as SiO2</td>
<td>38</td>
<td>52</td>
</tr>
<tr>
<td>Sodium</td>
<td>% as Na2O</td>
<td>0.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Sulfate</td>
<td>% as SO3</td>
<td>0.35</td>
<td>2.5</td>
</tr>
<tr>
<td>Titanium</td>
<td>% as TiO2</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Water soluble sulphate (L/S=2/1)</td>
<td>% as SO4</td>
<td>1.3</td>
<td>4</td>
</tr>
<tr>
<td>Sb</td>
<td>mg/kg</td>
<td>1</td>
<td>325</td>
</tr>
<tr>
<td>As</td>
<td>mg/kg</td>
<td>4</td>
<td>128</td>
</tr>
<tr>
<td>Ba</td>
<td>mg/kg</td>
<td>n.d.</td>
<td>36,000</td>
</tr>
<tr>
<td>B</td>
<td>mg/kg</td>
<td>5</td>
<td>310</td>
</tr>
<tr>
<td>Cd</td>
<td>mg/kg</td>
<td>&lt;1.0</td>
<td>4</td>
</tr>
<tr>
<td>Cl</td>
<td>mg/kg</td>
<td>0</td>
<td>2,990</td>
</tr>
<tr>
<td>Cr</td>
<td>mg/kg</td>
<td>33</td>
<td>192</td>
</tr>
<tr>
<td>Co</td>
<td>mg/kg</td>
<td>2</td>
<td>115</td>
</tr>
<tr>
<td>Cu</td>
<td>mg/kg</td>
<td>119</td>
<td>474</td>
</tr>
<tr>
<td>Fl</td>
<td>mg/kg</td>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td>Pb</td>
<td>mg/kg</td>
<td>&lt;1</td>
<td>976</td>
</tr>
<tr>
<td>Mn</td>
<td>mg/kg</td>
<td>103</td>
<td>1,555</td>
</tr>
<tr>
<td>Hg</td>
<td>mg/kg</td>
<td>&lt;0.01</td>
<td>0.61</td>
</tr>
<tr>
<td>Mn</td>
<td>mg/kg</td>
<td>3</td>
<td>81</td>
</tr>
<tr>
<td>Ni</td>
<td>mg/kg</td>
<td>35</td>
<td>583</td>
</tr>
<tr>
<td>P</td>
<td>mg/kg</td>
<td>372</td>
<td>2,818</td>
</tr>
<tr>
<td>Se</td>
<td>mg/kg</td>
<td>&lt;1</td>
<td>162</td>
</tr>
<tr>
<td>Sn</td>
<td>mg/kg</td>
<td>933</td>
<td>1,847</td>
</tr>
<tr>
<td>V</td>
<td>mg/kg</td>
<td>96</td>
<td>1,339</td>
</tr>
<tr>
<td>Zn</td>
<td>mg/kg</td>
<td>148</td>
<td>918</td>
</tr>
<tr>
<td>Dioxins</td>
<td>mg/kg</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>PAHs</td>
<td>mg/kg</td>
<td>&lt;0.5</td>
<td></td>
</tr>
</tbody>
</table>

100 UNITED KINGDOM QUALITY ASH ASSOCIATION UKQAA (2004)
According to the information available from the UKQAA website there are 20 coal fired power stations in operation currently. The UK coal fired power stations burn hard coals; the majority being only bituminous coals, but there is some use of anthracite.

Data on arisings and use of coal ashes for England and Wales were extracted from 2 surveys carried out in 2001\textsuperscript{301} and 2005\textsuperscript{302} by the Department for Communities and Local Government; data for Scotland derive from a survey carried out in 1999\textsuperscript{303} (see Table 168).

\begin{table}[h]
\centering
\begin{tabular}{l|c|c|c}
\hline
Element & Unit & MIN & MAX \\
\hline
Al   & mg/l & <0.01 & 9.8 \\
Sb   & mg/l & <0.01 & <0.2 \\
As   & mg/l & 0.06  & 0.16 \\
Ba   & mg/l & 0.2   & 0.4 \\
B    & mg/l & 0.1   & 6 \\
Cd   & mg/l & <0.005 & <0.005 \\
Cl   & mg/l & 1.6   & 17.5 \\
Ca   & mg/l & 15    & 250 \\
Cr   & mg/l & 0.02  & 0.06 \\
Co   & mg/l & <0.01 & <0.01 \\
Cu   & mg/l & <0.01 & <0.01 \\
Fl   & mg/l & <0.01 & 2.3 \\
Fe   & mg/l & <0.01 & <0.01 \\
Pb   & mg/l & <0.01 & <0.01 \\
Mg   & mg/l & <0.01 & 100 \\
Mn   & mg/l & <0.01 & <0.01 \\
Hg   & mg/l & <0.001 & <0.001 \\
Mo   & mg/l & 0.1   & 0.88 \\
Ni   & mg/l & <0.01 & <0.01 \\
P    & mg/l & <0.1  & 0.4 \\
K    & mg/l & 5     & 29 \\
Se   & mg/l & 0.04  & 0.16 \\
Si   & mg/l & 0.5   & 1.5 \\
Na   & mg/l & 5     & 44 \\
S    & mg/l & 15    & 510 \\
Sn   & mg/l & <0.01 & <0.01 \\
V    & mg/l & <0.01 & 0.55 \\
Zn   & mg/l & <0.02 & <0.02 \\
\hline
\end{tabular}
\caption{Leachable elements (DIN 38414-S4 and NRA leaching methods (L/S = 10/1 (typical ranges of UK PFA) (United Kingdom)\textsuperscript{300}).}
\end{table}

\textsuperscript{301} Department for Communities and Local Government (2002)
\textsuperscript{302} Department for Communities and Local Government (2007)
\textsuperscript{303} Winter et al. (2001)
Table 168: Arisings and use of coal ashes in the UK (in million tonnes) (United Kingdom).

<table>
<thead>
<tr>
<th></th>
<th>PFA</th>
<th>FBA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>England and Wales</td>
<td>Scotland</td>
</tr>
<tr>
<td>Aggregate use</td>
<td>4.87</td>
<td>5</td>
</tr>
<tr>
<td>Non aggregate use</td>
<td>1.66</td>
<td>0.9</td>
</tr>
<tr>
<td>Potentially available</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Usable stockpiles</td>
<td>55</td>
<td>-</td>
</tr>
<tr>
<td>Landfilled</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Another source for the generation of ashes from coal combustion processes is the English Pollution Inventory (see Table 169). However, there is no separation in PFA and FBA. Data on the waste management option is available for the year 2006 only.

Table 169: Arisings and waste management options for coal ash in England (in million tonnes)\(^{199}\).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>5.54</td>
<td>4.4</td>
<td>6.05</td>
</tr>
<tr>
<td>Disposal</td>
<td></td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>D1, Deposition in or under the terrain level (landfilling)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D4; Surface impoundment</td>
<td></td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>Recovery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R11, Use of wastes obtained from any of the operations numbered R 1 to R 10</td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>R4, Recycling/reclamation of metals and metal compounds</td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>R5, Recycling/reclamation of other inorganic materials</td>
<td></td>
<td></td>
<td>3.1</td>
</tr>
<tr>
<td>others</td>
<td></td>
<td></td>
<td>negligible</td>
</tr>
</tbody>
</table>

Data on the proportions of ash types sold in 2000 (74 % PFA, 25 % FBA, 1 % Cenospheres) is available from the UKQAA website. The following Table 170 gives an overview on the proportions of individual applications of ash products sold. It becomes obvious that the main applications are FBA utilisation, concrete addition, aerated blocks and fill and ground remediation. Although it is estimated by WRAP that a portion of 100 % of the arisings is suitable for aggregate use, there is information from UKQAA that in 2002 only approx. 60 % of the total production of power station ash was sold for use. Almost all of FBA was sold. 50 % of PFA was sold.
Table 170: Proportions of UK ash products sold for the various applications, (in %) (United Kingdom)\(^{304}\).

<table>
<thead>
<tr>
<th>Product</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill and ground remediation</td>
<td>8.2</td>
<td>10.54</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Aerated blocks</td>
<td>16.7</td>
<td>19.29</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Concrete addition</td>
<td>12.5</td>
<td>13.96</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>FBA utilisation</td>
<td>23</td>
<td>20.73</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Gypsum sold</td>
<td>15.9</td>
<td>17.62</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Grouting</td>
<td>8.6</td>
<td>3.86</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Non aerated concrete blocks and precast</td>
<td>5.3</td>
<td>4.01</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Blended cement</td>
<td>1.3</td>
<td>0.4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cement raw material</td>
<td>4.8</td>
<td>6.73</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Cenospheres</td>
<td>0.7</td>
<td>0.31</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Long term storage</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3.1</td>
<td>2.54</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

PFA in the UK is either taken directly from power station silos (dry ash), or with water added at source or on site to assist in handling/compaction (conditioned ash) or taken from stockpiles of previously conditioned ash located at the coal-burning power stations (stockpile ash) or recovered from storage lagoons (lagoon ash). Especially in older power stations surplus PFA is often transported as slurry in pipelines. This is then allowed to sediment in a lagoon. During this process a large part of the water soluble material present in PFA can be dissolved, which is removed along with the decanting water. The remaining soluble material consists of the sulphate and chloride of the alkali metals and trace metals that form soluble anions at high pH\(^{305}\).
8 LITERATURE

General


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ANONYMOUS (2005): Data on the quality and amount of slags from companies of the iron and steel industry, Austria.


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QUEBAUD, M (1996): Characterisation of the recycled aggregates composition and compartment studies for concrete with these aggregates, Thesis of the University of Artois.


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Austria


COUNCIL DECISION OF 19 DECEMBER 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC.


Belgium


Czech Republic

CZECH STANDARDS INSTITUTE (1988): CSN 07 7002, Disposal of solid residues from combustion of coal

Denmark

Estonia


Finland


MINISTRY OF THE ENVIRONMENT (2006B): Preamble to the Government Decree concerning the recovery of certain wastes in earth construction, Councillor Klaus Pfinster, 12.06.2006. (Only available in Finnish language)


VTT (2006b): Expert study to support building waste statistics of the year 2004. (Only available in Finnish language)

France


Germany


Ireland


Italy


Luxembourg


Malta


Netherlands

Poland

Spain
GOVERNMENT OF BASQUE COUNTRY (2003): Decree 34/2003 which regulates the recovery and subsequent use of slags originating from production of steel in electric arc furnaces in the Autonomous Community of Basque Country. (Only available in Spanish language)
Sweden


SNRA (2003): ATB VÄG, General technical description of road constructions, the Swedish National Road Administration, Borlänge, only available in Swedish language.


SWEDISH GEOTECHNICAL INSTITUTE (2003): Inventory of wastes which potentially can be recovered as construction materials as substitute for natural gravel.


United Kingdom


DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS AND THE ENVIRONMENT AGENCY (2002): CLEA software model support data -SGV1, 3, 4, 5, 7, 9, 10


THE ENVIRONMENT AGENCY (2006): Position statement. The use of small quantities of road planings on tracks and roads under a Paragraph 19A exemption


Literature used by WRAP for the decision BSF is no waste


8.1 Web

Germany Building Materials Institute FEhS
http://www.fehs.de

Clean Coal Centre United Kingdom IEA
http://www.iea-coal.co.uk

Czech Information System of Waste Management (ISOH)
http://ceho.vuv.cz

Czech Environmental Information Agency (CENIA)
http://www.cenia.cz

Department for Environment Food and Rural Affairs DEFRA
http://www.defra.gov.uk

Environmental Data Compendium Netherlands
http://www.mnp.nl

European Aggregates Association UEPG
http://www.uepg.eu
European Environmental Agency EEA
http://www.eea.europa.eu

European Topic Centre on Resource and Waste Management
http://waste.eionet.europa.eu

EUROSLAG
http://www.euroslag.com

EUROSTAT
http://epp.eurostat.ec.europa.eu

Estonia Ministry of the Environment
http://www.envir.ee

Estonia Energy
http://www.estoniaenergy.com

Finnish Environment Administration
http://www.environment.fi

Highways Agency, Welsh Assembly, Scottish Executive and the Department of the Environment for Northern Ireland
http://www.standardsforhighways.co.uk

National Roads Authority of Ireland
http://www.nra.ie

Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM)
http://www.vrom.nl

Practical Law Company
http://www.practicallaw.com

The UK Environmental Agency
http://www.environment-agency.gov.uk

Waste and Resources Action Programme WRAP
http://www.wrap.org.uk

United Kingdom Quality Ash Association
http://www.ukqaa.org.uk
9 ANNEXES

9.1 Annex 1: Lists of European Standards for tests for specific properties of aggregates

Table 171: Tests for general properties of aggregates (CEN TC/154)\(^{17}\).

<table>
<thead>
<tr>
<th>Standard reference</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>EN 932-1:1996</td>
<td>Tests for general properties of aggregates - Part 1: Methods for sampling</td>
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<tr>
<td>EN 932-2:1999</td>
<td>Tests for general properties of aggregates - Part 2: Methods for reducing laboratory samples</td>
</tr>
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<td>EN 932-5:1999</td>
<td>Tests for general properties of aggregates - Part 5: Common equipment and calibration</td>
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<tr>
<td>EN 932-6:1999</td>
<td>Tests for general properties of aggregates - Part 6: Definitions of repeatability and reproducibility</td>
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</table>

Table 172: Tests for chemical properties of aggregates (CEN TC/154)\(^{17}\).

<table>
<thead>
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<th>Title</th>
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</thead>
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<tr>
<td>EN 1744-1:1998</td>
<td>Tests for chemical properties of aggregates - Part 1: Chemical analysis</td>
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<td>EN 1744-3:2002</td>
<td>Tests for chemical properties of aggregates - Part 3: Preparation of eluates by leaching of aggregates</td>
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<tr>
<td>EN 1744-4:2005</td>
<td>Tests for chemical properties of aggregates - Part 4: Determination of water susceptibility of fillers for bituminous mixtures</td>
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<tr>
<td>EN 1744-5:2006</td>
<td>Tests for chemical properties of aggregates - Part 5: Determination of acid soluble chloride salts</td>
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<td>EN 1744-6:2006</td>
<td>Tests for chemical properties of aggregates - Part 6: Determination of the influence of recycled aggregate extract on the initial setting time of cement</td>
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</table>

Table 173: Tests for mechanical properties of aggregates (CEN TC/154)\(^{17}\).

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<td>EN 1367-1:2007</td>
<td>Tests for thermal and weathering properties of aggregates - Part 1: Determination of resistance to freezing and thawing</td>
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<td>EN 1367-2:1998</td>
<td>Tests for thermal and weathering properties of aggregates - Part 2: Magnesium sulfate test</td>
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<td>EN 1367-3:2001</td>
<td>Tests for thermal and weathering properties of aggregates - Part 3: Boiling test for &quot;Sonnenbrand basalt&quot;</td>
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<td>EN 1367-4:1998</td>
<td>Tests for thermal and weathering properties of aggregates - Part 4: Determination of drying shrinkage</td>
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<td>EN 1367-5:2002</td>
<td>Tests for thermal and weathering properties of aggregates - Part 5: Determination of resistance to thermal shock</td>
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</table>
Table 174: Tests for filler aggregate used in bituminous mixtures (CEN TC/154)\textsuperscript{17}.

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<tr>
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<tbody>
<tr>
<td>EN 13179-1:2000</td>
<td>Tests for filler aggregate used in bituminous mixtures - Part 1: Delta ring and ball test</td>
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<td>EN 13179-2:2000</td>
<td>Tests for filler aggregate used in bituminous mixtures - Part 2: Bitumen number</td>
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Table 175: Tests for geometrical properties of aggregates (CEN TC/154)\textsuperscript{17}.

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<tr>
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<td>Tests for geometrical properties of aggregates - Part 1: Determination of particle size distribution - Sieving method</td>
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<tr>
<td>EN 933-2:1995</td>
<td>Tests for geometrical properties of aggregates - Part 2: Determination of particle size distribution - Test sieves, nominal size of apertures</td>
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<td>EN 933-3:1997</td>
<td>Tests for geometrical properties of aggregates - Part 3: Determination of particle shape - Flakiness index</td>
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<td>EN 933-4:1999</td>
<td>Tests for geometrical properties of aggregates - Part 4: Determination of particle shape - Shape index</td>
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<td>EN 933-5:1998</td>
<td>Tests for geometrical properties of aggregates - Part 5: Determination of percentage of crushed and broken surfaces in coarse aggregate particles</td>
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<td>EN 933-6:2001</td>
<td>Tests for geometrical properties of aggregates - Part 6: Assessment of surface characteristics - Flow coefficient of aggregates</td>
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<tr>
<td>EN 933-7:1998</td>
<td>Tests for geometrical properties of aggregates - Part 7: Determination of shell content - Percentage of shells in coarse aggregates</td>
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<td>EN 933-8:1999</td>
<td>Tests for geometrical properties of aggregates - Part 8: Assessment of fines - Sand equivalent test</td>
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<td>EN 933-10:2001</td>
<td>Tests for geometrical properties of aggregates - Part 10: Assessment of fines - Grading of fillers (air jet sieving)</td>
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Table 176: Tests for mechanical properties of aggregates (CEN TC/154)\textsuperscript{17}.

<table>
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<td>Tests for mechanical and physical properties of aggregates - Part 10: Determination of water suction height</td>
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<tr>
<td>EN 1097-2:1998</td>
<td>Tests for mechanical and physical properties of aggregates - Part 2: Methods for the determination of resistance to fragmentation</td>
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<tr>
<td>EN 1097-3:1998</td>
<td>Tests for mechanical and physical properties of aggregates - Part 3: Determination of loose bulk density and voids</td>
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<td>EN 1097-4:1999</td>
<td>Tests for mechanical and physical properties of aggregates - Part 4: Determination of the voids of dry compacted filler</td>
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<tr>
<td>EN 1097-5:1999</td>
<td>Tests for mechanical and physical properties of aggregates - Part 5: Determination of the water content by drying in a ventilated oven</td>
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<tr>
<td>EN 1097-6:2000</td>
<td>Tests for mechanical and physical properties of aggregates - Part 6: Determination of particle density and water absorption</td>
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<tr>
<td>EN 1097-7:1999</td>
<td>Tests for mechanical and physical properties of aggregates - Part 7: Determination of the particle density of filler - Pyknometer method</td>
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<td>EN 1097-8:1999</td>
<td>Tests for mechanical and physical properties of aggregates - Part 8: Determination of the polished stone value</td>
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<td>Tests for mechanical and physical properties of aggregates - Part 9: Determination of the resistance to wear by abrasion from studded tyres - Nordic test</td>
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Table 177: Construction and demolition waste generated 2000 to 2003

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*: *Missing value
### Table 178: Excavated soils from construction and demolition waste generated 2000 to 2003^\text{28}^.

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### Table 179: Waste from the sector ‘construction’ generated 2000 to 2003

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<th>2003</th>
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*:… Missing value
Table 180: Waste from the sector ‘mining and quarrying’ generated 2000 to 2003\textsuperscript{28}.

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\textsuperscript{28}… Missing value
Table 181: Waste from the sector ‘manufacture of basic metals and fabricated metal products’ generated 2000 to 2003:

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*: Missing value
Table 182: Waste from the sector ‘electricity, gas and water supply’ generated 2000 to 2003.

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