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Present and Future Situation in Europe

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ABSTRACT

In Europe, coal combustion products (CCPs) are mainly utilised as a replacement for natural materials in the building material industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes in open cast mines. The majority of the CCPs are produced to meet certain requirements of standards or other specifications with respect to utilisation in certain areas.

The use of CCPs has several environmental and technical benefits. The environmental benefits are saving of natural resources, energy, emissions of pollutants to the air, CO_2 emissions and disposal space. The use has developed over the years and is mostly based on requirements of standards or other specifications which are subject to regular revision by CEN or national authorities.

This paper gives on overview on production and utilisation of CCPs in Europe and will focus on the development of environmental and technical legislation.

INTRODUCTION

Coal ash is produced with the production of electricity in coal-fired power plants. Coal ash is a synonym for the combustion residues boiler slag, bottom ash and especially fly ash from different types of boilers. These ashes form the major part of all coal combustion products (CCPs) which consist also of desulphurisation products like spray dry absorption product and FGD gypsum.

In 2007, about 61 million tonnes of CCPs were produced in Europe (EU15). The production in all the European member states is estimated to be about 100 million tonnes. Exact figures from most of the EU 12 member states are not yet available. Over the last years, the production of these CCPs has been increased in the member states due to legal requirements for flue gas cleaning. The utilisation of CCPs is well established in some European countries, based on long term experience and technical as well as environmental benefits. The CCPs are mainly utilised in the building material industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes in open cast mines. The majority of the CCPs is produced to meet certain requirements of standards or other specifications with respect to utilisation in certain areas.

The utilisation of CCPs in Europe is being influenced by environmental legislation and by the liberalization of the electricity market. At present, the most important discussion focuses on the definition of CCPs. With the revision of the Waste Directive also “by-products” and

"end-of-waste" will be defined. By-products will from the beginning not be subject to waste legislation; end-of-waste materials are resulting from the recovery of waste. For non-waste-materials the REACH regulation has to be considered and substances which are not waste are subject to REACH.

The use of CCPs has several environmental and technical benefits. It has developed by the years and is mostly based on requirements of standards or other specifications which are subject to regular revision by CEN or national authorities. At present, the European standards EN 450-1 and EN 450-2 are under revision. Also under revision are the new revised standards for hydraulic road binders, for aggregates and lightweight aggregates.

This paper gives an overview on coal ash utilisation in Europe and will focus on the development of environmental legislation (i.a. Waste Directive, REACH Regulation) and the revision of European standards.

PRODUCTION OF CCPS IN EUROPE

Since in 2004 the European Union (EU) grew up to 25 member states and again in 2007 to 27 member states the total production of CCPs in the EU is estimated to be about 100 million tonnes (EU 27). Unfortunately the data for production and utilisation figures of all of the 12 new EU Member States are not available to ECOBA, so more detailed information on the production in EU 27 cannot be provided for the time being. Therefore, the statistics presented in this report cover the situation in EU 15 member states.

The ECOBA statistics (*ECOBA*) on production and utilisation of CCPs reflect the typical combustion products such as 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) product and flue gas desulphurisation (FGD) gypsum.

In figure 1 the development of CCP production in EU 15 member states from 1993 to 2007 is shown. The total amount decreased from 57 million tonnes in 1993 to 55 million tonnes in 1999 and rose again to 64 million tonnes in 2005 due to higher production of electricity and heat by coal combustion.

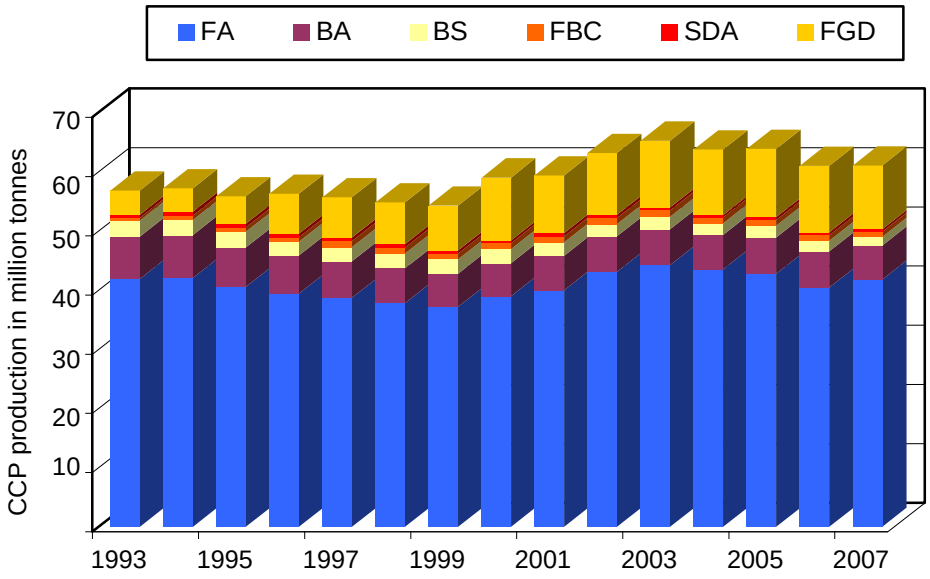

Fig.1. Development of the CCP production in Europe (EU 15) from 1993 to 2007

In 2007, the amount of CCPs produced in European (EU 15) power plants totalled 61 million tonnes, about 3 million tonnes less compared to 2005. This reduction was caused by smaller production by coal combustion in some countries due to higher production by hydro power or the installation of de-NOx and de-SOx measures. In 2007, all combustion residues amounted to about 82 % and the FGD residues to about 18 % by mass.

The development of the production of fly ash from hard coal and lignite combustion in dry-bottom boilers is shown in figure 2. Although in 2007 a smaller production of mostly hard coal fly ash for the EU 15 members states is observed it has to be noted that this figure does not reflect the situation in the single EU member states. In some countries the production was at the same level or even higher than the year before.

In contrast to the expectations based on the overall discussion about CO_2 reduction an increase of CCPs is expected due to retrofitting of existing coal fired power plants with FGD based on requirements of the Large Combustion Plants Directive (LCPD), the construction of new coal fired power plants in some countries as well as the increased use of imported coal with higher ash content.

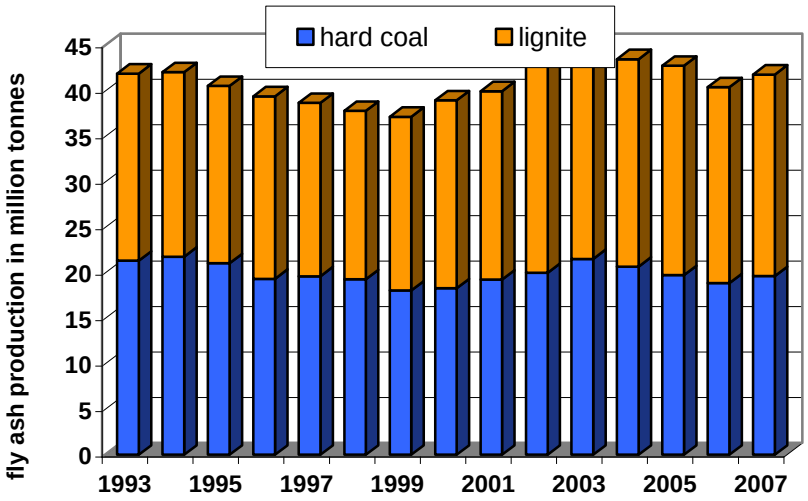

Fig.2. Development of the production of fly ash from hard coal and lignite in Europe (EU 15) from 1993 to 2007

UTILISATION OF CCPS

The CCPs are mainly utilised in the building material industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes in open cast mines. In 2007, about 53% of the total CCPs were used in the construction industry, in civil engineering and as construction materials in underground mining and about 36% for restoration of open cast mines, quarries and pits. About 2.5 % were temporarily stockpiled for future utilisation and about 8 % were disposed of (figure 3).

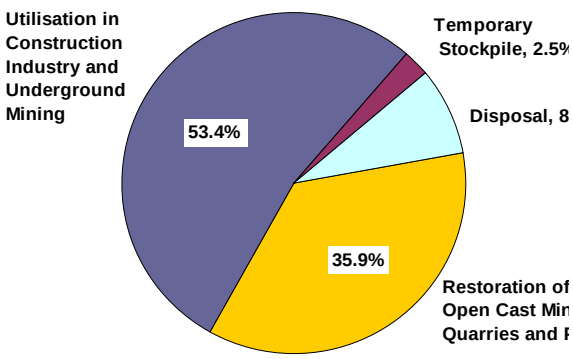

Fig. 3. Utilisation and disposal of CCPs in Europe (EU 15) in 2007

The rates of utilisation, temporary stockpile and disposal for each of the CCPs are given in figure 4.

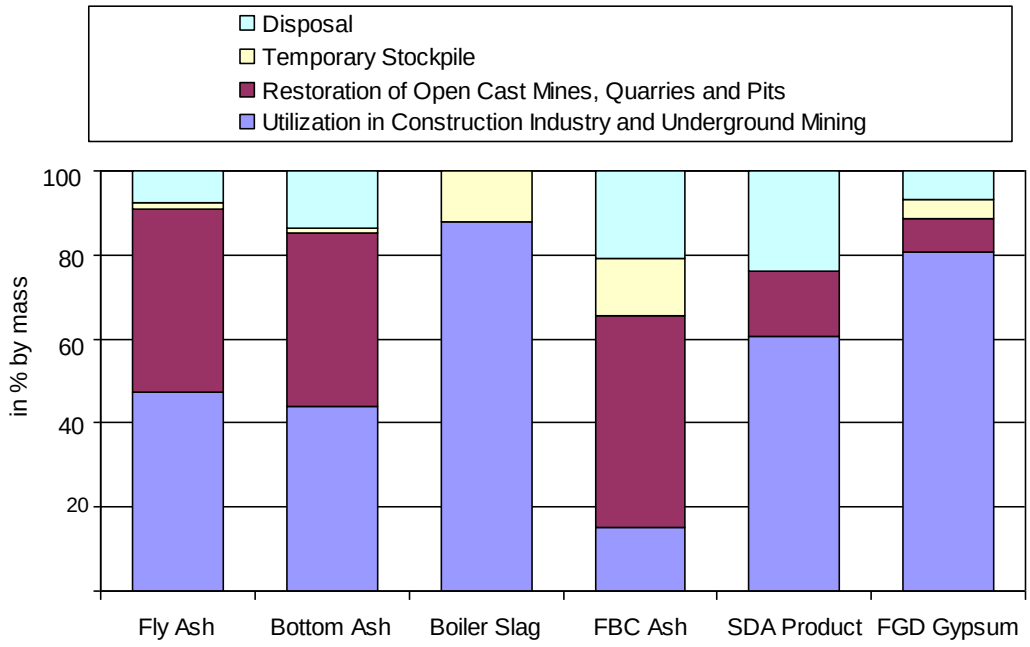

Fig. 4. Utilisation, temporary stockpile and disposal of CCPs in Europe (EU 15) in 2007

UTILISATION OF SPECIFIC CCPS

Fly ash

Fly ash is obtained by electrostatic or mechanical precipitation of dust like particles from the flue gas and represents the greatest proportion of the total CCP production. Depending on type of coal and type of boiler siliceous, silico-calcareous or calcareous fly ashes with

pozzolanic and/or latent hydraulic properties are produced throughout Europe. The utilisation of fly ash across European countries is different and is mainly based on national experience and tradition.

In 2007, about 20 million tonnes of fly ash were utilised in the construction industry and for production purposes in underground mining. Most of the fly ash produced was used as concrete addition, in road construction and as raw material for cement clinker production. Fly ash was also utilised in blended cements, in concrete blocks and for infill (that means filling of voids, mine shafts and subsurface mine workings) (see figure 5).

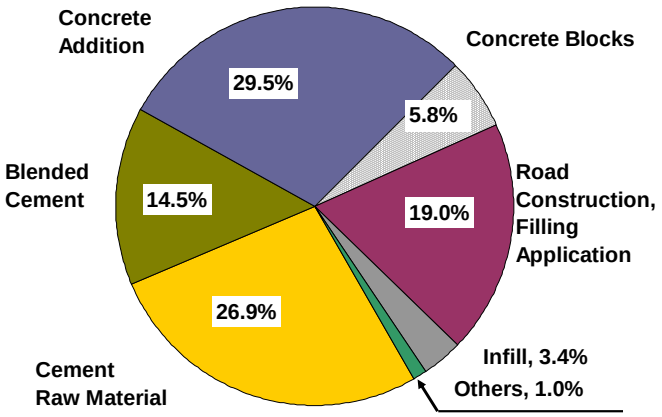

Fig. 5. Utilisation of Fly Ash in the Construction Industry and Underground Mining in Europe (EU 15) in 2007. Total utilisation 20.0 million tonnes.

Bottom ash

Bottom ash is a granular material removed from the bottom of dry bottom furnaces operated at furnace temperatures of 1000 to 1200°C. Bottom ash is much coarser than fly ash. About 2.5 million tonnes of bottom ash were used in the construction industry. Out of this about 45 % was used as fine aggregate in concrete blocks and in concrete, about 37 % in road construction and filling applications and about 13 % in cement production (see figure 6).

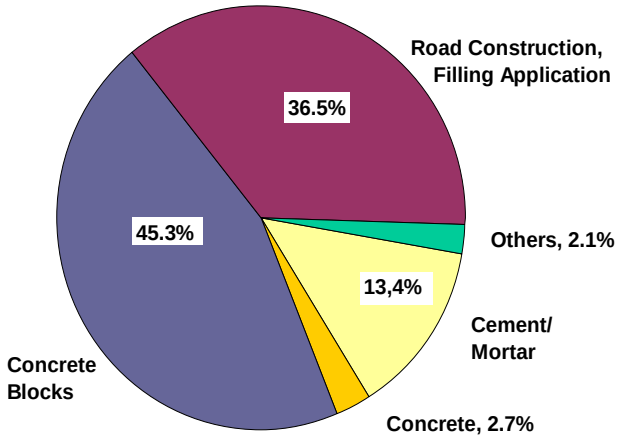

Fig. 6. Utilisation of Bottom Ash in the Construction Industry and Underground Mining in Europe (EU 15) in 2007. Total utilisation 2.5 million tonnes.

Boiler slag
Boiler slag is a vitreous grained material derived from coal combustion in wet bottom boilers operated at temperatures of about 1600°C. Due to the high furnace temperature the coal ash is molten, it flows down to the bottom of the furnace and is removed from a water bath below the furnace bottom. Boiler slag is a glassy material. About 66 % of the boiler slag produced was used as blasting grid, about 10 % for grouting and in drainage layers and about 14 % was used as aggregate in concrete.

Fluidized Bed Combustion (FBC) Ash
FBC ash is produced in fluidized bed combustion boilers. The technique combines coal combustion and flue gas desulphurisation in the boiler at temperatures of 800 to 900°C. As the combustion process is designed to handle different types of fuel also different kinds of sludges are often co-combusted (sewage sludge, paper sludge, etc.).

FBC ash is rich in lime and sulphur. In 2007, about 0.2 million tonnes were mainly used for engineering fill applications (40 %), for infill (30 %) and subgrade stabilisation (about 14 %). It has to be noted that the total amount of FBC-ash in EU 15 countries is small compared to the amount produced at least in Poland and the Czech Republic.

Spray Dry Absorption (SDA) Product
SDA Product is a fine grained material resulting from spray dry or semi dry flue gas desulphurization with lime as a sorbent. In 2007, about 0.3 million tonnes of the total SDA product was mainly utilised in filling applications (engineering fill, structural fill and infill). In addition, some 7 % were used for plant nutrition (8 %) and as a sorbent in wet FGD (23.5 %).

FGD Gypsum
FGD gypsum is produced in the wet flue gas desulphurisation process in coal-fired power plants. The desulphurisation of the flue gas in the power plant and a refining process in the FGD plant including an oxidation process are followed by gypsum separation, washing and dewatering. Based on its constant quality FGD gypsum is accepted in the gypsum and cement industry as a direct replacement of natural gypsum.

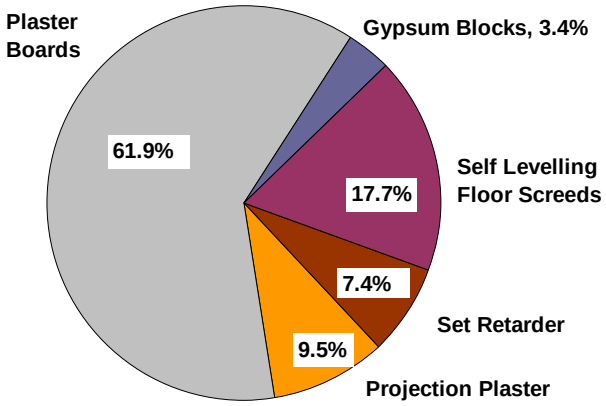

Fig. 7. Utilisation of FGD gypsum in the Construction Industry in Europe (EU 15) in 2007. Total utilisation 8.8 million tonnes.

FGD gypsum is used as a raw material for a number of gypsum products by the gypsum industry because of its purity and homogeneity compared to natural gypsum. About 62 % was used for the production of plaster boards. Other applications include the production of gypsum blocks, projection plasters and self levelling floor screeds (30.6 %). In the cement industry FGD gypsum is used as set retarder (7.4 %) (see figure 8).

REVISION OF EUROPEAN STANDARDS

Revision of EN 450-1 and EN 450-2

The application as concrete addition constitutes the highest added value for fly ash. By this, 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 (*EN 450:2004*) and the revised standards EN 450-1 und EN 450-2 entered force on January 1, 2007 (*EN 450-1:2005; EN 450-2:2005*). EN 450-1 deals with definitions, specifications and conformity criteria for siliceous fly ash, which is produced by burning of pulverized coal, with or without co-combustion materials, and collected in a dry state, or which is processed by e.g. classification, selection, sieving, drying, blending, grinding or carbon reduction or by a combination of these processes. This is because in some countries fly ash has been processed according to national regulations for years or, in some cases, decades. EN 450-2 deals with the conformity evaluation of fly ash for concrete produced in power plants and in processing plants. Most important is the documentation of procedures for the production control in a works quality manual.

In EN 450-1 requirements regarding homogeneity, soundness and effectiveness are stipulated. The chemical requirements refer to e.g. the loss on ignition, sulphur-, chloride- and free-lime-content. If fly ash is produced with co-combustion the content of reactive SiO_2, the total oxide content of SiO_2, Al_2O_3, Fe_2O_3, the alkali-, MgO- and phosphate-content have to be tested. The physical parameters stipulate requirements on the fineness, variation of fineness and density, on soundness and activity index. In addition to these requirements, fly ash from co-combustion has to meet the requirement of initial setting time and fly ash of category S for water demand. Within the ongoing revision of the standards all parameters are subject to critical review and the amount of co-combustion materials will be increased to incorporate the experience gained with European Technical Approvals (ETA). Proposed changes will be documented in a respective background report.

Revision of EN 13282 Hydraulically bound mixtures

The revision of the European standard for hydraulic road binders (*ENV 13282:2000*) resulted in the preparation of three parts. Part 1 is dealing with rapid hardening hydraulic road binders (*prEN 13282-1:2009*). These are cement based binders which follow the requirements as already known from prEN13282. Part 2 is dealing with normal hardening hydraulic road binders (*prEN 13282-2:2009*). These binders have lower cements contents, the compressive strength has to be tested after 56 days (part 1 at 28 days). A slaking procedure was implemented to guarantee that also lime rich mixtures can be evaluated in the laboratory. Part 3 of the standard deal with the conformity evaluation.

Calcareous fly ash meeting the requirements of EN 197 (*EN 197-2:2000*) as well as FBC ash meeting specific requirements regarding the chemical composition can be used as main constituents for the production of hydraulically bound mixtures.

Revision of EN14227 Hydraulically bound mixtures

In June 2009 the revision of the EN 14227-series was decided. EN 14227 part 3 is dealing with fly ash bound mixtures and part 4 with fly ash for these mixtures in which the definition and requirements for siliceous and calcareous fly ash are given. In contrast to the standard referring to the cement standard EN 197-1 for the definition of fly ash in this standard no reference is made. Due to the given definition also FBC-ash is covered and needs to fulfll the same requirements as the ashes from classical dust-fired boilers.

LEGAL ISSUES

Revision of the Waste Directive

According to the European Waste Framework Directive from 1996 waste is defined as follows:

"Waste shall mean any substance or object in the categories set out in Annex I, which the holder discards or intends or is required to discard".

The categories in Annex I as mentioned above include: *"Q 8 residues of industrial processes (e.g. slags, still bottoms, etc.)"* and *"Q 9 residues from pollution abatement processes (e.g. scrubber sludges, bag house dusts, spent filters etc.)"*.

Due to this Directive, CCPs have legally to be considered as waste. Since the early nineties discussions took place on the question if in certain cases a by-product from industrial processes is covered by the definition, i.e. has to be considered as waste or if waste properties could cease at a specific stage of the managing process. A typical example is FGD gypsum, which is on one hand a residue of a pollution abatement process and on the other hand was produced from scrubber sludge by an oxidation, cleaning and drying procedure aiming at a material, which meets technical specifications of the users (gypsum and cement industry). After several years of discussion it is now generally accepted by the authorities that FGD gypsum has ceased to be a waste after the processing in the power plant.

The case is not clear for fly ash as it is argued that no processing takes place in the power plant and that the recovery operation is the final use of the material. That would mean that the material is to be handled (collected, transported, stored) as a waste. By this, a concrete producer would use a waste to produce concrete, i.e. a ready mixed concrete plant becomes a waste handling plant. Even if the restrictions or the additional paper work required by the authorities are not too heavy it is the image problem of the concrete, which might become an additional obstacle for the concrete producer to use fly ash.

Within the revision of the Waste Directive the discussion on the legal definition of by-products and end-of-waste status was restarted at the European institutions and ended with the publication of a revised Waste Directive (*WD 2008*) including definitions for "by-products" and "end-of-waste" status. The Directive entered into force on 12 December 2008. Member States must adopt the measures to comply with the Directive within 24 months, i.e. by 12 December 2010.

In article 6 of the Directive "end-of-waste" is defined by "*certain criteria to be defined by the Commission*". The criteria shall *include limit values for pollutants where necessary and shall take into account any possible adverse environmental effects of the substance or object*.

The Commission ordered the Institute for Prospective Technological Studies (IPTS) and DG Joint Research Centre (JRC) to develop a general methodology for determining end-of-waste criteria. The developed methodology was evaluated for aggregates, compost and metal scraps. For these materials pilot studies were prepared and discussed at stakeholder workshops. The methodology is assessment based as a wide range of waste materials have to be considered. For aggregates – including bottom ash and boiler slag - the criteria will be based on leaching limit values. In April 2009, the Commission has established a Technical Adaptation Committee (TAC) which should deal with the proposal for end-of-waste criteria.

REACH Regulation

On 1st June 2007, the REACH-Regulation (*REACH 2006*) (Registration, Evaluation, Authorisation and Restriction of Chemicals) entered into force. REACH requires that chemical substances on their own, in preparations and those which are intentionally released from articles have to be registered to the European Chemicals Agency (ECHA).
The overriding goal of the regulation is to improve the protection of human health and the environment from the risks of chemicals while enhancing the competitiveness of the EU chemicals industry. By this, all chemicals manufactured in or imported into the EU have to be registered at the European Chemicals Agency (ECHA). The registration requires information on the properties and the potential risks of the substances.

REACH is not specifically made for CCPs. But as CCPs are mainly utilised in the building material industry, in civil engineering and in road construction they are placed on the market and therefore for many applications they are subject to REACH.

Each producer or importer of coal combustion products (CCPs) placed on the market as construction materials has to register its substances. Producers of so-called "phase in" substances had to pre-register from 1st June 2008 to 1st December 2008. The pre-registration required information on the substance identity, the tonnages and the name and address of the producer. The registration requires inter alia comprehensive information about toxicology and ecotoxicology of the substances.

In Europe, non registered substances can not be placed on the market after 1st June 2008! For CCPs, since they are already registered in the European Inventory of the Existing Commercial Chemical Substances (EINECS) the deadline for registration is extended to 1st December 2010. Pre-condition is that the producer/importer has pre-registered before 1st December 2008!

By 1st December 2008, the European Chemicals Agency (ECHA) received 2,752,646 submissions, which is much more than the original estimate of 132,292. Due to this, the number of pre-registered parties in Substance Information Exchange Forums (SIEFs) for the different CCPs is extremely high. After identification of the interested parties willing to co-operate consortia for registration of the substances will be formed.

At present, consortia for the joint registration of calcium sulphate, SDA-product and ash (from dry and wet bottom boilers as well as from FBC-boilers) are formed. Further consortia will be installed to register other types of ashes and other CCPs.

SUSTAINABILITY AND ENVIRONMENTAL COMPATIBILITY

CCPs also help to reduce energy demand as well as emissions to the atmosphere, for example CO_2, which are needed for - or result from the manufacturing process of the products which they are replacing. This is of special importance for the cement industry. It is chemically impossible to convert $CaCO_3$ to CaO, and then to cement clinker, without generating CO_2. The cement industry currently emits 0.7 to 1.2 kg of CO_2 for every kilogram of cement produced, depending upon the type of fuel used. The use of fly ash in cement and concrete helps to reduce this greenhouse gas emission by e.g. reducing the production of cement clinker. Additional CO_2 credits are achieved by reduced energy demand for mining and processing of natural raw materials, because in most cases fly ash or bottom ash are available as fine particles in dry or moistened state.

There are many environmental benefits connected with the use of CCPs such as saving of natural resources, saving of energy, saving of emissions of pollutants to the air, saving of CO_2 emissions and saving of disposal space. Nevertheless, the environmental impact of the use of CCPs has to be considered in any application. Fly ash and bottom ash as any natural minerals contain a certain amount of trace element compounds. The concentrations of some of the trace elements may be higher in fly ash than in natural minerals or products used for a certain application. In order to avoid any negative impact on the environment or on human health, regulations have been developed for the different uses of industrial by-products at a national level in the European Member States.

In November 2005, CEN established a new Technical Committee (CEN/TC 351) for "Construction products: Assessment of release of dangerous substances". The TC shall develop horizontal standardised assessment methods for harmonised approaches relating to the release (and/or the content when this is the only practicable or legally required solution) of regulated dangerous substances under the Construction Products Directive (CPD) taking into account the intended conditions of the use of the product. It addresses emissions to indoor air and release to soil, surface water and ground water. With the assessment methods information may be given for the CE marking of construction products on the release of dangerous substances in the use phase.

SUMMARY

In Europe (EU 15) about 61 million tonnes of Coal Combustion Products (CCPs) were produced in 2007. The annual production in EU 27 is estimated to amount to about 100 million tonnes. The CCPs include combustion residues such as boiler slag, bottom ash and fly ash from different types of boilers as well as desulphurisation products like spray dry absorption product and FGD gypsum.

CCPs are mainly utilised in the building materials industry, in civil engineering, in road construction, for construction work in underground coal mining as well as for recultivation and restoration purposes in open cast mining. They are used as a replacement of natural resources. Their utilisation helps to save natural resources and to reduce the energy demand and greenhouse gas emissions to the atmosphere caused by mining and generation of products which are replaced by CCPs.

The use of CCPs contributes to sustainability and has several environmental and technical benefits. It has developed by the years and is mostly based on requirements of standards or other specifications which are subject to regular revision by CEN or national authorities. At

present, the European standards EN 450-1 and EN 450-2 are under revision. Within the ongoing revision of the standards all parameters are subject to critical review. Proposed changes will be documented in a respective background report. Furthermore, the European standard for hydraulic road binders with basic definitions which includes FBC ash as a main constituent will be published in an updated version with three parts.

The utilisation is becoming more and more restricted by environmental regulations. A European Technical Committee is working on horizontal standardised assessment methods for the release of dangerous substances from construction materials. In addition, the legal definition of CCPs as waste causes hurdles, which are unnecessarily impeding the utilisation markets, which have been developed in the last decades. With the revision of the Waste Directive a definition of by-products will be introduced for materials which are from the beginning not a waste. Materials may also leave the waste regime after a recovery operation and meeting of waste stream specific end-of-waste criteria. For coal ash as aggregate these may be based on leaching limits.

Materials not being waste are subject to REACH and have to be registered before being placed on the market from 1st June 2008. For CCPs, a special regulation could be used since they are already registered in the European Inventory of the Existing Commercial Chemical Substances (EINECS). By this, the deadline for registration is extended to 1st December 2010 if the producer pre-registered by 1st December 2008! The pre-registered parties have to agree on the sameness of their substances. At present, consortia for the joint registration of calcium sulphate and ash (from dry and wet bottom boilers as well as from FBC-boilers) are formed. Further consortia will be installed to register other types of ashes and other CCPs.

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