Ash Quality in Europe
- Primary and Secondary Measures -

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INTRODUCTION

In 2008, 56 million tonnes of Coal Combustion Products (CCPs) were produced in the 15 member states of the European Union (EU 15) /1/ and in the larger EU of 27 member states the total production is estimated to be 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 desulphurization products such as spray dry absorption product and FGD gypsum.

With almost 67 % of the total, fly ash is the most important coal combustion product (CCP). Approximately 32 %, that is about 6 million tonnes, of the fly ash produced in the EU 15 member states are used as concrete addition and are replacing a part of the cement in concrete. For this application fly ash has to meet the requirements of the European standards EN 197-1 /2/ for cement EN 450-1 /3/ for concrete.

The quality of the coal ash is part of the control system of the power plant and consists of screening tests of coals to forecast burning behaviour and slag formation, the process control regarding e.g. burning conditions, maximum temperature, residence time at maximum temperature, to reach optimal burn out of carbon. Management systems including staff trainings are basic tools for power and steam generation as well as for ash production for each power plant operator. In addition, the conformity evaluations systems for products produced according to standards and regulations have to be considered.

Nowadays, beneficiation systems are increasingly used if also ash qualities from stock or those normally not produced to meet the requirements of the standards shall be used as construction raw material or if the ash quality can no longer be guaranteed due to retrofitting of plants with de-SO_x and de-NO_x installations or the use of other types of coal.

The report deals with the production and use of CCPs in Europe and focus primary and secondary measures to guarantee ash qualities ready to use.

PRODUCTION OF CCPS IN EUROPE

The ECOBA statistics on production and utilisation of CCPs /1/ 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 2008, the amount of CCPs produced in European (EU 15) power plants totalled 56 million tones. All combustion residues amounted to about 79 % and the FGD residues to about 21 % by mass (see figure 1). The production in all the European member states is estimated to be about 100 million tonnes.

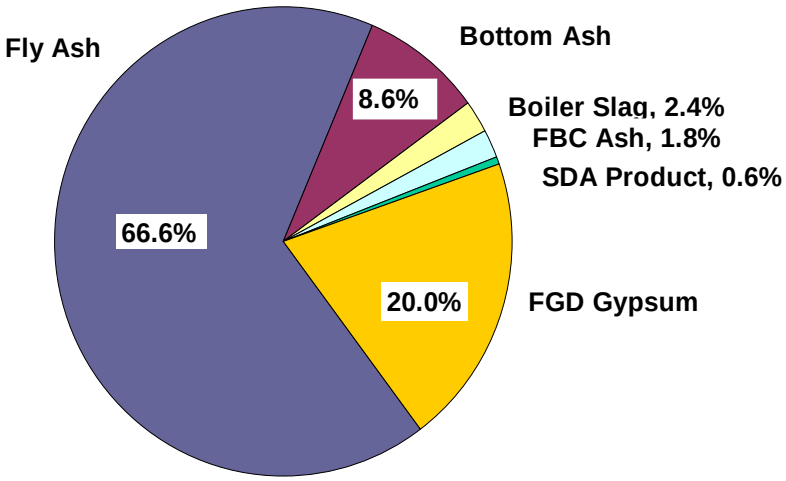


Figure 1 Production of CCPs in Europe (EU 15) in 2008
(total production 56 million tones;

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 2008, about 54% of the total CCPs were used in the construction industry, in civil engineering and as construction materials in underground mining and about 37% for restoration of open cast mines, quarries and pits. About 2.4 % were temporarily stockpiled for future utilisation and about 7 % were disposed of /1/.

Fly ash is the most important CCP with nearly 68 % of the total amount. Approximately 32 % of the total fly ash produced in Europe is used as cement raw material, as constituent in blended cements and as addition for the production of concrete. This means that it is a main constituent of the cement or it replaces a part of the cement necessary for the production of concrete.

In 2008, about 18 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 2).

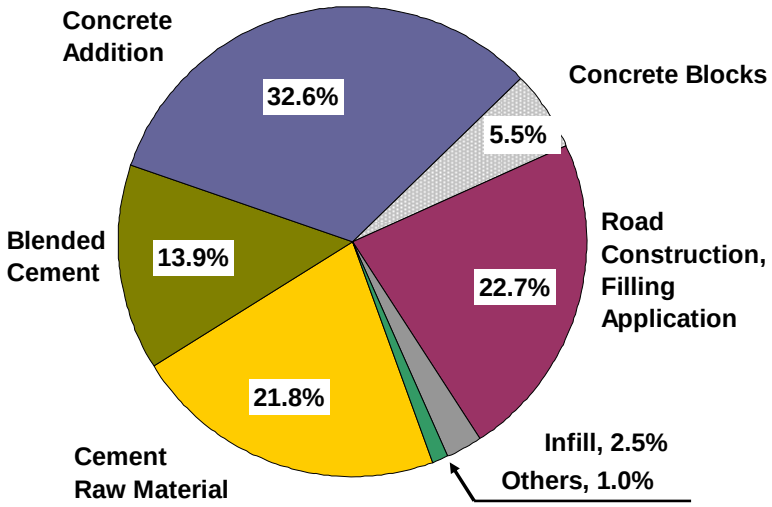


Figure 2. Utilisation of Fly Ash in the Construction Industry and Underground Mining in Europe (EU 15) in 2008.
Total utilisation 17.7 million tonnes

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. All measure to produce quality ash in the power plant are reported as primary measures in the following.

The utilisation of fly ash across European countries is different and is mainly based on national experience and tradition. A precondition for the use as construction material is the meeting of the requirements in standards and specifications. Approximately 32 % of the fly ash produced in the EU 15 member states are used as concrete addition and are replacing a part of the cement in concrete. For this application fly ash has to meet the requirements of the European standards EN 197-1 /2/ for cement EN 450-1 /3/ for concrete. The European Standard EN 450 "Fly Ash for Concrete" was first published in 1994 and the revised standards EN 450-1 /4/ und EN 450-2 /5/ entered into force on January 1, 2007. The revised standard covers also fly ash from processing plants, which is produced by e.g. classification, selection, sieving, drying, blending, grinding or carbon reduction. This is because in some countries fly ash has been processed according to national regulations for years or, in some cases, decades. These processes are reported as secondary measures in the following.

PRODUCTZION OF CCPS IN THE POWER PLANT

Most of the CCPs are produced in so called dry-bottom furnaces, i.e. a combustion processes with temperatures of 1100 - 1400°C. The combustion process of in a dry-bottom furnace and the generation of coal combustion products (CCPs) is shown in figure 3.

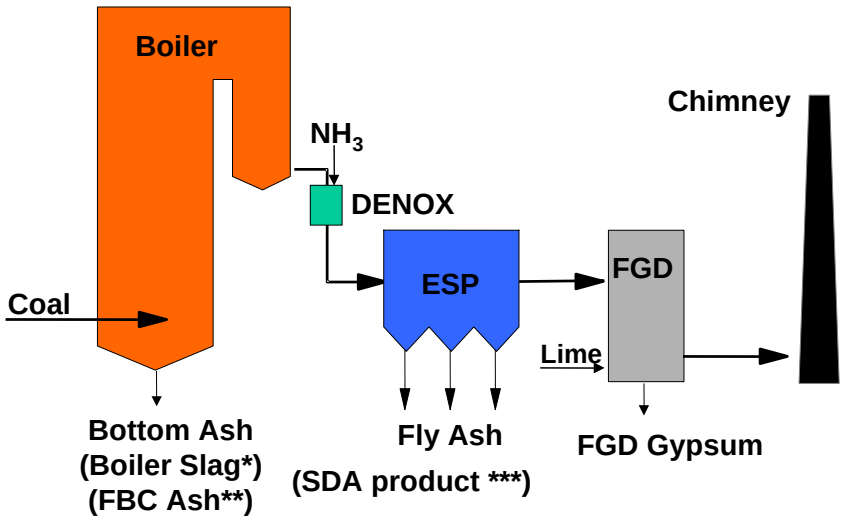


Figure 3 Production of coal combustion products (CCPs) in coal-fired power plants

For pulverised fuel combustion the coal is ground as fine as dust in coal mills and is pneumatically fed to dust burners. The pulverised coal is incinerated in the furnace of the power plant boiler. The heat produced heats the water in the water-steam-circuit, developing steam powers the turbine. Selecting the fuel, it's combustion and slagging behaviour, as well as the process parameters, are of greatest importance. Task is to convert as much of the process heat in the boiler as possible to produce steam in pipes going to the turbine and slagging of the pipes must be avoided. To ensure this, the fuel used for power production is routinely analysed for burnable matter, the melting point and the slagging components. After combustion of the coal, a minor part of the coal ash falls on the bottom of the furnace from where it is removed as bottom ash. The major part, approximately 90% of the fine ash content, is carried along with the flue gases via the DENOX catalyst up to the electrostatic precipitators where more than 99.9% of the ash is separated from the flue gas. Afterwards, and if fitted, the flue gas flows via the FGD plant, where FGD gypsum is produced. The final flue gas is then released to the atmosphere via the chimney.

A similar process (wet-bottom furnace) is used for production of boiler slag. Within this combustion process the burning temperature is higher (1500 - 1700°C) and the fly ash normally is fed back to the boiler where it melts again and forms boiler slag.

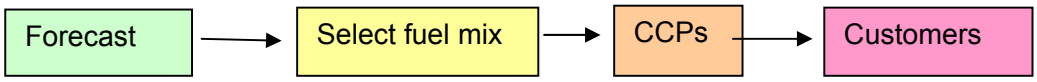
Fluidised bed combustion (FBC) ash is produced in fluidised circulating bed boilers at lower temperatures (800 to 900°C). Spray dry adsorption (SDA) product results from dry and semi dry flue gas desulphurization.

PRIMARY MEASURES FOR ASH QUALITY

The quality of CCPs is a result of coal quality and in the individual plant/boiler design using these coals and the operating parameters. Therefore changes in coal quality might need to be compensated by adjustment in fuel mix and/or changes in set-points for the plant.

A scheme for production of if quality products with the precondition that there are no changes in plant settings is given in figure 5

Figure 5 Generalized plan for production of quality materials



There is a need for an abundance of information. First it is important to know precisely the quality requirements that have to be satisfied. That includes both European standards and industry standards but also specific requirements by the customers who purchase products from the plant. From Sales you need to know what quantities and qualities they expect to sell in the near future

Management of Coal mix

The basic information on coal is mostly only referring to parameters important for coal combustion such as calorific value, water and ash content, grindability (hardgrove index), grain size, melting behaviour and chemical parameters regarding emissions (N, Cl, S, C, H). The chemical and physical parameters for coal ash characteristics are compiled in separate data bases.

To guarantee a good ash quality suitable for direct supply to customers the data bases have to be linked and – in an optimal situation – the coal quality ordered also according the resulting ash quality. If this not the case a coal database describing different qualities that are already available should be combined with information from the fuel supply department.

Very often fuel supply will focus on price of fuel and potentially wish to spread the purchase over various suppliers from different sources (countries, minefields etc). There will be a slight potential to place preferences for particular fuel qualities especially if prices of two different qualities are almost the same and one of the qualities can provide an extra advantage for CCP handling.

Plant operation / operating parameters

Depending on the type of coal the plant settings have to be defined to guarantee an optimal use of the carbon for heat and steam generation. The optimal burn out is depending on the maximum burning temperature and the residence time of coal particles at that high temperature which is steered with addition of additional air and boiler equipment. On the other hand the emission parameters are continuously controlled and the temperature adjusted. In parallel, the information of unburned carbon and fineness from ash testing adds up to information used by the operating manager to steer the complete process. From time to time there may be openings for changes in plant settings. This may be caused by requirements from totally different reasons. For example:

- The optimal setting of burners for achieving low NOx emission can harm LOI in fly ash. But with the right attitude from the engineers responsible for such adjustment settings may be carried to satisfy both the low NOx requirement and the low LOI.
- High LOI fly ash can sometimes be alleviated by using selected biofuels to help compensate for a low volatile coal.
- High moisture Desulphurization Gypsum can sometimes be dewatered better by increasing the sulphur load.

These are just a few examples. The challenge is to know details about the operation of a power plant and providing obvious reasons why a sincere consideration of CCPs should play a role in the decision making. Also the training of operators and personnel involved in CCP handling is necessary to obtain the stipulated results.

Storage and logistics

Sometime higher quantities of CCP are produced than the market can absorb and likewise at other times the market demand for quality products is higher than the production. Therefore the use of storage facilities needs to be considered. In this context storage can be considered very wide as for example silos on the plant, storage facility at selected customers, and possibility to store in the open air etc. You may also need to combine these efforts with the possibility for other outlets than to the primary markets. Part of the customer’s perceived quality is:

- in-time deliveries
- in the qualities ordered
- and delivered in the right silo
- in the right plant.

It is an integral part of CCP management to ensure that the internal auto control and handling of CCPs.

Management of primary measures

To be successful in reaching a goal of up to 100 % utilization of CCPs as strategic products for relevant industries it is necessary to interact closely together with the power station, especially:

- Planning Department who advices on production of electricity/heat and the necessary fuel input.
- Fuel Supply, who takes care of the supply of various fuels and handles the logistics of these.
- The plant Coal Yard, who takes care of stored fuels
- CCP Sales Department who will know the quality requirements of different CCP's for different customers. They will also provide a forecast for quantities
- The Plant Operators who will be responsible for the local logistic into silos, stocks and separation of complying and non-complying qualities.
- The plant engineers who can advice on adjustment of different settings of the plant.
- External service providers like transporters, laboratories etc.

SECONDARY MEASURES FOR ASH QUALITY

In the fully controlled combustion process fly ash is produced to meet the requirement of standard. The most important parameters for the process control are fineness and loss on ignition, which represents the unburned carbon. Two categories for the fineness of fly ash were introduced in the new EN 450 for fly ash for concrete. Category N 1994 (≤ 40 % by mass on 45 µm sieve), which includes the requirements of the former EN 450 from 1994, and category S 1994 (≤ 12 % by mass on 45 µm sieve) for finer fly ash, for which the requirements of the British Standard BS 3892-1 /6/ were taken.

Also for the loss on ignition three categories (cat. A: < 5 % by mass; cat. B: 2 - 7 % by mass and cat. C: 4 to 9 % by mass) were introduced. Based on the national experience the use of fly ash for concrete will be restricted according to a specific category of LOI. Over the last years fly ash was processed in European countries to meet the request and the requirements of the customers and to improve certain properties (e.g. reduction of LOI or increase of fineness). In Europe, mostly systems for fly ash processing, i.e. classification (air separation, sieving), carbon reduction (STI), blending and activation are installed in some European countries.

Classification –dry

In the UK, fly ash with a high fineness, classified as PFA according to BS 3892 part 1, is produced by air classification. Classification lead to fine fly ash (EN 450 category S /4/; formerly according to BS 3892-1 /6/) with a reduced LOI content.

In Germany, an ultrafine fly ash is produced the air classfication for the production of Microsit, a fly ash with a maximum grain size of 10 µm (Microsit M10) or 20 µm (Microsit M20). Microsit can be used as an addition for concrete but also in plastics and paints.

Classification – wet (Rocktron)

The RockTron plant at Fiddlers Ferry Power Station in the UK is capable of processing up to 800,000 tonnes of fly ash per annum. The plant is designed to process 100% of the fly ash with no waste stream. One of the key features of the RockTron process is that, because it can treat both freshly produced and stockpiled fly ash, it is capable of delivering products on a continuous all-year round basis and is not dependent upon seasonal generation profiles.

Essentially, RockTron uses a traditional mining technology, called 'froth flotation'. This beneficiation process separates and washes the components that make up fly ash to produce minerals which have many applications. The products are a fly ash low in carbon and defined fineness (< 2 % LOI - alpha product), a coarser material with also pozzolanic properties and a moisture content of up to 15 % (delta product), cenospheres (CenTron^{TM} product), magnetit product (MagTron^{TM}), solid alumino-silicate micron sized glass spheres (MinTron^{TM}) and a microbiocide product (RockTron Microbiocide$^{TM)}$ /7,8/.

Sieving/Mixing

In the Netherlands a fly ash meeting the requirements of EN 450 will be produced by sieving and mixing of different fly ashes which, individually, do not necessarily conform to the requirements of the standard.

The fly ash is processed by sieving and mixing in the SMZ (Storage, Blending and Sieving) center of Vliegasunie near the Maasvlakte power station at the harbour of Rotterdam. All fly ash produced in the Netherlands is transported by ship, truck or pipe (from Massvlakte station) to intake silos. After quality control of the incoming ash these are stored in different silos. With a capacity of 250.000 tonnes per annum (normal throughput 180.000 to 210.000 tpa), this plant is designed to upgrade 25 to 40 % of the total fly ash produced by the Dutch electricity generating companies. The plant has two prime objectives, namely storage and upgrading of fly ash. The storage facility allows matching of production and demand, while the upgrading of the material guarantees a constant high quality to customers.

Carbon reduction

For the carbon reduction triboelectric separation technique from STI is installed at four power stations in the UK (Longannet Power Station, West Burton Power Station, Didcot Power station and Aberthaw Power Station. In 2010, also in Poland the first STI plant was installed /9/.

With the triboelectric separation technique a wide range of fly ash with consistent LOIs can be produced.. Furthermore, a high carbon product is produced that can be reburned to recover the fuel value of the unburned carbon.

Re-drying

Another challenge that has to be faced in Europe is in satisfying the increasing demands of the concrete market. In some countries not enough fly ash is available during the construction season despite the large amount of storage capacity that has been installed during the last century. In some countries, therefore, fly ash re-drying systems were installed to provide additional fly ash on demand.

In France re-drying of stockpiled fly ash is of particular importance. Two units for drying and upgrading the stockpiled coal ash have been installed. Due to these activities the utilisation rate for fly ash is more than 100% of the annual production in France.

Also in Germany a re-drying facility was commissioned in 2000 for re-drying of fly ash which was placed on stock in a depleted clay mine during wintertime. In summer up to 60.000 tonnes of fly ash can be re-dried for use as concrete addition. The plant is designed to re-dry up to 40 t/h.

Activation

In Poland, processes for mechanical activation of siliceous fly ash and fluidized bed combustion (FBC) ash are installed.

The product of activated siliceous fly ash is called MEGAPAR. The activation leads to increased specific surface and improved strength contribution.

The activated FBC-ash is called FLUBET. The process was developed for increased and more efficient use of lime-based sorbent for flue gas desulphurization. It is now also used for FBC-ash activation. The activation produce a quality which can be used as an addition

CONCLUSIONS

With almost 67 % of the total, fly ash is the most important coal combustion product (CCP). Approximately 32 %, that is about 6 million tonnes, of the fly ash produced in the EU 15 member states are used as concrete addition and are replacing a part of the cement in concrete. For this application fly ash has to meet the quality requirements of the European standards EN 197-1 for cement EN 450-1 for concrete.

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should also reflect the final use and the market conditions, i.e. demand and logistic systems. Management systems including staff trainings are basic tools for power and steam generation as well as for ash production for each power plant operator. In addition, the conformity evaluations systems for products produced according to standards and regulations have to be considered.

Fly ash is produced to meet the requirements of the technical standards. Regarding LOI, most of the power plants in European countries produce a fly ash with an LOI < 5 % by mass. Due to additional requirements of customers regarding fine fly ash, fly ash with constant quality, or with retrofitting of old boiler and the use of imported coal leading to qualities not satisfying all requirements - in some countries processing plants and installations have been installed over the last years. These are mostly systems for fly ash classification (air separation, sieving, wet classification), carbon reduction (STI), blending and activation.

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