Part 3

ASH AND SLAG HANDLING

3.7. Analytics

3.7.23. FGD Gypsum: a by-product in line with a resource efficient Europe

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1. INTRODUCTION

FGD gypsum is produced in the wet flue gas desulphurisation process of sulphur oxide emitting processes, especially of those in coal-fired power plants. The production process includes the scrubbing of the sulphur from the flue gases into a slurry which is further processed by oxidation, classification, washing and dewatering to produce a FGD gypsum of high quality. Over the last years increasing amounts of FGD gypsum were produced which totalled to more than 10 million tonnes in Europe (EU15) [1]. After extensive research work in the 90'ies FGD gypsum is used as a raw material replacing natural gypsum, the major part is used in the gypsum industry. The use of FGD gypsum started with the former definition as « industrial by-product » or as « product » due to the processing steps in a seperate production unit at the power plants. Based on the definitions in the revised Waste Directive the producers consider it a by-product as the basic requirements are fully met and consequently registered FGD gypsum as calcium sulphate under the REACH regulation.

The use of FGD gypsum is fully in line with the recently started initiative for a resource efficient Europe as addressed in the e.g. « Flagship initiative under the Europe 2020 Strategy ». In this strategy many objectives of the EU Raw Materials Initiative, launched in 2008 and consulted in 2010, were implemented – i.a. savings of primary raw materials and savings of energy. But resource efficiency is also addressed to energy production by fossil fuels as coal is a major fuel for energy and steam production in European coal-fired power plants. Coal combustion has an effect on the environment which must be kept as low as possible. Clean Coal Technology in coal-fired power plants today is not only addressed to de-NO_x and de-SO_x systems but also to carbon-free production based on carbon capture storage. Due to the impact of all regulations on the operation of a power plant the production of FGD gypsum is hard to predict when also considering the development of energy needs in the member states.

2. PRODUCTION OF FGD GYPSUM

2.1. Process

In coal-fired electricity generating power plants solid minerals are produced during and after the combustion of fine ground coal with and without co-combustion in a fully controlled process. The unburnable mineral matter from the fuels forms ashes (bottom ash, fly ash, boiler slag, FBC-ash). The desulphurisation products are obtained from a chemical reaction between the sulphur dioxide, which is derived from the sulphur in the coal during the combustion process, and a calcium based absorbent, in flue gas desulphurisation installations (SDA product and FGD gypsum). Most of the by-products are produced in so called dry-bottom furnaces, i.e. a combustion processes with temperatures of 1100 – 1400 °C. The combustion process in a dry-bottom furnace and the generation of coal combustion products (CCPs) is shown in figure 1.

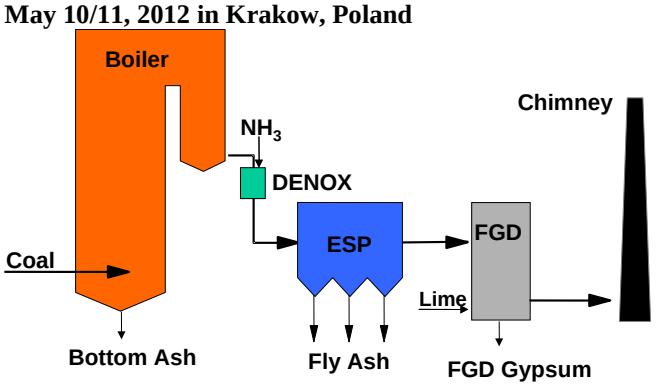

Fig. 1 Production of coal combustion products (CCPs) in coal-fired power plants

FGD gypsum is produced in the flue gas desulphurisation unit of coal-fired power plants. This unit incorporates the desulphurisation of the flue gas in the power plant and a refining process in the FGD plant including an oxidation process followed by gypsum separation, washing and dewatering.

The process involves the following sequence of process steps within the plant [2]:

1. The suspension containing limestone/chalk ($CaCO_3$) or quicklime (CaO) which is sprayed into the flue gas scrubber reacts with the sulphur dioxide (SO_2) present in the flue gas to form mainly calcium sulphite ($CaSO_3$). This results in a liquid mixture, the solid components of which are calcium sulphite and calcium sulphate which are circulated in the scrubber cycle.
2. Calcium sulphite is oxidized by adding defined quantities of air, and in the subsequent crystallization process it binds two molecules of water; this results in a suspension of gypsum (calcium sulphate dihydrate: $CaSO_4 \cdot 2H_2O$) in the scrubber sump.
3. In the further course of the process the gypsum suspension, which is monitored internally to track its chemical and physical properties, now passes through hydrocyclones where partial dewatering takes place and the gypsum particles are graded. The fine material is returned to the flue gas scrubber.
4. Further dewatering and purification of the gypsum with leaching of water-soluble components (e.g. chloride) takes place either in a centrifuge or on a belt-type vacuum filter. The washing water undergoes further reprocessing in a separate unit. The residual moisture content of FGD gypsum (excluding bound crystal water) is between 5 and 12 %.
5. The finished FGD gypsum, which may be dried first, goes to an on-site interim storage facility (silo, hall). From there it is transported to the user by water, road or rail. (A certain amount of the FGD gypsum produced in Germany goes to raw material depots to ensure continuous long-term supplies to the gypsum industry.)

The quality of the gypsum is monitored daily. The samples are taken immediately before the onsite interim

store. The laboratory tests are performed in accordance with the instruction sheet "FGD gypsum – Quality Criteria and Analytical Methods" [3] and additional parameters agreed between producer and customer.

2.2 Produced amounts and use

In figure 2 the development of the production of FGD gypsum from hard coal and lignite in the EU 15 member states is given. The FGD gypsum production in 2009 is only slightly reduced compared to 2008. It has to be noted that the figures from East European countries are not covered by the EU 15 statistics of ECOBA [1]. Due to the already existing FGD units in the other member states the produced amount of FGD gypsum is already higher than the figures as published by ECOBA and due to further retrofitting of power plants in the East European countries the amount of FGD gypsum is expected to increase.

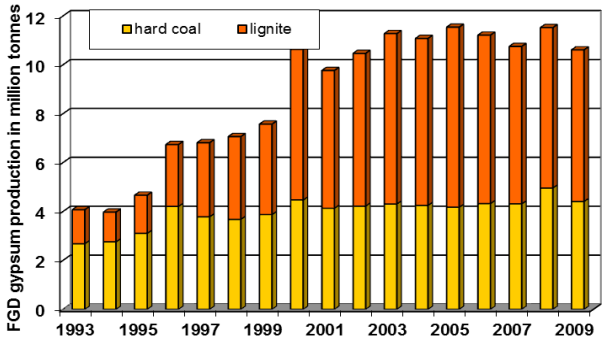

Fig. 2 Development of FGD gypsum production from hard coal and lignite in EU 15 from 1993 to 2009 [1]

About 76 % of the FGD gypsum is used in the construction industry, about 7 % were used for reclamation, about 9 % were placed on depots of temporary stockpiles and about 7 % were disposed off. The figures for utilisation of FGD gypsum in the construction industry in 2009 are given in figure 3.

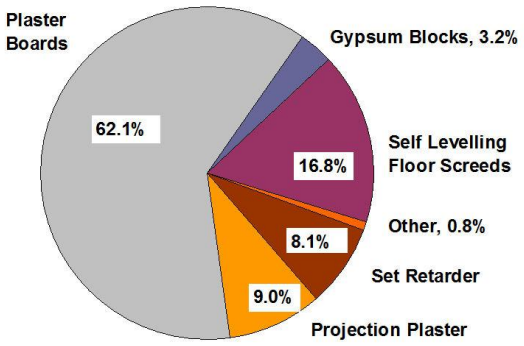

Fig. 3 Utilisation of FGD Gypsum in the Construction Industry in Europe (EU 15) in 2009 (Total utilisation: 10.6 million tonnes) [1]

3. STATUS OF FGD GYPSUM

3.1. Waste Framework Directive

According to the European Waste Framework Directive from 1996 Coal Combustion Products (CCPs), that are all combustion residues and desulphurisation products from coal–fired power plants, have legally to be considered as waste as the primary aim of the process is the power and steam production. Since the early 90ties of the last century 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, see also [3]). After several years of discussion it was generally accepted by the authorities that FGD gypsum has ceased the waste properties after the processing in the power plant.

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 including definitions for "by-products" and "end-of-waste" status. The Directive entered into force on 12 December 2008 [4]. Member States had to adopt the measures to comply with the Directive within 24 months, i.e. by 12 December 2010. By-products according article 5 will from the beginning be not subject to waste legislation, end-of-waste materials are resulting from a recovery process. For both types of materials specific criteria must be met. For "by-products" according to article 5 of the Directive these criteria are:

(a) further use of the substance or object is certain;
(b) the substance or object can be used directly without any further processing other than normal industrial practice;
(c) the substance or object is produced as an integral part of a production process; and
(d) further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

Well knowing about the former acceptance of the « product »- status of FGD gypsum the industry had to realize that the new discussion did not consider the former status. Therefore, due to the criteria in the revised Waste Directive the CCP producers are of the opinion that CCPs and especially FGD gypsum are by-products as the production process is fully controlled to meet the requirements of emission regulations as well as of standards and specifications and as the product is offered to existing construction material markets for many years as a raw material [5]. In some countries and areas of the EU members FGD gypsum is accepted as product or as a by-product for specific applications. But the reasons for the by-product status are based on different argumentation and therefore does not solve the need of the industry for homogeneous evaluation across Europe.

3.2. REACH Regulation

On 1st June 2007, the REACH-Regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals) entered into force [6]. By this, also each producer or importer of coal combustion products (CCPs) has to register the marketed or imported substances at the European Chemicals Agency (ECHA) situated in Helsinki. Since 1 June 2008, CCPs which are not registered cannot be produced and placed on the market.

As the power plants operators consider FGD gypsum a product (or by-product) they have consequently registered FGD gypsum as calcium sulphate. The joint registration covers natural as well as FGD gypsum. The compiled results showed again that the use of calcium sulphate and also of FGD gypsum does not have any adverse environmental or

human health impacts and is therefore lawful. By this, the 4th criterion on the Waste Directive is also fulfilled and the acceptance as by-product should be possible on a European level than only on regional and national level.

4. RESOURCE EFFICIENCY

In 2008 the Commission launched the EU Raw Materials Initiative (RMI) [7] as the prices in all major markets, including energy, metals and minerals, agriculture and food, are increasing over the last years. This development is based on a series of changes in global supply and demand patterns as well as short term shocks in key commodity and raw material markets. The years 2002 to 2008 were marked by a major surge in demand for raw materials, driven by strong global economic growth, particularly in emerging countries such as China. This increase in demand will be reinforced by the further rapid industrialisation and urbanisation in countries such as China, India and Brazil.

Following the publication of the first Communication in November 2008, the Commission reported to the Council on the progress made in implementing the RMI and in 2010, the preparation for a second RMI was started by the Commission which invited stakeholders to comment on a range of questions on raw materials policy issues. The results of this open consultation provided important input into the Communication on Commodities Markets & Raw Materials, which was published in February 2011. This Communication not only reported on progress made with the implementation of the RMI, but also indicated future action. It also extended the analysis to general commodity markets.

In January 26, 2011 the Commission published a communication on « A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy » [8] as natural resources underpin the functioning of the European and global economy and the quality of life. The resources include raw materials such as fuels, minerals and metals but also food, soil, water, air, biomass and ecosystems. The 2020 strategy aims to deliver smart, sustainable and inclusive growth and to create a framework for policies to support the shift towards a resource-efficient and low-carbon economy which will help us to:

- boost economic performance while reducing resource use;
- identify and create new opportunities for economic growth and greater innovation and boost the EU's competitiveness;
- ensure security of supply of essential resources;
- fight against climate change and limit the environmental impacts of resource use.

Due to this, FGD gypsum is fully in line with a resource efficient Europe as it is used as a raw material replacing natural gypsum and therefore safeguard natural gypsum resources and the environmental impacts related to its mining and processing.

5. CLEAN COAL TECHNOLOGY

Aside resource efficiency for the operation of a coal-fired power plants also other legislative aspects have to be considered which can be addressed with clean coal technology. The most important decisions and their impacts on coal-fired power stations and on CCPs are described in the following.

5.1. Impact of Directives

Industrial activities, including the use of coal in coal-fired power plants, have a significant impact on the environment which must be kept as low as possible. Emissions from industrial installations have therefore been subject to EU-wide legislation. Individual member states may set their own national legislation but all member states must comply with EC Directives, although derogations may be permitted. The most important Directives are:

IPPC –Integrated Pollution Prevention and Control
LCPD –Large Combustion Plant Directive
IED –Industrial Emissions Directive

The IPPC Directive [9] sets out the main principles for the permitting and control of installations based on an integrated approach and the application of best available techniques (BAT) [10]. It covers all emissions and overall plant performance.

The LCP Directive [11] aims to reduce acidification, ground level ozone and particulates by controlling the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plants (i.e. plants with a rated thermal input of equal to or greater than 50 MW_{th}). All combustion plants built after 1987 must comply with the emission limits in LCPD. Those power stations in operation before 1987 are defined as 'existing plants'. Existing plants can either comply with the LCPD through installing emission abatement (Flue Gas Desulphurisation) equipment or 'opt-out' of the Directive. An existing plant that chooses to 'opt-out' is restricted in its operation after 2007 and must close by the end of 2015. Due to this, several old boilers in the member states are subject to close or are retrofitted.

The IE Directive [12] is the successor of the IPPC Directive and in essence, it is about minimising pollution from various industrial sources throughout the European Union. The IED is based on several principles, namely (1) an integrated approach, (2) best available techniques, (3) flexibility, (4) inspections and (5) public participation. The IED replaces the IPPC Directive and the sectoral Directives as of 7 January 2014, with the exemption of the LCP Directive, which will be repealed with effect from 1 January 2016.

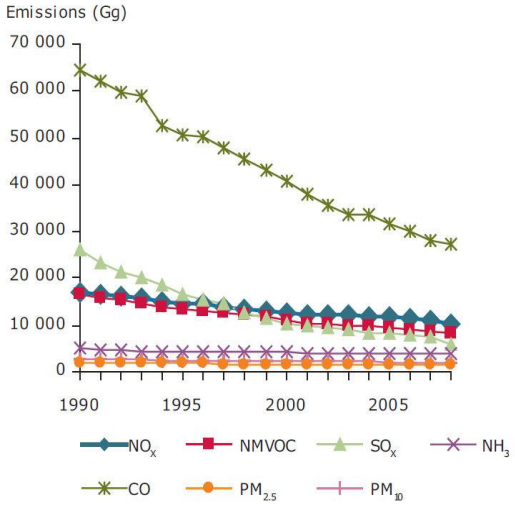

Fig. 4. EU-27 emission trends for main air pollutants [13]

As a result of these regulations the emissions from power plants are reported in the European Pollutant Release and Transfer Register (E-PRTR [13]), which replaces and improves the previous European Pollutant Emission Register (EPER). After several years of evaluation the reduction of emissions can best be shown on the example of SO_x (see figure 4) as it demonstrates the largest percentage reduction

of emissions since 1990 of the main pollutants across the European Union. Emissions in 2008 were 78 % less than in 1990, mostly by reduction in EU 15 countries. It is noteworthy that SO_x emissions decreased rather sharply, falling 20% in 2008 compared to 2007, mainly due to reductions reported in Bulgaria, Poland and Spain. In each of these Member States, the lower emissions were mainly due reductions reported from public power plants. For example in Spain the emission reduction was largely due to using lower amounts of coal for electricity generation and use of more natural gas and renewables such as wind, photovoltaics and biomass [14]. Together with the reduction of emissions the amount of residues from flue gas cleaning, i.e. fly ashes and FGD-gypsum, is increased.

5.2. Clean Coal Technology - Impact of energy plans

On 11 December 1997, the representatives of 37 industrial countries agreed to reduce greenhouse emissions (GHC) to an average of five per cent against 1990 levels over the five-year period 2008-2012. This agreement is known as Kyoto Protocol [15] which entered force in 2005. The protocol is linked to the United Nations Framework Convention on Climate Change [16]. When the Convention encourage industrialised countries to stabilize GHG emissions, the Protocol only commits them to do so.

In December 2008, the European Parliament and the Council agreed upon the so-called "Climate and Energy Package", which entered force in 2009. The legislative package put in place what is collectively known as the EU-20-20-20 targets to be met by 2020:

Reduction of greenhouse gas emissions of at least 20 % below 1990 level,

Increasing the share of renewable energy to 20% , and

Improving the EU's energy efficiency by 20%.

With this package additional legislation was installed for promotion of the use of renewable energy (RES), geological storage of carbon dioxide and a revised Trading Scheme for greenhouse gases (GHG). From 2013, the system for allocating emission allowances will change significantly compared to the two previous trading periods (2005 to 2012). At first, the emission allowances will be distributed according to fully harmonised and EU-wide rules. At second, auctioning will become rule for the power industry, i.e. the allowances will not be any longer allocated for free.

In addition, the EU is of the opinion that there is a potential to further reduce emissions. In Article 28 of the revised EU ETS for GHG an adaptation of the already ambitious mandatory target to reduce GHG by 20 % in 2020 to a 30 % reduction is foreseen if an international agreement is reached. The European Council has also given a long-term commitment to the decarbonisation path with a target for the EU and other industrialised countries of 80 to 95 % cuts in emissions by 2050 [17]. To reach this again ambitious aim the European Commission adopted the Communication "Energy Roadmap 2050" on 15 December 2011. In the Energy Roadmap 2050 the Commission explores the challenges posed by delivering the EU's decarbonisation objective while at the same time ensuring security of energy supply and competitiveness. The Energy Roadmap 2050 is the basis for developing a long-term European framework together with all stakeholders.

The instruments of the industry to reduce greenhouse gases (CHG) are on one hand the increase in energy efficiency. A most effective use of coal will on the other hand also lead to the reduction of CO_2-emission. In figure 5 the CO_2 reduction potential of European power plants is given together with the energy efficiency, fuel consumption and – based on this – the CO_2 emission. The state-of-the-art efficiency in the EU is 45 % which is going to be increased to 50 % with the construction of the new power plants. Further reduction with carbon capture storage will give higher CO_2 reduction rates but will counteract all efforts regarding efficiency by efficiency losses of 10 to 12 %.

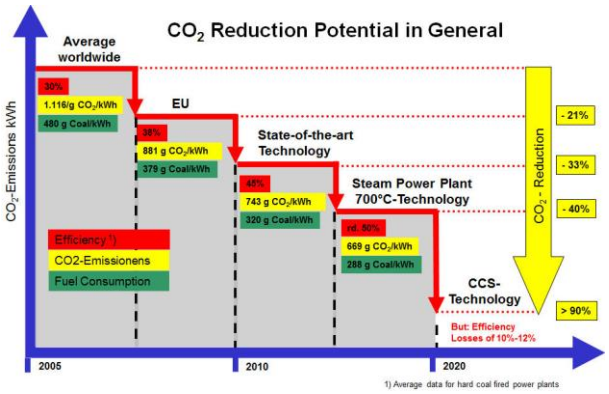

Fig. 5. Power Plant efficiency and CO2 reduction potential of the European power industry [18]

With the construction of new power plants the EU member states on one hand prepare to meet the increasing demand for energy and on the other hand meet the GHG emission reduction targets. Due to the country specific situation (own coal reserves, availability of rivers for hydropower, accessibility for see trade,…) the energy plans of each country are different.

Due to the announcement of projects for the production plants by wind, hydropower, nuclear power, lignite and turf, hard coal, oil and gas the way to improve EU energy efficiency as well as to increase the share of renewable energy is shown. With the increased use of biomass in pure biomass combustion plants the load of coal-fired power plants is reduced. Together with production by other renewables like wind, solar and hydropower a change from base load to partly peak load production was observed in some countries. This has an impact on the maintenance of the power plants and therefore on production cost. Also the quality of CCPs is effected and more attention must be given to CCPs production.

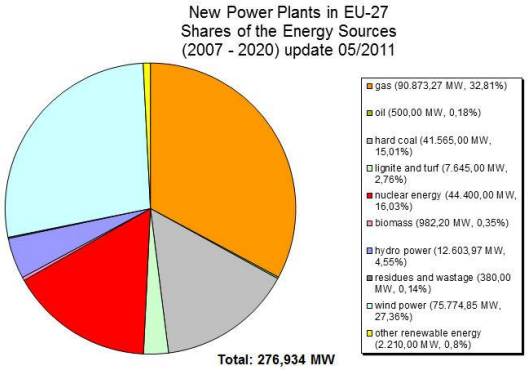

Fig. 6 New power plants projects in European member states [19]

The projects for coal-fired plants - 42.565,00 MW in total- are partly already started and/or near to start energy production. The power plants will partly replace old power stations. The construction of coal-fired power plants in Germany and the Netherlands are far advanced and the first production is expected soon. The power plants in the

Netherlands and Germany for hard coal are all developed are designed to burn import coal as well as for co-combustion of higher shares of co-combustion materials.

Furthermore, coal plays an important role in energy mix in the European countries as most reliable, affordable and safe energy source, especially in Central and Eastern Europe. In single countries the production by coal totals up to 88 %, for the EU 27 member states the share is about 26 %. The role of coal in the national energy mix of EU 27 member states in 2009 is given in figure 7 [20].

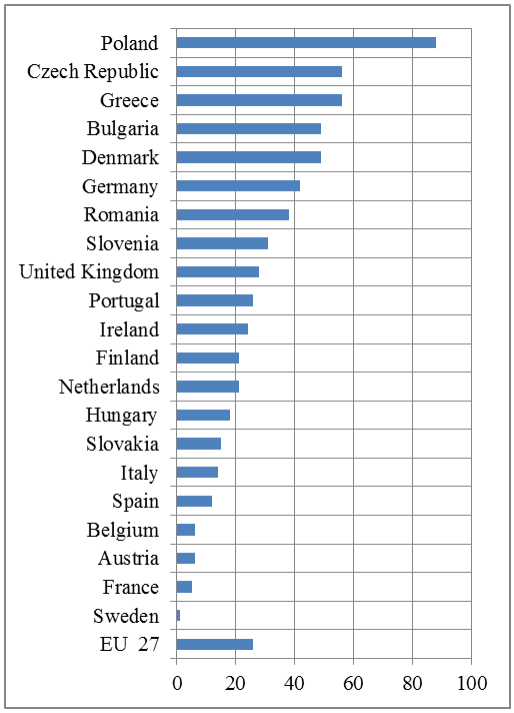

Fig. 7. Role of coal in energy mix in European member states in 2009 [20]

About 192 million tonnes of hard and 521 million tonnes of lignite (including a small amount of sub-bituminous coal) were mined and used for power production in Europe in 2010 [21]. In addition, about 237 million tonnes of hard coal were imported. Due to this it is expected that coal will further play an important role in the energy mix of some of the European member states.

6. CONCLUSION

FGD gypsum is produced in the wet flue gas desulphurisation process of coal-fired power plants and further processed by oxidation, classification, washing and dewatering to deliver a FGD gypsum of high quality which is considered a product by the producers. Over the last years increasing amounts of FGD gypsum were produced which totalled to more than 10 million tonnes in Europe (EU15). In many member states it is completely used as as a raw material replacing natural gypsum, the major part is used in the gypsum industry. Due to the recent revision of the Waste Directive and the new criteria for « by-products » and « end-of-waste » the producers consider FGD gypsum a by-product as all criteria are fully met.

The use of FGD gypsum is fully in line with the recently started initiative for a resource efficient Europe as addressed in the e.g. « Flagship initiative under the Europe 2020 Strategy" as it safeguards natural gypsum resources and the environmental impacts related to its mining and processing. But resource efficiency is also addressed to energy production by fossil fuels as coal is a major fuel for energy and steam production in European coal-fired power plants. Clean Coal Technology in coal-fired power plants today is not only addressed to de-NO_x and de-SO_x systems but also to carbon-free production based on carbon capture storage. The higher efficiency of modern coal-fired power plants will be negatively affected when CCS technologies have to be installed. The new power plant projects signal that FGD gypsum will also be produced in the next decades and will serve as a raw material for the gypsum industry. However, due to the impact of all regulations on the production of FGD gypsum a long term forecast cannot be given. The close and beneficial cooperation between the European power industry and the gypsum industry will guarantee that the use of FGD gypsum will further consider the need of producers and users.

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