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Improving efficiency, reduction of pollution and CO2 emission from Power Plant Kosovo

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Abstract. Earth's atmosphere is composed of a variety of chemical compounds that act as greenhouse gases. Carbon dioxide (CO_2) is of primary concern due to growing global emissions in recent history. Since the expansion of coal use during the industrial revolution and the expansion of petroleum use during the 20th century, CO_2 emissions have risen steadily. The protection lack of environment during the last 16 years,(especially earlier in history) as well as the conflict in Kosova has the origin of huge problems regarding present environmental situation in Kosova. The most important emissions to air from the combustion of fossil fuels are SO_2, NOx, particulate matter (PM), heavy metals and greenhouse gases such as CO_2. The problem with dust emissions is serious and apparently cannot be solved without major redesign of the boilers. Ash from the both power plants is currently transported by open belt conveyors and is deposited at dumpsites. No environmental protection measures in the dumpsites are taken to prevent ash spreading by wind.

Keywords: Atmosphere pollution, reduction of pollution and CO_2 emission

Introduction

In recent years, global warming has been a major issue due to continuous growth of greenhouse gas emissions from different sources. It has been estimated that the global temperature will rise between 1.4 –5.8 °C by the year 2100 (Williams, 2002). The contributors to greenhouse effects are carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4), and nitrous oxide (N_2O). The contribution of each gas to the greenhouse effects is CO_2- 55%, CFCs - 24%, CH_4 - 15%, and N_2O - 6% (Demirbas, 2008). Carbon dioxide (CO_2), a major greenhouse gas which is mainly blamed for global warming occupies a large volume of the total emissions. Figure 1 shows the trend of CO_2 emissions over the years (Demirbas, 2005).

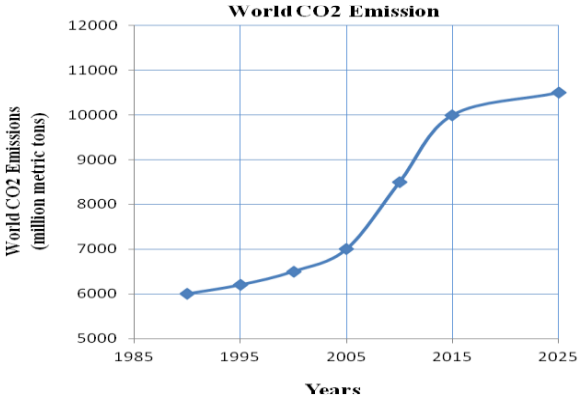

Fig. 1. World CO2 emissions between 1990 and 2025

Different industrial processes such as power plants, oil refineries, fertiliser, cement and steel plants are the main contributors of CO_2 emissions. Fossil fuels such as coal, oil and natural gas are the main energy sources of power generation and will continue to generate power due to the large reserves and affordability. It is expected that coal utilisation in power generation will continue to increase in this century too. Demirbas (2005) reported that about 98% of CO_2 emissions result from fossil fuel combustion, and 30%–40% of world CO_2 emissions are generated by coal combustion among all the fossil fuels. The coal fired power plants generate the majority of the electricity and produce the highest rate of CO_2 per kilowatt hour (Department of Energy and Environmental Protection Agency, Washington DC, 2000).

About 46% of the world's power generation is estimated to be from coal combustion, including 50%, 89% and 81% of the electricity generated in the United States, China and India respectively (Parker *et. al*., 2008). It is estimated that combustion of coal for power generation will be responsible for about 41% of the world's CO_2 emissions by 2025.

The coal fired power plant

Electricity can be produced by various sources such as fossil fuels, nuclear fission, renewable sources etc. Figure 2 shows a typical schematic diagram of electricity production from burning coal. A typical pulverized coal (PC) combustion power plant is equipped with three units, boiler block, generator block and flue gas clean up block. The boiler block is the main unit where coal is burned with air to generate high pressure steam; the generator block contains the steam turbine/electric generator set, condenser and cooling water; and the third block is the flue gas clean-up unit which removes particulate matter (PM) and other pollutants from the flue gas to control emissions.`

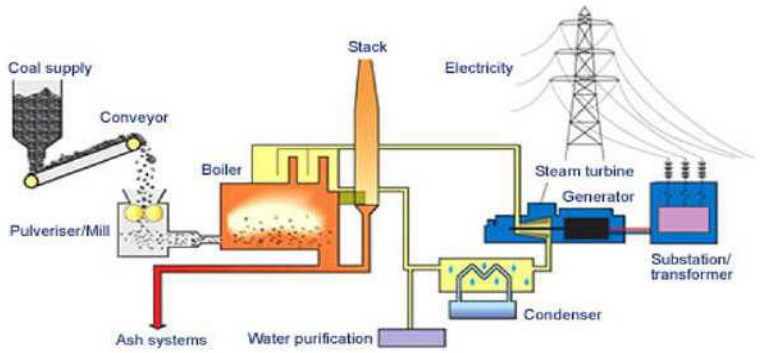

Fig. 2. Diagram of electricity generation from coal (World Coal Institute, 2010)

Carbon dioxide capture

Post-combustion capture

CO_2 can be captured from the flue gas of a combustion process. This can be flue gas coming from any (pressurized) combustion in a boiler, gas turbine or industrial process yielding CO_2. Various capture mechanisms, or combinations of them, can be applied, being: phase separation, selective permeability and sorption. The last mechanism, sorption, is the most widely suggested mechanism to be used at large point sources. This mechanism encompasses chemical or physical absorption and also adsorption. In the CO_2 capture processes based on this mechanism a sorption medium, or a sorbent, is used. When these sorbents are in solution they are called solvents. The current research, development and demonstration (RD&D) focus is on using chemical and physical solvents to separate the CO_2 from the gas stream. Retrofitting existing power plants with CO_2 capture will highly likely be done with a chemical absorption based post-combustion capture technology.

CHANGE IN KEY ATMOSPHERIC EMISSIONS DUE TO CO_2 CAPTURE

Key direct atmospheric emissions of specific interest for biomass and coal fired concepts are CO_2, NOx, NH_3, SO_2, HCl, HF, VOC, PM, Hg, Cd, and other heavy metals. For gas fired concepts CO_2 and NOx are the most dominant atmospheric emissions. Equipping power plants with CO_2 capture technologies affects both the formation and fate of many of these emissions. We limited our study to three main
capture systems for the removal of CO_2 : post-combustion, pre-combustion and oxyfuel combustion. The chemical absorption technologies that we reviewed in detail include technologies using alkanolamines, such as monoethanolamine (MEA), and MHI's KS-1 solvent. Other technologies reviewed are based on absorption using chilled ammonia (NH_3), alkali salts (i.e. potassium carbonate -K_2CO_3) and amino salts. The post-combustion system can be applied to various energy conversion technologies. In this study we focus on its application to Pulverized Coal (PC), Natural Gas Combined Cycle (NGCC) and Pressurized Fluidized Bed Combustion

(PFBC) power plants. The energy conversion technology that is envisaged using pre-combustion that is mainly investigated in this study is the Integrated Gasification Combined Cycle (IGCC) power plant. The energy conversion technologies using oxyfuel combustion that have been reviewed in this study more extensively are rather conventional PC and NGCC power plants. Advanced technologies briefly touched here include, for instance, chemical looping combustion. A summary of emission factors for key atmospheric emissions reported in literature for these technologies is presented in Fig. 2. The main effects of CO2 capture on atmospheric emissions are summarized below for the key atmospheric emissions.

Carbon dioxide

CO_2 emissions predominantly depend on the type of fuel, on the efficiency of the energy conversion and of the removal efficiency of CO_2. The removal efficiency for the oxyfuel combustion concept is found to be the highest on average (95-98%), yielding the lowest CO_2 emissions for the gas fired conversion technologies (0-60 g/kWh). Post- and pre-combustion show about equal removal efficiencies of 87-90% and 89-95%, respectively. The typically higher conversion efficiency for gasification or reforming results however in typically lower net CO_2 emissions for the pre-combustion concepts (21-97 g/kWh) compared to the postcombustion concepts (55-143 g/kWh). Often no distinction is made in the consulted literature between various sizes8 of emitted particulate matter in emission reporting. In this review, therefore also no distinction could be made between size fractions. The high variance for *post-combustion* capture technologies for solid fuel fired power plants stands out in Fig. 2. An increase in emission per MJ primary is never assumed. Together with the energy penalty due to CO_2 capture, PM emissions may however increase per kWh. The low particulate matter emissions found for the *oxyfue*l combustion technology are partly due to the enhanced removal efficiency of the ESP that is possible during oxyfuel combustion. Particulates may also be partially co-injected with the CO_2 stream. Another possibility is that particulates are vented from the CO2 treatment section. Yet another option is that PM is removed with the condensate stream that is formed when SO_2 and NOx are removed as sulphuric and nitric acid, as mentioned earlier. All together, PM emissions are estimated to be very low. IGCC power plants are assumed to have lower PM emission factors compared to other conversion technologies and types of power plants.
Life Cycle Assessment (LCA) is today one of the most used tools for evaluating the potential environmental impact of products and materials. LCA is a technique for assessing the environmental aspects and potential impacts associated with inputs and outputs of a product system. In the case of CCS, a full LCA includes the production of the fuel carrier (e.g., mining of coal), fuel transport, power production, CO_2 capture, CO_2 transport and CO_2 storage.

CO2 equivalent emissions

The main goal of CCS is to reduce CO2 emissions and consequently, Global Warming Potential (GWP). For pulverized coal-fired power plants with post-combustion capture technology using MEA a range in GWP over the life cycle of 79-275 gCO2eq/kWh is reported (range for PC without CCS is in the range 690 to 1100 gCO2eq/kWh). Where PCs without CCS have a share of power plant operation in life cycle GWP of about 80-95%, installing CO2 capture decreases this share to about 43-60%. Thus, the deployment of CCS results in a pronounce increase in the share of indirect CO2eq. emissions in the complete life cycle15. In the case of IGCCs with pre-combustion CO2 capture, GWP values reported are in the range 110 to 181 gCO2eq/kWh (the range for IGCCs without CCS is 666 to 870 gCO2eq/kWh). Lignite-fired IGCCs with CCS have almost 20% less absolute emissions compared to hard coal-fired IGCCs with CCS. Installing

CCS results in a reduction of about 82 to 87% for lignite-fired IGCCs with CCS relative to IGCCs without CCS, while for hard coal-fired IGCCs the relative differences are in the range of 69 to 81%. Interestingly, hard coal-fired power plants with CCS technology are reported as having between 20% (IGCC with CCS) and 30% (PC with CCS) more GHG emissions than similar lignite-fired power plants with CCS, while without CCS technology the hard coal-fired power plants have about 10% lower emissions than lignite-fired power plants.

Particulate matter

PM_{10} emissions reported for the life cycle of PC power plants with post-combustion using MEA range between 0.013 and 0.434 gPM_{10}/kWh while $PM_{2.5}$ for the same type of plants are reported between 0.05 to 0.07 $gPM_{2.5}$/kWh. PC plants without CCS report PM_{10} in the range 0.009 to 0.35 gPM_{10}/kWh and $PM_{2.5}$ in the range 0.009 to 0.35 gPM_{10}/kWh. Contrary to the results found for GWP, no clear difference is reported for hard coal-fired and lignitefired power plants. Only two studies (Viebahn, Nitsch et al. 2007;RECCS 2008) report the contribution of the different part of the CCS chains. In these studies, the contribution of the PC plant with CO2 capture is estimated at 33% and 45%, which is lower than the estimated contribution of a similar PC plant without CCS (60% and 65%, respectively).
The amount of studies reporting PM emissions for other CO_2 capture technologies is limited. The value is lower than those reported for PCs due to the high removal of PM in the syngas (to avoid detrimental effects in the turbine). NEEDS (2009) reports PM values for NGCCs equipped with MEA based postcombustion technology in the order of 0.005-0.006 gPM_{10}/kWh and 0.009-0.010 $gPM_{2.5}$/kWh (the values for a NGCC without CCS are in the range of 0.003-0.012 gPM10/kWh and 0.007- 0.008 $gPM_{2.5}$/kWh).
In this case, PM emissions are mainly associated with NOx emissions (which are PM precursors) from the power plant and the winning of natural gas. Values for oxyfuel power plants with CO_2 capture are also reported by NEEDs (2009). For PM_{10} the range reported is 0.012 to 0.025 gPM_{10}/kWh while for $PM_{2.5}$ this is 0.07 to 0.36 $gPM_{2.5}$/kWh.
Based on the available literature Låg et al. (2009) suggested exposure guidelines for four amines; particularly for AMP and MDEA there are few high quality studies. The guidelines presented are therefore just indicative. The uncertainty factors were chosen in accordance with EU guidelines. Based on inhalation exposure risk, the general population, over time, should not be exposed to levels in the air higher than:

- MEA: 10 $\mu g/m^3$
- AMP: 6 $\mu g/m^3$
- MDEA: 120 $\mu g/m^3$
- Piperazine: 5 $\mu g/m^3$

Finally, it has been stated that it is highly relevant to know which precise amine is used in CCS, because each individual amine has different effects and potential risks. Furthermore, use of more than one amine infers that the exposure guidelines should be evaluated again, since amines seem to
have similar adverse effects and might therefore also show additive or synergistic effects.

CONCLUSIONS AND WAY FORWARD

Depending on the applied CO_2 capture technology, trade-offs and synergies can be expected for key atmospheric emissions, being: NOx, SO_2, NH_3, particulate matter, Hg, HF and HCl. For all

three (pre-, post- and oxyfuel combustion) capture systems it was found that SO_2, NOx and PM emissions are expected to be reduced or remain equal per unit of primary energy input compared to power plants without CO_2 capture. Increase in primary energy input as a result of the energy penalty for CO_2 capture may for some technologies and substances result in a net increase of emissions per kWh output. The largest increase is found for the emission of NOx and NH_3 when equipping power plants with post-combustion capture. A decrease is expected for SO_2 emissions, which are low for all power plants with CO_2 capture. Additional research (measurements and modelling) and regulatory efforts (norm setting) are required to cope with 'new' emissions from predominantly post-combustion CO_2 capture technologies. Laboratory and field experiments are necessary to obtain more precision in the estimates of emission levels, as little information exists in open literature. It is recommended to focus research on the determination of atmospheric degradation paths, precise degradation yields, and degradation products' lifetime in the atmosphere. Development of models is necessary to quantify the mass fluxes and chemical interactions, and finally to integrate them in a dispersion model to quantify the load and possible environmental consequences. We recommend to set up extensive environmental monitoring programmes at currently planned CO2 capture (demonstration) plants aimed at creating a better understanding of the formation and fate of solid, liquid and atmospheric pollutants.

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