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Feasibility of significant CO_2 emission reductions in thermal power plants – comparison of biomass and CCS

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Abstract

In the future greenhouse gas emission targets will be more ambitious and therefore solutions for of CO_2 emissions reduction more than 80% are sought. In thermal power plants these high levels of emission reductions can be reached with CCS technologies or by utilizing high shares of biomass based fuels. Following from the national targets of Finland, the power plants being planned at the moment need to take these targets into account in the planning phase as options that need to be fulfilled at least in the future if not immediately. In this paper high plant level CO_2 emission reduction targets are analysed for two large power plants that are planned to be constructed in Finland in the near future. Both are located close to urban areas and supply also district heat to neighboring cities. Both also face high political pressure to significant emission reductions in comparison to existing system.

This paper is based on a case study of a planned combined heat and power (CHP) plant in Finland having fuel power of $420MW_{fuel}$. The boiler island is plant based on circulating fluidized bed (CFB) boiler technology enabling combustion of high shares of biomass. The paper is shortly describing technologies that are needed for reduction of CO_2 emissions when carbon capture based on oxyfuel technology and biomass firing based on high shares of forest residues are considered. The implications of applying these technologies and suitability for CHP environment are considered and economic feasibility of the solutions compared. Also the possibilities and feasibility of reaching negative emissions with combination of biomass firing and CCS is briefly assessed.

Results show significant emission reduction potential associated to both technologies. The major costs associated to CCS are caused by the equipment investment, loss of electricity production due to energy penalty and transportation and storage of CO_2. The costs associated to biomass combustion with high shares are mainly caused by higher prices of biomass fuel in comparison to coal and lower power-to-heat ratio. Large biomass share has an increasing impact also on plant investment and O&M costs.

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On the other hand, significant savings are achieved in terms of CO_2 allowances. When discussing the biomass option one must also address questions related to availability of sustainable biomass, effecting pricing and competition of raw material between different uses such as forest industry or liquid biofuels production. And this further highlights the discussion on carbon stocks and carbon debt especially when Bio-CCS is considered.

If the profound emission reduction targets are to be met, economically the difference between the technologies considered is not clear in all circumstances. All the most important parameters for the economic lifetime of the power plant include significant uncertainty therefore in this paper main focus has been in sensitivity analysis. The study reveals some major economical restrictions of the applicability of these emission reduction solutions. The pros and cons of the technologies in the light of feasibility and the role of these technologies as carbon abatement tools are discussed. The major factor effecting the technology decision is plant location in relation to availability of biomass, coal and CO_2 transportation&storage options, as well as heat demand (possibility to utilize CHP) in addition to political atmosphere and acceptability of technologies.

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Keywords: Oxy-fuel; co-firing; Bio-CCS; BECCS; CHP, feasibility

1. Introduction

1.1. Greenhouse gas emission reduction targets

The urgency to stabilize the global temperature rise at 2°C calls for solutions that can remove CO_2 from the atmosphere. In the future greenhouse gas (GHG) emission targets will be more ambitious and therefore solutions for reduction of CO_2 emissions more than 80% are sought to reach the profound targets. Currently European Commission is proposing a uniform 40% GHG reduction targets for ETS (sectors within European Emission Trading Scheme, like energy and GHG intensive industry) and Non-ETS sectors (such as households, agriculture, transport) [1]. CCS (Carbon Capture and Storage) and bioenergy both seem to have a significant role in reaching the high emission reduction targets in Europe and also in Nordic countries [2].

In principal, there are two technical solutions to significantly reduce GHG emissions in thermal power plants: carbon capture and storage (CCS) technologies and fuel switch e.g. by utilizing high shares of biomass based fuels. Combining these two can also lead to a carbon sink [3]. The technical and economic feasibility of these GHG mitigation solutions are investigated in this paper through a case study on power plant situated in Finland. National taxes and renewable subsidies are not included in order to make the results widely applicable and to investigate the non-political (other than CO_2) feasibility order of these solutions.

1.2. Co-firing of biomass and technical applicability of CCS to biomass co-firing plant

Co-firing of coal and various kinds of biomasses is now a mature technology and is currently being practiced all over the world successfully, though it does not eliminate CO_2 emissions entirely. Fluidized bed boilers provide the best fuel flexibility for co-firing. With properly designed CFB boilers, biomass fuels can be co-fired with coal on 0–100 % share [4].

In general, similar solutions are suitable for capturing CO_2 from biomass applications as for fossil fuels. The main differences relate to different kind of impurities in the combustion process, ash and flue gas and typically significantly larger moisture content of biomass resulting more vapor in flue gases enabling also high heat recovery potential. However, no principal technical restrictions with the capture of biogenic CO_2 exist. Despite of fluidized bed technology's high flexibility regarding the fuels, in the case of biomass combustion some challenges exist. Some of these challenges may be emphasized in the case of utilization of CCS. For example with oxy-fired fluidized bed boilers even small concentrations of chlorine in the fuel can lead to deposits of harmful alkaline and chlorine compounds on boiler heat transfer surfaces due to components enrichment in the flue gas because of lack of nitrogen in furnace and flue gas re-circulation.