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Kristin Onarheim
VTT Technical Research, kristin.onarheim@vtt.fi

Stanley Santos
IEAGHG

Ville Hankalin
AF Consult Oy

Petteri Kangas
VTT Technical Research

Antti Arasto
VTT Technical Center

TECHNO-ECONOMIC EVALUATION OF RETROFITTING CCS IN AN INTEGRATED PULP AND BOARD MILL – CASE STUDIES

Kristin Onarheim, VTT Technical Research Center of Finland, Ltd.
kristin.onarheim@vtt.fi
Stanley Santos, IEAGHG
Ville Hankalin, ÅF Consult Oy
Petteri Kangas, VTT Technical Research Center of Finland, Ltd.
Antti Arasto, VTT Technical Research Center of Finland, Ltd.

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Urgently reducing global greenhouse gas emissions (GHG) could be achieved by carbon sinks or negative emissions, i.e. removing CO_2 from the atmosphere and offsetting historical CO_2 emissions. Negative emissions can be achieved when CO_2 is captured from processes based on biomass feedstock (bio-CCS). Biomass withdraws atmospheric CO_2 through natural processes such as the photosynthesis. Capturing and permanently storing this CO_2 away from the natural carbon cycle enables a withdrawal of CO_2 from the atmosphere. Sustainable growth and harvest of biomass resources is critical to achieve carbon negativity and to allow for sound biomass regrowth. As a result, bio-CCS provides a potential mitigation tool to reduce the CO_2 concentration in the atmosphere. The pulp and paper industry is one of the potential candidates for large scale demonstration of bio-CCS and industrial CCS application. In Europe, the pulp and paper industry is the largest user and producer of biomass energy, contributing to around 60% of the biomass based electricity and heat production. There are three main sources of CO_2 emissions in the pulp and paper production (via Kraft pulping process): (1.) the Kraft recovery boiler, (2.) the lime kiln and (3.) the multi-fuel boiler (bark boiler). Typically, over 90% of CO_2 emissions from a pulp mill are of biogenic origin as fossil fuel is used only for firing the lime kiln. The main function of the recovery boiler is to recover the spent cooking chemicals from the black liquor for reuse in wood chips cooking and the combustion of the organic matter in the black liquor to produce heat for steam and electricity generation. The lime kiln is part of the chemical recycle loop and this includes the calcination of the lime mud (mainly calcium carbonate) to produce CaO that is used in the recovery of the cooking chemicals (i.e. processing of the green liquor). As a result, the lime kiln produces a flue gas with high concentration of CO_2. The multi-fuel boiler is typically used to burn any wood waste and residue biomass (i.e. bark and bio-sludge) from the pulp production to produce steam used in the process and for power production. This study addresses the operational costs, capital investment costs and technical aspects of retrofitting a modern Kraft market pulp mill with a split flow post-combustion CO_2 capture based on amine absorption. The pulp production units and the CO_2 capture units are presented with detailed mass and energy balances. Two types of mills were evaluated; i) Stand-alone pulp mill producing 800 000 adt of softwood pulp annually and ii) Integrated pulp and board mill producing 740 000 adt of softwood pulp and 400 000 3-ply folding boxboard annually. Annual CO_2 emissions are 2.1 Mt CO_2/a. Six different cases were studied for each mill type; CO_2 capture from the three individual point sources and three combinations of these. The implementation of a post-combustion CO_2 capture process requires additional steam for the amine reboiler and additional power input for pumps and compressors. In some cases the excess power production at the pulp mill may be sufficient to support the integration of a CO2 capture plant. In other cases an additional auxiliary boiler is required. The split flow MEA-based capture process enables a reduction in the heat duty for the CO_2 stripper reboiler. The average reboiler duty was calculated to around 2.7 – 2.8 MJ/kg captured CO_2. Steam is provided from the steam turbine island. A major focal point of the study was to investigate the optimal extraction of steam and condensate return. Most pulp and paper mills are self-sufficient with electricity and produce excess electricity that is exported to the local/national grid. 90% CO_2 capture was assumed for all cases, but in future evaluations partial CO_2 capture might prove more viable, depending on the amount of excess steam or electricity available at the mill. This is also affected by the price of electricity, price of emission allowances and any renewable energy subsidies/incentives. Capturing biogenic CO_2 could potentially create additional revenues for the mill operator, depending on whether the emission of biogenic CO_2 would be accounted for as negative CO_2 emissions in emission allowance trading schemes. As a result, accounting for negative CO_2 emissions could potentially be a low-hanging fruit and lead to demonstration or large scale industrial business cases for the implementation of CCS in the near future.