Carbon-negative biopower via direct conversion and co-firing: Systemic impacts of capture and storage of CO_2 applied to Indonesia

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Keywords: Biopower, BECCS, co-firing, CO_2 mitigation, negative emissions

ABSTRACT

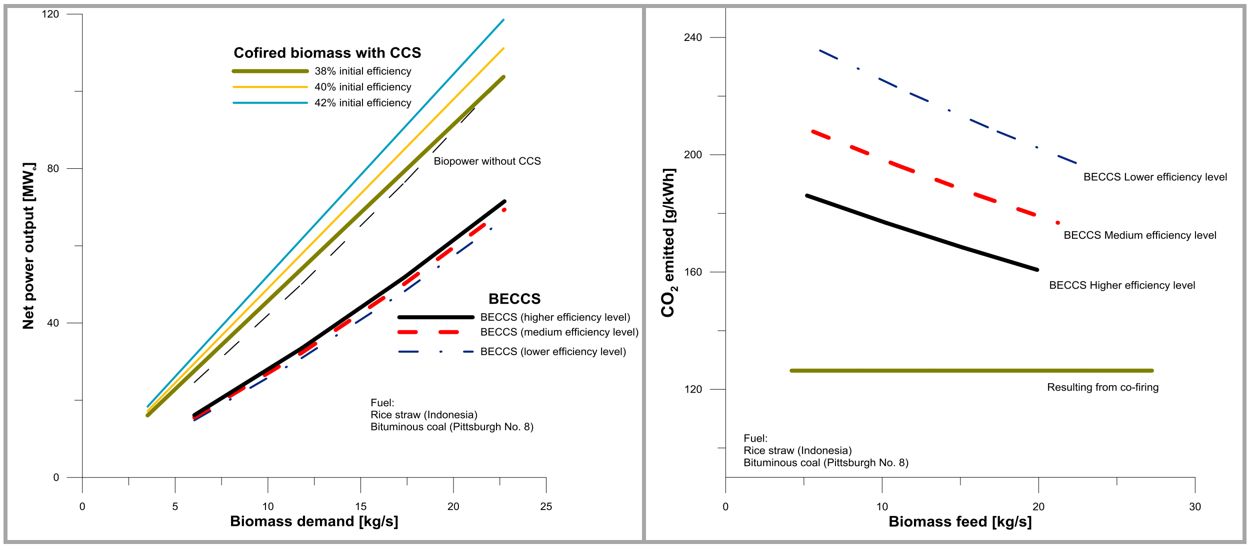
This paper is a contribution to the on-going debate on carbon-negative energy solutions. It deals with CCS applied to bioenergy systems (BECCS) and optional co-firing of biomass with coal. In this context, bioenergy refers to the use of biomass to generate electricity (i.e. biopower) in compliance with the needs of regions without seasonal heating demand. In this study, direct-fired and co-fired systems have been addressed, combined mainly with post-combustion flue gas cleaning. The question is which CCS alternative should be preferred in order to reach negative emissions: either building multiple smaller biopower units, or employing co-firing of biomass and coal in modern coal power plants. Based on efficacy and the potential for mitigating greenhouse gas emissions as key indicators, some major differences between the alternatives are shown. With co-firing, more net electric energy can be provided from the feedstock of biomass than would be obtainable from a dedicated BECCS plant, although the amount of CO_2 captured and stored will be the same.

According to the 5th assessment report of the IPCC (Working Group 3), about half of the scenarios needed to limit the atmospheric concentration of greenhouse gases at 430-480 ppm CO_2 equivalents feature BECCS. As these scenarios jointly account for more than 5% of the global primary energy supply, it is necessary to further assess the potential for CO_2 mitigation from a systemic perspective.

Recent studies of power generation from biomass (biopower) suggest that circulating fluidised bed systems (CFB) in the 800 MW_e class may reach efficiencies up to 41-42% (LHV). However, with this high efficiency the capital expenses will become prohibitive. In order to reduce expenses, an efficiency level approaching 40% seems feasible, but in most cases the availability of biomass within a reasonable distance from the plant is limited. For instance, supplying 800 MW_e of biopower generated in a plant with 40% efficiency requires over 700 tonne biomass per hour[1], equivalent to 24 lorries carrying 30 tonne each. Aggregated over the year, this implies 200 000 deliveries. From a logistic point of view, deployment of biopower on this scale appears to be a considerable challenge. For this reason, in order to become viable, additional firing options are required to allow for at least 50% fossil-based fuels. Evidently, this will have an impact on the resulting CO_2 emissions, which makes comparative assessment of biopower and co-firing interesting.

[1] Air dried biomass with [C,H,O,N,S,moisture,ash]=[0.3028,0.0352,0.2563,0.0704,0.0000,0.4014,0.00352] with LHV 10.55 MJ/kg.

In modern coal-fired power plants, co-firing with biomass is converted with a substantially higher net efficiency. To the extent that coal power plants are readily available, co-firing therefore represents a true option. By replacing a portion of coal with biomass, co-firing seems to be the most economic near-term solution for employing biopower at large. In general, modern coal power plants can accept up to 15% biomass without modifying the steam boiler system. Because the existing environmental control equipment can be used even at a higher percentage of biomass without major modifications, co-firing is a far less expensive option than building a new biopower plant on a green field.



Impact of biomass on the net power output (left) and the CO_2 emitted (right) depending on technology (BECCS and co-firing with coal) and the feeding rate of biomass.

The study indicates significant advantages of a co-firing scheme over an independent biopower plant when CCS is applied. Provided that an operational coal-power plant is at hand, more net electric energy can be generated from the biomass than would be the case in a dedicated BECCS plant, although the amount of CO_2 captured and stored will be identical. According to the study, an independent bioenergy power plant, with the same electric energy, must burn roughly 27-75% more biomass and will generate a corresponding amount of additional CO_2 (dependent on the size and complexity of the plant) (cf. figures above).
When it comes to safeguarding the energy supply, which is important in countries with power scarcity such as Indonesia, the use of available biomass resources for co-firing in coal power plants will be preferable. Clearly, this has a considerable limitation as concerns the logistics of providing the required biomass feedstock. Furthermore, in a regulatory regime with a sufficient price on carbon emissions, independent biopower plants may be preferred to the co-firing alternative mainly due to the CO_2 which is accountable either as negative or neutral emission. In this case, an accounting system capable of handling negative CO_2 emissions is mandatory.