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Identifying/Quantifying Environmental Trade-offs Inherent in GHG Reduction Strategies for Coal-Fired Power

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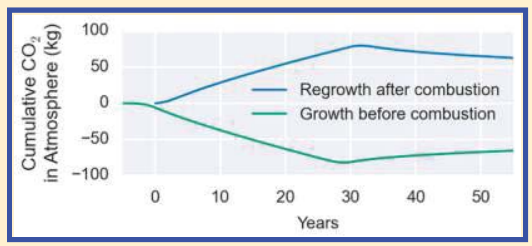
Ⓢ *Supporting Information*

ABSTRACT: Improvements to coal power plant technology and the cofired combustion of biomass promise direct greenhouse gas (GHG) reductions for existing coal-fired power plants. Questions remain as to what the reduction potentials are from a life cycle perspective and if it will result in unintended increases in impacts to air and water quality and human health. This study provides a unique analysis of the potential environmental impact reductions from upgrading existing subcritical pulverized coal power plants to increase their efficiency, improving environmental controls, cofiring biomass, and exporting steam for industrial use. The climate impacts are examined in both a traditional—100 year GWP—method and a time series analysis that accounts for emission and uptake timing over the life of the power plant. Compared to fleet average pulverized bed boilers (33% efficiency), we find that circulating fluidized bed boilers (39% efficiency) may provide GHG reductions of about 13% when using 100% coal and reductions of about 20–37% when cofiring with 30% biomass. Additional greenhouse gas reductions from combined heat and power are minimal if the steam coproduct displaces steam from an efficient natural gas boiler. These upgrades and cofiring biomass can also reduce other life cycle impacts, although there may be increased impacts to water quality (eutrophication) when using biomass from an intensely cultivated source. Climate change impacts are sensitive to the timing of emissions and carbon sequestration as well as the time horizon over which impacts are considered, particularly for long growth woody biomass.



■ INTRODUCTION

There is increasing regulatory pressure, and an environmental and social imperative, to reduce the greenhouse gas emissions (GHGs) from fossil fuel-based power generation in the United States and around the world. Commonly espoused solutions are a large scale switch to renewables or to a less GHG-intensive fossil fuel such as natural gas.[1−6] Other studies have investigated ways to reduce GHG emissions from coal-fired power through methods such as cofiring biomass.[7−11] Recent work shows that reducing GHG emissions can also benefit air quality.[12−14] This paper builds on previous studies and brings together traditional LCA impact assessment with an analysis of GHG timing.

In regions of the U.S. where a large percentage of the electricity comes from coal-fired power generation – in 2012 West Virginia, Kentucky, and Wyoming produced 96%, 92%, and 88% of their power, respectively, from coal[15] – alternatives need to be evaluated that can be achieved through modification of existing coal power infrastructure that is still within its service life. To continue utilizing coal power infrastructure and still reduce GHGs, carbon capture, and subsequent storage or utilization is a potential solution, but there are significant regulatory and economic barriers which, to this point, have prevented the technology from being commercially deployable.[16]

In this paper, we examine the potential for three different changes to existing coal-fired power plants to reduce climate impacts without the need for capturing and sequestering CO_2 at the power plant. The first of these changes is an efficiency improvement, enabled by replacing a conventional subcritical pulverized coal boiler, which is the most commonly deployed technology in the U.S. coal fleet, with a state-of-the-art coal circulating fluidized bed (CFB) boiler.[17,18] The second potential improvement diverts some of the produced energy, in the form of steam heat, for use in a nearby industrial application, commonly known as combined heat and power (CHP). This has the dual effect of making the combined operation more efficient, as more of the input fuel's energy is being used in making a marketable product from a waste heat, and from an accounting standpoint, sharing the environmental burdens with the consumer of the steam. The third possible GHG reduction examined here introduces 30% biomass by

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