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A 500 MW_e Coal-Fired Power Plant Operated under Partial Oxy-Combustion: Methodology and Economic Evaluation

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Abstract : The European Union aims at strongly reducing their CO_2 emissions from energy and industrial sector by 2030. The energy sector contributes with more than two-thirds of the CO_2 emission share derived from anthropogenic activities. Although efforts are mainly focused on the use of renewables by energy production sector, carbon capture and storage (CCS) remains as a frontline option to reduce CO_2 emissions from industrial process, particularly from fossil-fuel power plants and cement production. Among the most feasible and near-to-market CCS technologies, namely post-combustion and oxy-combustion, partial oxy-combustion is a novel concept that can potentially reduce the overall energy requirements of the CO_2 capture process. This technology consists in the use of higher oxygen content in the oxidizer that should increase the CO_2 concentration of the flue gas once the fuel is burnt. The CO_2 is then separated from the flue gas downstream by means of a conventional CO_2 chemical absorption process. The production of a higher CO_2 concentrated flue gas should enhance the CO_2 absorption into the solvent, leading to further reductions of the CO_2 separation performance in terms of solvent flow-rate, equipment size, and energy penalty related to the solvent regeneration. This work evaluates a portfolio of CCS technologies applied to fossil-fuel power plants. For this purpose, an economic evaluation methodology was developed in detail to determine the main economical parameters for CO_2 emission removal such as the levelized cost of electricity (LCOE) and the CO_2 captured and avoided costs. ASPEN Plus™ software was used to simulate the main units of power plant and solve the energy and mass balance. Capital and investment costs were determined from the purchased cost of equipment, also engineering costs and project and process contingencies. The annual capital cost and operating and maintenance costs were later obtained. A complete energy balance was performed to determine the net power produced in each case. The baseline case consists of a supercritical 500 MWe coal-fired power plant using anthracite as a fuel without any CO_2 capture system. Four cases were proposed: conventional post-combustion capture, oxy-combustion and partial oxy-combustion using two levels of oxygen-enriched air (40%v/v and 75%v/v). CO_2 chemical absorption process using monoethanolamine (MEA) was used as a CO_2 separation process whereas the O_2 requirement was achieved using a conventional air separation unit (ASU) based on Linde's cryogenic process. Results showed a reduction of 15% of the total investment cost of the CO_2 separation process when partial oxy-combustion was used. Oxygen-enriched air production also reduced almost half the investment costs required for ASU in comparison with oxy-combustion cases. Partial oxy-combustion has a significant impact on the performance of both CO_2 separation and O_2 production technologies, and it can lead to further energy reductions using new developments on both CO_2 and O_2 separation processes.

Keywords : carbon capture, cost methodology, economic evaluation, partial oxy-combustion
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