**Economic analysis of oxy-combustion technology with carbon capture**

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**Highlights**

* Process simulation for 500 MWe air and oxy-coal power plants with CO2 capture
* Amine absorber unit (AAU) and CO2 processing unit (CPU) for CO2 capture
* Oxy-combustion with CPU was more efficient than air-combustion with AAU

**1. Introduction**

Carbon dioxide (CO2) has been considered as a major greenhouse gas (GHG), and the fossil fuel combustion produced about 41% of global GHG in 2010 [1]. The CO2 capture and storage (CCS) is important for the coal-fired power plant to meet future targets on reduction of GHG emissions [2]. The amine absorber unit (AAU) is typically used in the air-coal combustion power plant for CCS [3.4]. The CO2 processing unit (CPU) with a cold box is applied to the oxy-coal power plant due to high CO2 content in flue gas [2]. However, few researchers have addressed the energy and economic analyses under the same operating parameters of the two plants with CCS. There remains a need for a comparison between the two plants to identify the economic feasibility. This study aims to develop the process flow diagram (PFD) of the two plants with and without CCS, and to evaluate economic values such as the total capital investment (TCI), total production cost (TPC), capital investment cost (CIC), carbon capture cost (CCC), and levelized-cost of electricity (LCOE).

**2. Methods**

The PFDs of the two power plants were simulated by a commercial code (ASPEN Plus) to calculate the mass and energy balances. The PFD of the air-coal power plant consisted of five main areas: A100 (coal pretreatment), A200 (circulating fluidized-bed combustion-CFBC), A300 (electricity generation), A400 (flue gas desulfurization-FGD), and A500 (AAU). In the oxy-coal power plant, A400 was replaced by a flue gas conditioning (FGC), A600 (air separation unit-ASU) was added, and A500 was substituted with A700 (CO2 processing unit-CPU).

The operating parameters applied equally to the two plants included: (1) The coal feed rate is fixed at 3080 t/d, (2) The CFBC is operated at 875oC and 1 atm, (3) The heat loss of CFBC is 5 % of LHV during coal combustion, (4) The equivalence mass ratio (O2 to fuel) is 2.5, (5) Ultra super-critical (USC) steam (600oC and 300 bar) is generated, (6) 90% SO2 is removed inside the combustor by CaO (limestone), (7) The CFBC includes SCR with aqueous NH3 for NOx removal, and electrostatic precipitator (ESP) for dust removal, (8) The produced CO2 over 95 % purity and over 90% recovery in the gas phase aims to be sequestrated under the ground, (9) The produced CO2 at 8 bar and 20 °C contains water under 250 ppm, and (10) The total amount of CO2 captured are the same. Three cases were considered to compare the energy and economic analyses: Case 1 (air-coal power plant without carbon capture), Case 2 (air-coal power plant with AAU), and Case 3 (oxy-coal power plant with CPU). The energy and economic analyses included the net thermal efficiency, heat penalty, TCI, CIC, CCC, LCOE.

**3. Results and discussion**

The process performance of the three cases is shown in Table 1. Case 1 has the highest net electricity and net thermal efficiency because of no carbon capture. The heat penalty of Case 2 (air-coal power plant with AAU) is higher than that of Case 3 due to high amine regeneration heat in AAU. As mentioned earlier, the CO2 captured is the same for Cases 2 and 3. The TCI of Cases 2 and 3 is higher by 66.42 and 91.3 M$, respectively, than that of Case 1. The LCOE increases by 39.4 and 25.6 $/MWh for Cases 2 and 3, respectively, because of CO2 capture. The CIC and CCC of Case 2 are higher than those of Case 3 and higher the CO2 price (26.3 $/t) was reported by Moioli *et al*. (2017) [5]. Therefore, Case 3 (oxy-coal power plant with CPU) shows the better energy and economic performances than Case 2.

**Table 1.** Process performance of air- and oxy-coal power plants.

| Performance indicators | Case 1 | Case 2 | Case 3 |  |
| --- | --- | --- | --- | --- |
| Net electricity (MWe) | 502 | 403 | 420 |
| Net thermal efficiency (%HHV) | 45 | 36.1 | 37.6 |
| Heat penalty (%, based on Case 1) | – | 20.5 | 16.8 |
| CO2 captured (t/d) | – | 7278.7 | 7282.4 |
| TCI (M$) | 361.2 | 427.6 | 452.5 |
| LCOE ($/MWh) | 78.5 | 117.9 | 104.1 |
| CIC ($/kWh.y) | 132.9 | 307.0 | 280.2 |
| CCC ($/t) | - | 28.08 | 25.50 |

**4. Conclusion**

The CO2 capture is important for the coal-fired power plant to reduce the CO2 emission. The energy and economic performance was evaluated for the 500 MWe air-coal and oxy-coal power plants with CO2 capture under the same operating parameters. It was found that the oxy-coal power plant with CPU was more efficient than the air-coal power plant with AAU in terms of LCOE, CIC and CCC. It would be better to design effectively heat networks.

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