Solid-Fueled Pressurized Chemical Looping with Improved Plant Efficiency and CO₂ Capture

Among the available or proposed technologies for CO₂ capture, pressurized chemical looping combustion/gasification (PCLC/G) is among the most promising. In PCLC/G, coal is combusted with solid oxygen carriers in the absence of air, resulting in a flue gas containing near pure CO₂ after water condensation.

**Elimination of external air separation unit (ASU):**

In the PCLC process, air is directly introduced to the air reactor to combust the reduced form of oxygen carriers (OCs), and the OCs oxidation substitutes for O₂/CO₂ combustion, avoiding an ASU to provide high purity O₂. According to a NETL systems analysis study, the ASU is responsible for about 65% of the increase in COE for 1st generation oxy-fuel systems.

**CLC plus combined cycle:**

High temperature exhaust gas from the air reactor (~1100 °C), containing mostly nitrogen, is directed to the gas turbine to generate electricity, followed by a heat recovery unit to power a conventional steam cycle. When exhaust CO₂-stream pressures of 100 bar are generated, an overall plant efficiency of 48% at steam temperatures of 600–620°C is achieved that is almost double that achieved in a sub-critical PC plant equipped with an amine scrubber (~25% efficiency) or of an oxyfuel-PC system used to concentrate CO₂ (~27%).

**Synthesis of Ligands and Catalysts**

Novel organic ligands for CO₂ capture catalysts are designed and synthesized at CAER based on density functional theory (DFT) calculations performed by Lawrence Livermore National Laboratory. Purification and characterization of target ligands and catalyst candidates are carried out at our facilities using, but not limited to, NMR, GC-MS, FTIR, powder XRD, ESI-MS, MALDI-MS, and column chromatography.

![Efficiency Comparison of Various Carbon Capture Technologies](image-url)
High performance and cost-effective oxygen carrier

Oxygen carriers with high reactivity and oxygen transfer capacity help reduce solid inventory, the amount of recycling solid flow, and the size of the reactor and related plant components. We have demonstrated that iron-based OCs show moderate reactivity and capacity, a high resistance to water vapor, low ash fouling, and low rates of attrition. Over 90% CO$_2$ capture efficiency has been achieved in using an iron-based oxygen carrier reduction in a single fuel reactor. Another iron-based OC made from an industrial waste material is under development at CAER, which could further reduce the cost of the carrier significantly while providing comparable performance compared to expensive synthetic carriers.

Elimination of internal heat exchange surface area

With high temperature flue gas from the oxidizer to drive a flue-gas turbine, elimination of internal heat exchange surface area inside the reactor (oxidizer) leads to higher temperature of heat source and lower operating cost. The overall analysis on the COE indicates that the proposed PCLC coupled with supercritical steam generation (600/620°C) would reduce the portion of consumable operating and maintenance (O&M) in the COE value from $12.17/MWe to $10.06/MWe compared to conventional CFBC, exceeding the DOE program objectives.