Post-Combustion CO_2 Capture

U.S. Research Team Lead	China Research Team Lead
• Kunlei Liu, University of Kentucky, Center for Applied Energy Research	• GAO Shiwang, China Huaneng Group
U.S. Partners	**China Partners**
• University of Kentucky • University of Wyoming • Los Alamos National Laboratory • Lawrence Livermore National Laboratory	• China Huaneng Group Clean Energy Research Institute • Tsinghua University • China Power Engineering Consulting Group Corporation • China Power Investment Corporation

Research Objective

The ACTC team is directly addressing the need for steep emissions reductions from the existing coal fleet by analyzing, testing, and demonstrating technologies for post-combustion capture integrated with sequestration at real power plants. Through streamlined bilateral joint cooperation, U.S. and Chinese researchers are focusing on the following:

- Research on efficiency developments for affordable post-combustion CO_2 capture technologies
- Coordinated efforts between U.S. and Chinese partners
- Development of models for post-combustion CO_2 capture, utilization, and storage technology at a commercial scale

Technical Approach

To enable commercial-scale, cost-efficient carbon capture, utilization, and storage, the ACTC team is addressing the gap between theoretical efficiency for post-combustion capture and present-day commercially available technologies.

- Researchers in the United States (led by LANL) use novel fabrication technologies to create high-permeability, high-selectivity membranes for CO_2 separation using nanotechnology
- Researchers in the United States, led by UK and assisted by Huaneng led-team in China, develop an organo-metallic enzyme that mimics catalyzed solvent to speed up the CO_2 reaction and reduce capital costs
- Researchers enrich the carbon concentration prior to solvent regenerator to minimize the stripper size and energy consumption
- Researchers in China, led by Huaneng and assisted by UK in the United States, develop/evaluate new capture reagents with high solute capacity and higher resistance to solvent degradation and contamination. They also conduct process heat integration/optimization and techno-economic analysis for 1 million tons/year post-combustion CO_2 capture for both U.S. and China applications

A joint committee will be formed to accomplish the following:

- Collect and study the similarities and differences of coals and coal-derived flue gas conditions, power plant operation, and environmental requirements between the United States and China
- Establish guidelines/protocols/criteria for system optimization and evaluation, techno-economic analysis, and comparison for a commercial-scale application
- Develop a research matrix beneficial to both of the previously mentioned activities

Recent Progress

A series of catalyst candidates were synthesized based on initial literature reports for carbonic anhydrase mimics. It was determined that compounds with long Zn-O yet low (< 8.5) (pKa) are needed. A longer OH-bond leads to lower Lewis acidity of metal-ligand complex, more of a “free” hydroxide (and more nucleophilic), and higher acid dissociation (pKa) for the H_2O deprotonation step.

Researchers designed, synthesized, and demonstrated a novel class of next-generation ionic liquid-based materials and membranes at LANL. LANL’s ultrasonic-spray-coating-technology-based membrane fabrication platform was used to prepare the membranes of these next-generation materials in both stand-alone and supported formats. A SiF_6 salt compound that was synthesized at CAER was also tested. The testing was performed at LLNL using stopped flow kinetics measurement, and the rate constant was found to be comparable to the Zn cyclen (perchlorate salt) synthesized at LLNL. This test confirmed that the Zn-cyclen complex does have confirmed activity for catalyzing the CO_2 hydration reaction.

LLNL has worked with both Duke Energy and the HCERI to achieve several milestones for the analysis, assessing the feasibility of Huaneng's carbon capture technology. Researchers used validated Aspen models to initialize post-combustion capture simulations at Gibson-3. They acquired parametric data for Shidongkou to constrain a suite of model runs bounding different operating conditions (e.g., different circulation pressures and solution concentrations), and ran models for conventional monoethanolamine to validate PCC runs at Gibson-3, including preliminary economic analyses. Researchers also identified and repaired model mismatches and inconsistent results by identifying gaps in Huaneng data needed to finalize model runs with proprietary Huaneng solution, and a Chinese patent with relevant chemical thermodynamic and kinetic information.

Expected Outcomes

The project will produce optimized design options of competing technology pathways (e.g., amines and advanced solvent) for post-combustion CCUS cost, retrofitability, engineering, and environmental performance. The results from this work will lay the groundwork for decision makers in both nations to understand the potential role of post-combustion retrofits in achieving steep reductions, and provide new operational insights to the integration of capture and storage while developing new low-cost, post-combustion capture options.

Piping network in an existing coal power plant