the ENERGY lab

PROJECT FACTS

Carbon Capture

Efficient Regeneration of Physical and Chemical Solvents for CO_2 Capture

Background

Fundamental and applied research on carbon capture and storage (CCS) technologies is necessary to allow the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. These technologies offer great potential for mitigating carbon dioxide (CO_2) emissions into the atmosphere without adversely influencing energy use or hindering economic growth.

Deploying these technologies in commercial-scale applications requires a significantly expanded workforce trained in various CCS technical and non-technical disciplines that are currently under-represented in the United States. Education and training activities are needed to develop a future generation of geologists, scientists, and engineers who possess the skills required for implementing and deploying CCS technologies.

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL), through funding provided by the American Recovery and Reinvestment Act (ARRA) of 2009, manages 43 projects that received more than $12.7 million in funding. The focus of these projects has been to conduct carbon capture and geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States.

Project Description

NETL has partnered with the University of North Dakota (UND) to conduct research and training on two membrane-based alternative solvent regeneration processes for chemical and physical solvents used in carbon capture technologies. Composite polymer membranes and porous membrane contactors will be evaluated for their ability to cost-effectively recover CO_2 from the CO_2-rich solvent streams in coal gasification synthesis gas (syngas) CO_2 capture systems.

In coal gasification systems, coal is converted into syngas by applying heat under pressure in the presence of steam resulting (after additional processing in a water-gas shift reactor) in a stream of primarily CO_2 and hydrogen (H_2). The CO_2 is relatively concentrated and at a high pressure, allowing for more cost-effective capture. Removal of the CO_2, to leave a H_2-rich syngas for combustion, is typically conducted using solvent-based technologies and produces a CO_2-rich solvent stream, which requires further processing to separate the CO_2 and regenerate the solvent for reuse. As a significant amount of energy is required for regeneration of the solvent, materials and processes must be developed to reduce the capital and operating costs of the solvent regeneration process.

The membrane systems under development in this project have the potential to decrease costs by reducing or eliminating the thermal and/or pressure cycling requirements of

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PARTNERS

None

PERFORMANCE PERIOD

Start Date	End Date
12/01/2009	05/31/2013

COST

Total Project Value
$300,000

DOE/Non-DOE Share
$300,000/$0

American Recovery and Reinvestment Act (ARRA) funded.

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traditional solvent regeneration systems and facilitate CO_2 transport out of the solvent by increasing the interfacial contact area for mass transfer. Composite polymer membranes operate via a solution-diffusion mechanism. In this process, a species must first dissolve into and then permeate across the selective layer (Figure 1a). Differences in solubility and permeability lead to the selectivity of one species over another. Porous membrane contactors consist of a thin porous structure without a selective layer that provides a gas-liquid interface and relies on surface tension to reduce the ability of the liquid to pass through the pores, allowing only the gas to pass through (Figure 1b).

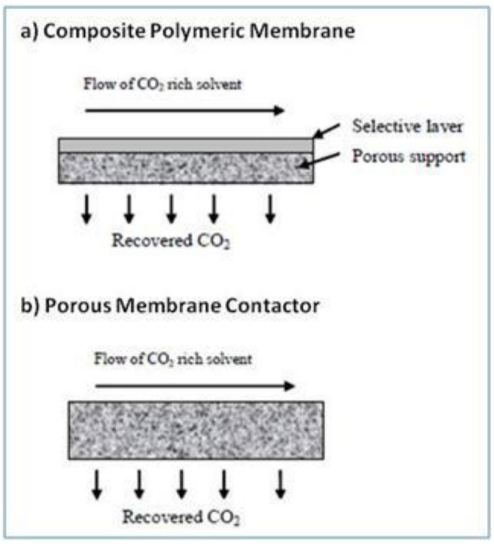

Figure 1. Membrane types that will be investigated in this study.

Laboratory-scale testing will be conducted on several types of composite polymer membranes and porous membrane contactors. Candidate membranes will be tested with various chemical and physical solvents in a continuous bench-scale system using a mixture of CO_2 and H_2 to determine the rate of CO_2 removal and solvent regeneration as a function of temperature, initial solvent pressure, and permeate pressure. Membranes with promising results will be evaluated in a parametric study in which the rates of CO_2 removal, solvent loss, and solvent degradation will be measured as a function of operating conditions. Selected membrane-solvent combinations will undergo further evaluation with simulated syngas to determine the effect of other gas components, including hydrogen sulfide and carbon monoxide, on membrane performance. A case study will be performed for one of the most promising membrane-solvent candidate systems to evaluate the commercial feasibility of a CO_2 separation system based on membrane solvent regeneration. This work will also be applicable to similar post-combustion carbon capture systems.

Goals/Objectives

The overall goal of the project is to determine the feasibility of using composite polymer membranes and porous membrane contactors for the recovery of CO_2 from CO_2-rich solvent streams from gasification syngas. The project objectives are to (1) design and construct a test apparatus to evaluate membranes, (2) assess the membranes in the test apparatus, (3) conduct a feasibility study based on the test results, and (4) engage and train students in the multiple facets of the project.

Accomplishments

- As of September 2012, three chemical engineering students had accumulated 4,421 training-related hours under the program.
- Designed, fabricated, and validated a membrane testing system.
- Completed baseline screening for CO_2 permeability and selectivity for both composite polymer membrane and porous membrane contactor candidates.
- Conducted additional experimentation with eight membrane samples, consisting of seven different materials, and monoethanolamine to verify that the performance of some porous membrane materials is affected by the materials' hydrophobicity and chemical incompatibility with the chemical solvent.
- Completed parametric studies of porous membrane contactors, which examined CO_2 removal, solvent loss, and solvent degradation as a function of temperature, feed rate, sweep rate, and pressure effects. Early results indicate that 40 percent of CO_2 had been recovered from solution in a single pass.
- Constructed a system to study physical solvents—which is now being used to evaluate several different types of composite membranes—and investigated the contributors to mass transfer resistance.
- Conducted experiments to investigate the mass transfer, wetting, and fouling mechanisms during the regeneration of chemical solvents using porous membrane contactors with different pore sizes.
- Studied the energy performance of porous membrane contactors as indicated by the temperature polarization coefficient. Temperature was found to influence the temperature polarization coefficient of the system significantly while retentate flow rate and sweep gas rate were not found to have a significant effect.
- Initiated parametric studies of composite membranes to examine feed gas flow rate, temperature, pressure, solvent flow rate, and permeate-side CO_2 partial pressure.

Benefits

The project is making a significant contribution to the scientific, technical, and institutional knowledge necessary to establish frameworks for the development of commercial-scale CCS. The technology produced by this research has the potential to minimize the thermal energy requirement for regeneration of solvent-based CCS technologies. By reducing or eliminating the regeneration energy penalty, this technology may attain the DOE goals of achieving over 90 percent CO_2 capture at a less than 10 percent increase in the cost of electricity. In addition, the project offers students an opportunity to train and develop skills required to implement and deploy vital carbon capture technologies.