the ENERGY lab

PROJECT FACTS

Carbon Capture

# Pilot Test of a Nanoporous, Super-hydrophobic Membrane Contactor Process for Post-combustion Carbon Dioxide Capture

## Background

The mission of the U.S. Department of Energy Office of Fossil Energy (DOE FE) Carbon Capture Research & Development (R&D) Program, implemented through the National Energy Technology Laboratory (NETL), is to develop innovative carbon dioxide ($CO_2$) emissions control technologies for fossil fuel-based power plants. The Carbon Capture R&D Program portfolio of pre- and post-combustion $CO_2$ emissions control technologies and related $CO_2$ compression is focused on advancing technological options for new and existing power plants to enable cost-effective $CO_2$ capture for beneficial use or storage of $CO_2$ and ensure that the United States will continue to have access to safe, reliable, and affordable energy from fossil fuels. The DOE FE/NETL goal is to demonstrate second-generation technologies that can capture 90 percent of the $CO_2$ at less than $40 per metric ton (tonne) in the 2020–2025 timeframe. DOE is also committed to extend R&D support to even more advanced transformational carbon capture technologies that will increase the competitiveness of fossil-based energy systems beyond 2035.

Post-combustion $CO_2$ capture technologies are applicable to conventional pulverized coal (PC)-fired power plants, where the fuel is burned with air in a boiler to produce steam that drives a turbine generator system to produce electricity. The $CO_2$ is exhausted in the flue gas at atmospheric pressure and a concentration of 10–15 percent by volume. Post-combustion separation and capture of $CO_2$ from PC-fired plants is a challenging application due to the low driving force resulting from the low pressure and dilute concentration of $CO_2$ in the waste stream, trace impurities in the flue gas that affect removal processes, and the parasitic energy cost associated with the capture and compression of $CO_2$. Carbon capture technologies developed by the DOE program may also be applied to natural gas power plants after addressing the R&D challenges associated with the relatively low concentration of $CO_2$ in the flue gas, typically 3–4 percent, of natural gas plants. Hybrid approaches that synergistically combine individual technologies can result in cost-effective processes for $CO_2$ capture from PC-fired flue gas.

## Project Description

The Gas Technology Institute (GTI), along with its partners, will continue development of a novel nanoporous, super-hydrophobic membrane contactor process for post-combustion $CO_2$ capture from coal-fired power plants. The polyether ether ketone (PEEK) hollow fiber contactor (HFC) process will be advanced from


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## PARTNERS

PoroGen Corporation
Hitachi, Ltd.
Trimeric Corporation
Ramgen Power Systems

## PROJECT DURATION

| Start Date | End Date |
|---|---|
| 10/01/2013 | 09/30/2017 |

## COST

**Total Project Value**
$12,544,638

**DOE/Non-DOE Share**
$10,034,979/$2,509,659

## PROJECT NUMBER

FE0012829

bench-scale (research previously supported by NETL/DOE under DE-FE0004787) to pilot-scale testing. The PEEK HFC process takes advantage of both the compact nature of a membrane process and the high selectivity of an absorption process. In the new process, $CO_2$-containing flue gas passes through one side of the PEEK HFC, while an advanced $CO_2$ selective solvent flows on the other side. The $CO_2$ permeates through the hollow fiber membrane pores and is chemically absorbed into the solvent. The $CO_2$ rich solvent is regenerated in a second PEEK HFC module operated in a reverse manner. Economic analysis based on the previous bench-scale data suggests the cost ($/tonne of $CO_2$ captured) of the HFC technology is 36 percent lower than conventional amine-based technology.

In this project, pilot-scale testing will be conducted with commercial-sized 20 centimeter (cm) (8 inch) diameter modules on 1 megawatt electrical (MWe) equivalent of coal-derived flue gas. The previous bench-scale testing was conducted at a 25 kilowatt electrical equivalent scale using 10 cm (4 inch) diameter modules on coal-derived flue gas. Detailed preliminary techno-economic and environmental, health, and safety assessments (EH&S) will be performed based on results from the previous bench-scale tests. Design and construction of the 1 MWe pilot plant will be completed and the system will subsequently be installed at a testing facility. The PEEK HFC process will be tested in the pilot-scale system under continuous steady-state operation on coal-derived flue gas for a minimum of two months, and data necessary for further process scale-up will be collected. The final techno-economic analysis—based on proposed final design configuration and operating conditions when integrated into a 550 MW power plant—and an EH&S assessment will be completed.

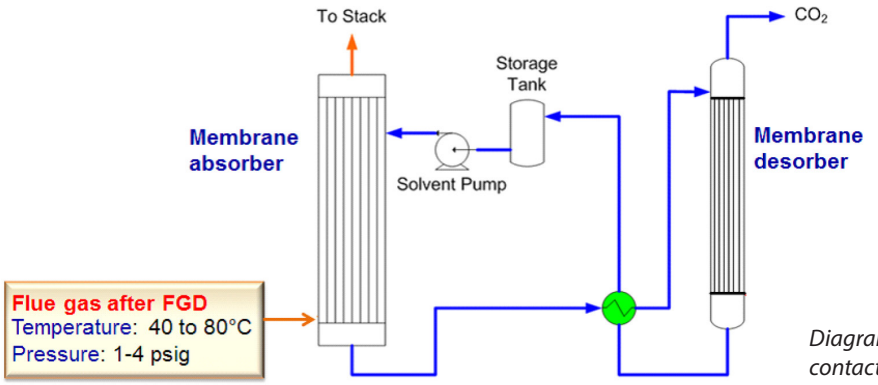


*Diagram of the membrane contactor process.*

## Primary Project Goal

The primary project goal is to continue development of the PEEK HFC process through scale-up and testing at the 1 MWe pilot scale to validate its potential toward achieving DOE's Carbon Capture performance goal of 90 percent $CO_2$ capture rate with 95 percent $CO_2$ purity at a cost of $40 per tonne of $CO_2$ captured by 2025.

## Objectives

The project objectives are to (1) build a 1 MWe equivalent pilot-scale $CO_2$ capture HFC system using PEEK hollow fibers in a membrane contactor, (2) conduct pilot-scale tests using actual flue gas, (3) test with continuous, steady-state operation for a minimum of two months, and (4) gather data necessary for further scale-up of the process.

## Planned Activities

- Complete preliminary techno-economic and EH&S analyses.
- Design the 1 MWe $CO_2$ capture system.
- Develop and fabricate 8-inch commercial-sized modules.
- Determine operating conditions for the advanced amine-based solvent in the HFC.
- Construct, transport, and install the 1 MWe test system at the pilot test site.
- Measure key performance properties through parametric pilot-scale testing.
- Optimize the solvent and modules based on pilot-scale testing results.
- Conduct continuous steady-state operation for a minimum of two months.
- Complete a final techno-economic and EH&S analyses based on the pilot test results.

## Accomplishments

Project awarded in September 2013.

## Benefits

The project will advance a PEEK HFC prototype system to the 1 MWe scale with extended-duration testing on flue gas from a utility coal-fired boiler. This technology has the potential to provide a step change reduction in the cost of capturing $CO_2$ from flue gas and is anticipated to meet DOE's performance goals for a retrofit technology for $CO_2$ captured from PC-fired power plants. In addition to enabling cost-effective capture of $CO_2$ from flue gas, the successful development of this technology will provide other broad benefits including the removal of other gas pollutants such as $NO_x$ and $SO_x$, the separation of $CO_2$ from hydrogen in refinery streams, and the separation of $CO_2$ from natural gas (natural gas sweetening).