the ENERGY lab

PROJECT FACTS

Carbon Capture

# Optimizing the Costs of Solid Sorbent-Based $CO_2$ Capture Process through Heat Integration

## Background

The mission of the U.S. Department of Energy Office of Fossil Energy's (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 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. Sorbent-based technologies, which adsorb $CO_2$ onto a solid sorbent, have the potential to effectively reduce the costs associated with post-combustion $CO_2$ capture due to lower energy penalties than aqueous systems; however, there are opportunities to further decrease the parasitic energy demand for solid-based processes and reduce the overall costs.

## Project Description

ADA-ES, teamed with Solex Thermal Science, Technip Stone and Webster Process Technologies, and the Energy Research Center at Lehigh University, will evaluate heat integration opportunities for a dry sorbent-based post-combustion system. The project is focused on reducing the overall levelized costs of electricity associated with sorbent-based $CO_2$ capture by reducing the energy penalty and limiting any increase in capital costs associated with adding equipment such as heat exchangers.

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## PARTNERS

Solex Thermal Science

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## PROJECT DURATION

| Start Date | End Date |
|---|---|
| 10/01/2013 | 12/31/2014 |

## COST

**Total Project Value**
$1,111,154

**DOE/Non-DOE Share**
$888,851/$222,303

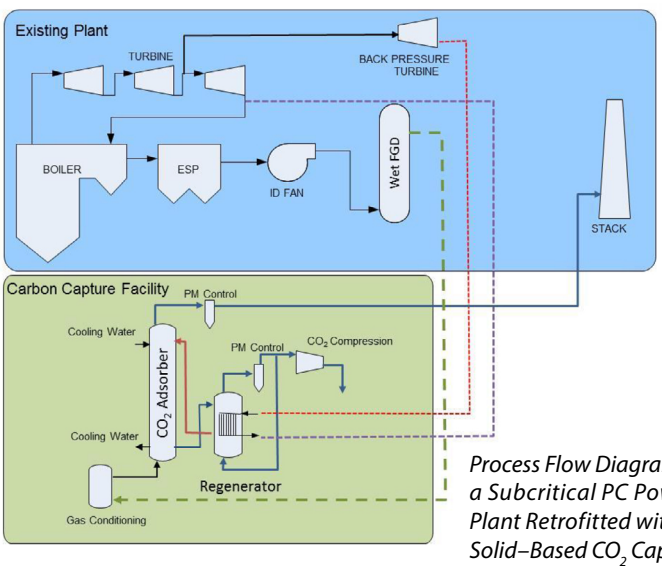
## PROJECT NUMBER

FE0012914

U.S. DEPARTMENT OF ENERGY

The project team will investigate heat recovery for a temperature-swing-adsorption (TSA) capture process, including the use of a cross heat exchanger to recover sensible heat from the sorbent leaving the regenerator. This recovered heat energy would then be added to the sorbent entering the regenerator. While cross heat exchangers are standard features of solvent-based processes, large-scale heat exchangers appropriate for solids in this application currently do not exist. Although the fundamental components for solids-based heat exchangers are commercially available, the design details and integration approach must be developed and optimized to ensure that the additional equipment capital costs do not outweigh benefits associated with reduced overall energy penalty. A key component of the project will address the technology gap of a cross heat exchanger for solids through bench-scale testing of select concepts, computational modeling, and a techno-economic assessment.

The project optimizes a promising dry sorbent-based post-combustion capture process—the ADAsorb™ process—developed by ADA-ES under another DOE-funded project (DE-FE0004343). However, the concepts will be applicable to other TSA processes. The optimization study will include a sensitivity analysis across a range of sorbent properties to identify cost and energy demand trends so that the general conclusions can be applied to most sorbent-based $CO_2$ capture processes. The model development in this project will provide the opportunity to evaluate other options for heat integration and energy savings, such as using heat from the $CO_2$ compressors to supplement the regeneration energy requirement, reducing the moisture content of the flue gas to lower heat loss from the latent heat of water vaporization, and reducing system pressure drop.




*Process Flow Diagram of a Subcritical PC Power Plant Retrofitted with a Solid–Based $CO_2$ Capture Process.*

## Primary Project Goal

The overall project goal is to advance the development of post-combustion carbon capture technologies that utilize solid sorbents by reducing the energy penalty and cost for $CO_2$ capture. This goal will facilitate progress toward meeting the DOE goal to demonstrate second-generation technologies that can capture 90 percent of the $CO_2$ at less than $40 per tonne in the 2020–2025 timeframe.

## Objectives

The project objectives are to determine how much energy can be saved through heat integration, flue gas drying, and design optimization to reduce pressure drop and improve the overall cost for $CO_2$ capture. Specific objectives are to evaluate cross heat exchangers through bench-scale testing, identify the most cost-effective configurations through computational modeling, optimize the cross heat exchanger design, perform a sensitivity analysis, and complete a techno-economic analysis.

## Planned Activities

- Conduct bench-scale testing of a heat exchanger concept with a single sorbent to collect the data required for scale-up modeling and the subsequent computational modeling.
- Perform modeling to determine the optimal operating conditions for the heat exchanger integrated into the overall $CO_2$ capture process to minimize capital and operating costs.
- Conduct process modeling to assess the viability of heat integration options, the impacts of flue gas moisture, and the design of the adsorber and regenerator to reduce pressure drop.
- Complete a techno-economic assessment of the optimized equipment and operating conditions incorporated into a 550 MWe supercritical plant, including identification of sorbent properties, to meet the DOE's $CO_2$ capture cost goals.
- Complete an environmental, health, and safety assessment.

## Accomplishments

Project awarded in September 2013.

## Benefits

Developing options to reduce the energy penalty and costs for sorbent-based temperature swing $CO_2$ capture processes, such as optimizing the ADAsorb process, have the potential to improve the economics of solids-based post-combustion carbon capture and make progress toward the DOE Carbon Capture Program cost goals. Although based on a specific $CO_2$ capture process, this project will produce general conclusions applicable to most sorbent-based $CO_2$ capture processes. In addition to lower regeneration energies, sorbents have lower environmental impacts as compared to aqueous amine processes, with negligible corrosion, decreased water usage, and decreased emission of hazardous chemicals into the air or wastewater. These benefits together can bring $CO_2$ emissions control technologies for fossil fuel-based power plants closer to realization.