Modeling and Risk Assessment of CO_2 Sequestration at the Geologic-Basin Scale

Background

Increased attention is being placed on research into technologies that capture and store carbon dioxide (CO_2). Carbon capture and storage (CCS) technologies offer great potential for reducing CO_2 emissions and, in turn, mitigating global climate change 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 specialties 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) has selected 43 projects to receive more than $12.7 million in funding, the majority of which is provided by the American Recovery and Reinvestment Act (ARRA) of 2009, to conduct geologic sequestration training and support fundamental research projects for graduate and undergraduate students throughout the United States. These projects will include such critical topics as simulation and risk assessment; monitoring, verification, and accounting (MVA); geological related analytical tools; methods to interpret geophysical models; well completion and integrity for long-term CO_2 storage; and CO_2 capture.

Project Description

NETL is partnering with the Massachusetts Institute of Technology (MIT) to develop tools to better understand and model CO_2 storage permanence in geologic formations at the geologic basin scale. This research will contribute to deploying CCS as a climate change mitigation technology at a gigatonne per year injection scale over the course of several decades. Continuous CO_2 injection of this magnitude must be understood at the geologic basin scale. The project will perform fundamental research on CO_2 migration, fate, and displaced brine at the geologic basin scale. Additionally, MIT will develop analytical sharp-interface models of the evolution of CO_2 plumes over the duration of injection (decades) and after injection (centuries).

Recently, MIT has investigated closed-form analytical solutions that account for plume shape during the injection and for regional groundwater flow. From accomplishments obtained in this past research, MIT will extend this model to include the essential physics governing plume migration: (1) induced pressure gradients, (2) capillary trapping,

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PROJECT DURATION

Start Date
12/01/2009

End Date
11/30/2012

COST

Total Project Value
$299, 045

DOE/Non-DOE Share
$299,045 / $0

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(3) buoyancy, (4) regional groundwater flow, (5) aquifer slope, (6) dissolution into the brine (due to both diffusion from residual CO_2 and convective mixing from mobile CO_2), and (7) loss through the confining unit (Figure 1).

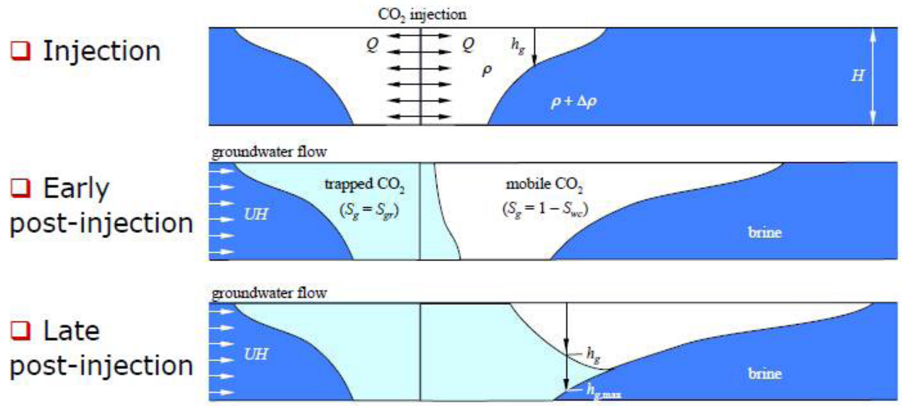

Figure 1. Conceptual model of work to be undertaken that will take into consideration the effects of: capillary and dissolution trapping; injection and post-injection periods; and the regional groundwater flow and slope of the geological formation.

MIT will apply the analytical solutions of CO_2 plume migration and pressure evolution to specific geologic basins to estimate the maximum footprint of the plume, and the maximum injection rate that can be sustained during a certain injection period without fracturing the caprock. These results will lead to more accurate capacity estimates, based on fluid flow dynamics, rather than ad hoc assumptions of an overall "efficiency factor" typically used in storage capacity estimation calculations. In addition, MIT will use risk assessment methodologies to evaluate the uncertainty in their predictions of storage capacity and leakage rates. The results of the research will be incorporated into the short course titled "Carbon Capture and Storage: Science, Technology, and Policy" offered through the MIT Professional Institute to train the present and future CCS workforce.

Goals/Objectives

The main goal of the project is to develop tools to better understand modeling and risk assessment of CO_2 storage permanence in geologic formations at the geologic basin scale. The primary project objective is to understand CCS at the gigatonne-per-year injection scale required to have an impact on the abatement of CO_2 emissions. To meet this objective, the project will develop mathematical models of capacity and injectivity at the basin scale, build quantitative risk assessment methodologies, and obtain quantitative estimates of capacity and injectivity of geologic basins across the continental United States.

Benefits

Overall the project will make a vital contribution to the scientific, technical, and institutional knowledge base needed to establish frameworks for the development of commercial-scale CCS. More specifically, the mathematical models and uncertainty quantification methodologies developed by the project will offer a physically-based approach for estimating capacity and potential leakage risk at the basin scale. The simplified model of pressure evolution will account for non-uniform injection rates and different boundary conditions of the geologic stratum. The capillary trapping model will account for the combined effect of the injection period, groundwater flow, geological formation slope, and caprock undulations. The models of CO_2 migration along layers will consider discrete events of potential leakage through the caprock, representing flow through active faults.