the ENERGY lab

PROJECT FACTS

Carbon Storage – MVA

Deep Controlled Source Electromagnetic Sensing: A Cost Effective, Long Term Tool for Sequestration Monitoring

Background

The goal of the Department of Energy's (DOE) Carbon Storage Program is to develop and advance technologies to significantly improve the effectiveness of geologic carbon storage, reduce implementation costs, and prepare for widespread commercial deployment between 2025 and 2035. Research to develop these technologies will ensure safe and permanent storage of carbon dioxide (CO_2) to reduce greenhouse gas (GHG) emissions without adversely affecting energy use or hindering economic growth.

Geologic carbon storage involves securely and permanently injecting CO_2 into onshore and offshore underground formations. Current research and field studies are focused on developing a better understanding of the science and technologies needed for safe and permanent CO_2 storage in onshore and offshore storage reservoirs, which include: clastic formations, carbonate formations, unmineable coal seams, organic-rich shales, and basalt interflow zones. DOE's Storage Program is accomplishing this through: (1) developing technologies that address technical challenges and ensure the cost effectiveness of carbon storage, (2) validating technologies that ensure safe and permanent carbon storage, and (3) facilitating public, industry, and international community awareness of research and development (R&D) efforts underway related to carbon storage. These technologies will facilitate future CO_2 management for coal-based electric power generating facilities and other industrial CO_2 emitters by enabling the safe, cost-effective, permanent geologic storage and utilization of CO_2 in all storage types.

The Carbon Storage program is comprised of three primary technology areas (1) Core Storage R&D, (2) Storage Infrastructure, and (3) Strategic Program Support. These three areas work together to address significant technical challenges in order to meet program goals that support the scale-up and widespread deployment of carbon capture and storage (CCS). Within these technology areas, emerging technologies are supported through applied laboratory- and pilot-scale research. In addition, promising technology options are being validated through small- and large-scale field projects. This approach allows technologies to develop from concept through validation in the field and increases the Nation's confidence in future safe, effective, and permanent geologic CO_2 storage. The Core Storage R&D technology area is sub-divided into three research areas: (1) Geologic Storage Technologies and Simulation and Risk Assessment (GSRA); (2) Monitoring, Verification, Accounting (MVA), and Assessment; and (3) Carbon Use and Reuse. This project is part of the MVA research area, which is designed to confirm permanent onshore and offshore CO_2 storage in geologic formations through monitoring capabilities that are reliable and cost effective. Monitoring is an important aspect of CO_2 injection, because it focuses on a number of permanence issues. Monitoring technologies are being developed for atmospheric,

CONTACTS

Traci Rodosta
Carbon Storage Technology Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-1345
traci.rodosta@netl.doe.gov

Karen Kluger
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236
412-386-6667
karen.kluger@netl.doe.gov

Douglas LaBrecque
Principal Investigator
Multi-Phase Technologies, LLC
1430 Greg St., Suite 503
Sparks, NV 89431
775-356-7844
dlabrecque@mpt3d.com

PARTNERS

Lawrence Berkeley National Laboratory

German Research Centre for Geosciences

PROJECT DURATION

Start Date	End Date
10/01/2013	09/30/2016

COST

Total Project Value

$798,074

DOE/Non-DOE Share

$623,496 / $174,578

AWARD NUMBER

DE-FE0012266

near-surface, and onshore and offshore subsurface applications to ensure that injection, abandoned, and monitoring wells are structurally sound and that CO_2 will remain within the storage complex. This project, being led by Multi-Phase Technologies, LLC, is developing and testing a geophysical sensor array for long-term monitoring of CO_2 stored in deep geologic formations using a controlled source electromagnetic method (CSEM) that is based on the electrical properties of subsurface rocks and fluids.

Project Description

This project is developing and testing a robust, cost-effective sensor array for long-term monitoring of CO_2 in deep geologic formations. The sensor array is based on a dipole borehole source and receivers, and uses CSEM to measure electrical properties (e.g., resistivity) of CO_2 storage formations. The source generally comprises a pair of widely separated electrodes used to generate current in the subsurface (referred to as a dipole) and a combination of electric and magnetic field receivers some distance away from the source. CO_2 injected into the subsurface displaces the electrically conductive pore brine fluids, resulting in an increase in resistivity. The relationship between electrical resistivity and saturation is well known, particularly in the types of highly saline aquifers present in typical oil fields or in deep aquifers suitable for long-term CO_2 storage. In addition to monitoring the CO_2 plume migration in the reservoir based on the CO_2 displacing the brine, leakage of dissolved phase CO_2 away from the primary reservoir is expected to produce an increase in resistivity through the leakage pathway.

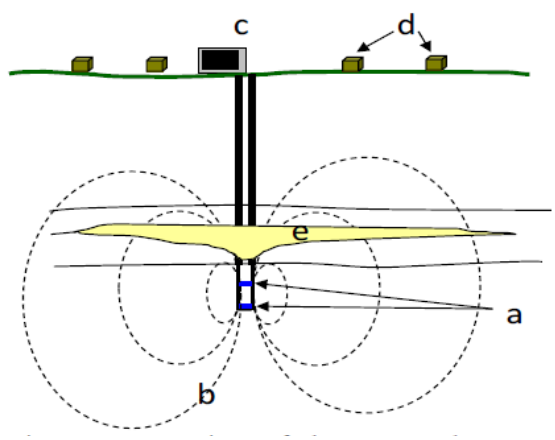

Figure 1. Overview of the proposed CSEM configuration showing (a) the borehole electrodes;(b) electric field/ current flow lines; (c) transmitter/current source; (d) mobile surface electric and magnetic field receivers; and (e) the CO_2 reservoir.

The proposed system is being designed to operate as a permanent, autonomous monitoring and data collection system capable of providing much higher temporal data density than can be economically achieved with 3-D seismic surveys. In addition, CSEM is expected to be capable of operating over broad areas for long periods to provide full 3-D monthly data sets at very low cost. This data acquisition technique is flexible enough to incorporate information from seismic surveys to construct high resolution models of CO_2 progression within reservoirs. The system uses borehole-based vertical-electric-dipole sources placed in the formation at reservoir depths (Figure 1). The electric and magnetic fields induced by this source will be received on the surface via an array of stations. The first phase of the project is to demonstrate the feasibility of the system for collecting static/reference data at the Ketzin site in Germany. Numerical modeling is being used to determine optimal configurations and requirements for sensor sensitivity and data accuracy. The existing CSEM hardware will be modified based on these requirements and field tested at the Ketzin site. Data acquired will be compared with independent estimates of the reservoir and overburden geo-electrical characteristics. The second phase of the project will demonstrate the ability of CSEM to provide sensitive, cost-effective measurements of changes in reservoir properties and overlying formations via a second round of measurements at the Ketzin site. The research team is testing a surface-based prototype autonomous recording system to collect CSEM-generated data at a subset of the subsurface measurement points. In the final phase of the project, the project team will quantify the advantages of the fully autonomous data collection subsystems by comparing them with repeated measurements made with mobile stations. The final phase will also provide an additional time point in measuring changes after cessation of CO_2 injection activities in and above the storage formation at the Ketzin site. Recommendations for implementation of the methodology at other sites will be provided in addition to a cost analyses for deployment of the system as a monitoring tool.

Objectives

The goal of this research project is to develop a technology based on deep CSEM, which could potentially provide the foundation for a cost-effective strategy to monitor storage or movement of supercritical/gas phase CO_2 and changes in dissolved phase CO_2 within underground reservoirs. Specific project objectives include:

- Development of a cost-effective sensor array for long-term monitoring of CO_2 through the use of CSEM methods with a borehole source to measure the electrical properties of CO_2 reservoirs.
  - The array will operate as a permanent, autonomous monitoring and data collection system.
  - The sensors will provide much higher temporal data density than can be economically achieved with alternative survey types.
- Demonstration of the sensor array at the Ketzin site, including baseline post site closure monitoring, survey with a simulated CO_2 release, and at least one follow-on surveys.

Accomplishments

- The CSEM hardware and software was modified for CCS based applications. The frequency domain for the transmitter and receiver, and the addition of magnetic field sensors were altered to better meet the research needs of the project. The hardware was then tested at Astor Pass, Nevada for software integrity and to evaluate the need for further modification.
- The model study showed significant changes in both electric and magnetic field responses between model scenarios and transmitter types. Measuring the magnetic field components with sufficient accuracy is challenging, particularly for long offsets and high frequencies.
- Two CSEM surveys were completed in October 2014 at Ketzin in Germany in conjunction with the GFZ Potsdam (German Research Center for Geosciences) controlled CO_2 release test. These included a pre-test and post-test survey, with survey results still being processed and validated.

Benefits

The project is making a vital contribution to the scientific, technical, and institutional knowledge base needed to establish frameworks for the development of commercial-scale CCS. In general, electrical measurements complement seismic methods. Specifically, this research will develop one component of a comprehensive system to accurately locate and monitor the target storage formation as well as verify the integrity of sealing formations and key potential leakage locations in the subsurface.

FE0012266, January 2015