the ENERGY lab

PROJECT FACTS

Carbon Storage – MVA

Scalable, Automated, Semi-permanent Seismic Method for Detecting CO_2 Plume Extent During Geological CO_2 Injection

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

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PARTNERS

None

PROJECT DURATION

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

COST

Total Project Value

$3,000,000

DOE/Non-DOE Share

$2,400,000 / $600,000

AWARD NUMBER

DE-FE0012665

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, 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 led by the Energy & Environmental Research Center is developing a scalable, semi-permanent seismic array that can be automated to perform seismic surveys for the purpose of identifying the location of the CO_2 plume in the subsurface.

Project Description

The goal of this project is to develop a proof-of-concept technology in which seismic surveying is used not to create a subsurface image, but rather to provide indications of physical changes occurring at monitored locations within the storage reservoir that signify the presence of CO_2. Currently, CO_2 plume location and extent are determined via multiple 3-D seismic surveys, which provide detailed images of the subsurface but also have drawbacks: they can be expensive, labor intensive, and experience long delays. The project team is developing an approach using the seismic method as an indicator for tracking plume position with minimal expense and delay. A scalable, automated, semi-permanent seismic array (SASSA) is being developed and deployed at the Bell Creek combined CO_2 enhanced oil recovery and CO_2 storage project site in Montana, which will provide a unique and ideal opportunity to research and evaluate the technical viability and cost-effectiveness of SASSA at an active, large-scale site. SASSA is based on one or more downhole seismic sources that periodically fire into a sparse array of autonomous surface receivers (Figure 1 [receivers] and Figure 2 [setup]) and a string of permanently installed geophones downhole in a wellbore (Figure 2). The surface array is designed so that a coarse, regular grid of reflection points sample the surface overlying the reservoir/storage formation. As the CO_2 plume moves through the formation, detectable character changes that occur are reflected from the reservoir, providing a means of determining when the CO_2 plume moves past monitored reflection points. The physical basis of this method involves a pressure increase at a known location within the storage formation, which is expected to cause an increase in the seismic reflection coefficient, resulting in a higher-amplitude reflection from the storage formation at that location. A CO_2 plume, because of gas saturation, would result in a high reverse-polarity reflection coefficient and, therefore, a high-amplitude reversed reflection at the reservoir. The downhole sources provide a consistent signal from fixed locations and can be remotely operated. Several individual shot records can be stacked to improve the signal-to-noise ratio. Data can also be acquired regularly, so that a time-lapse survey is created.

Figure 1. Surface receiver unit to be deployed as part of the SASSA package. The surface receiver gathers seismic reflection data from the source instrumentation located in the subsurface.

The proposed semi-permanent receiver array consists of shallowly buried three-component geophones connected to autonomous battery-powered seismic recorders. Because each unit is autonomous there are no wires stretched between them, thus providing a minimal environmental footprint and greater flexibility in deploying, removing, and servicing them. The results of SASSA will be compared to traditional baseline and repeat 3-D surface seismic surveys and 3-D vertical seismic profiles that are being acquired at the Bell Creek site. This comparison between the proposed system and traditional seismic acquisition methods will allow for a cost–benefit analysis, validation of the concept, and will advance the science of seismic monitoring for CO_2 storage projects.

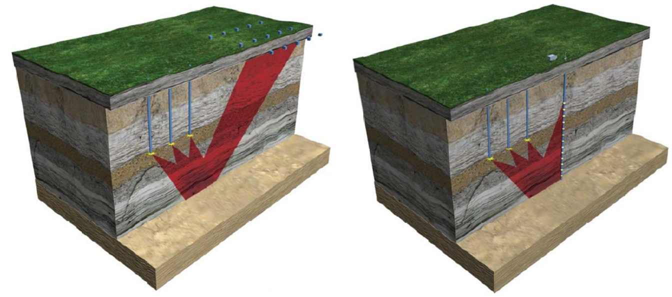

Figure 2. Three-component, autonomous, near-surface receiver array setup (left), and permanently installed downhole receiver array (right).

Objectives

The objectives of this project are to understand and evaluate novel methods for scalable, semi-permanent seismic deployments that can be automated to show where and when a pressure front or CO_2 plume passes a particular subsurface location. Specific technical objectives of the project include:

- Demonstrating that a sparse array of carefully placed surface receivers paired with a remotely controlled source can detect a passing CO_2 plume using minimally processed time-lapse shot records.
- Evaluating the use of reflection points gathered by other seismic data collection and processing operations being used at the Bell Creek site that is redundant with the borehole array as a check. (The borehole array has finer spatial coverage between one injector-receiver pair.)
- If a change is detected, checking that the borehole array results match the reservoir modeling results and predicting when the next furthest receiver will be affected.
- Evaluating other potential uses for the SASSA system.

Accomplishments

- The project team has procured seismic processing software (RadExPro) as part of the SASSA operational system. The project team has also investigated purchase and lease options for surface acoustic receiver units, and identified potential modeling software suites that would be appropriate for the research effort.
- Preliminary modeling of downhole sources with a permanent vertical receiver array has been initiated. A 1-D velocity model was created from a nearby monitoring well, 05-06 OW. A notional source location was modeled to provide an offset to vertical seismic profile (VSP) geometry between injector and receiver given the current field injector-producer patterns and geologic dip in the study area.
- Preliminary modeling of downhole sources with a semi-permanent surface receiver array was also initiated. The model gauged whether 64 surface receiver units were sufficient within a likely source location range and determining order of magnitude of the needed source range.

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. The development and evaluation of an SASSA system at commercial-scale CCS operations would represent a significant step for CCS operators by making technologies available that can increase the accuracy and cost-effectiveness of existing MVA programs and reduce the long-term monitoring costs associated with them. High-frequency near-real-time monitoring of the SASSA system provides a means of quickly identifying deviations from the predicted injection response. Rapid identification of deviations, anomalies, or out-of-zone fluid migrations enables operational parameters to be modified and/or mitigation strategies deployed, reducing uncertainty in MVA programs when compared to conventional programs.

FE0012665, January 2015