

2014 Legislative Report for WY-CUSP:

Characterization of the premier storage reservoirs and geological CO₂ storage site in Wyoming

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The Wyoming Carbon Underground Storage Project (WY-CUSP), funded by the U.S. Department of Energy/National Energy Technology Laboratory, award number DE-FE0002142 and the State of Wyoming, ended in December 2013: final reclamation of the well site was completed in June 2014. The five-year project met its primary objective of providing the state of Wyoming with a characterized storage site. This project has thoroughly characterized two suitable saline reservoirs, the uncertainties regarding long-term geologic containment, as well as designed a pressure management/fluid treatment program and facility on the Rock Springs Uplift (RSU)—the study site. Meeting the project's objectives was necessary for assessing the following crucial aspects of the potential storage site: (1) accurately estimate CO₂ storage capacity, (2) evaluate long-term integrity and permanence of the confining layers in the advent of injection, (3) safely manage injection pressures and brine production, and (4) integrate CO₂ utilization into carbon storage strategies. Meeting these objectives required conducting a 3-D seismic survey, drilling a stratigraphic test well, obtaining core from seals and reservoirs, obtaining various well log suites, in-situ well testing, numerical simulation, modeling, and data analysis.

Fieldwork

Prior to fieldwork, potential storage sites and reservoirs in Wyoming were inventoried and prioritized on the basis of existing data. This work identified the RSU as the best potential study site for meeting the projects goals. Fieldwork began by shooting a 5mi x 5mi 3-D seismic survey on the northeastern flank of the RSU. The data was re-processed to remove acquisition footprints and provide a concise 3-D image. Working with Baker Hughes, Inc., a stratigraphic test well was drilled to a total depth of 12,800 feet. Approximately 916 feet of core was acquired from targeted strata. Various log suites, vertical seismic profiles (VSP) survey, drill stem test (DST), injection tests, and additional rock samples were also obtained. Reservoir fluids were collected on two occasions, and some were collected at depth in state-of-the-art pressure cylinders. Digital geophones were placed at 3 different seal horizons to create a baseline for the microseismic activity. When fieldwork was completed, the well was plugged and abandoned and the study site was reclaimed to meet DEQ's environmental standards.

Analysis, computation, and modeling

Data from the 3-D seismic survey was used to create initial seismic attribute volumes. Those volumes, combined with early observations from the stratigraphic test well, were used to prepare preliminary CO₂ injection numerical simulations. As new data was acquired, the simulations were improved and uncertainties reduced.

Realistic 3-D geological petrophysical property models of targeted storage reservoirs and confining layers were constructed by combining lithofacies/petrophysical analyses with seismic attribute computations and mapping (calibrated with laboratory measurements, sonic and log porosity, acoustic impedance and density porosity). The procedure allowed petrophysical properties to be extrapolated away from the stratigraphic test well into the 3-D seismic volume.

The integrated 3-D property models (porosity, permeability, and lithofacies models, especially petrophysical heterogeneity of reservoir intervals) were exported to numerical simulations for performance assessments. A diverse set of CO₂ injection/storage scenarios was evaluated to determine the optimum CO₂ storage capacity for the target storage reservoir and the regional storage domain. The reservoir storage capacity for the Weber and Madison formations on the RSU was initially estimated at 26 Gt using the diagnostic protocol suggested by the DOE for the FutureGen project. In contrast, using actual stratigraphic well data and the techniques developed during this project by the WY-CUSP team, the storage capacity of those formations was more accurately estimated at 14 Gt to 17 Gt. Results from the collected data, rock/fluid analyses, and the 3-D models demonstrated that the confining layers in the stratigraphic interval containing the Paleozoic reservoir rocks are characterized by integrity and permanence at the study site.

Early on in the project it was evident that pressure management in the form of formation fluid removal (production/treatment) would be essential in any injection/storage scenario envisioned for the RSU. Without brine production during CO₂ injection/storage, performance assessments all suggested that reservoir pressures would exceed fracture pressures, or that brines would migrate outside the boundaries of the storage domain. A brine production/treatment strategy was designed to avoid such migration, as well as to utilize the elevated temperature and pressure to power the treatment of brine and to recover potable water and metals.

As part of this project, Wyoming's CO₂ sources and potential CO₂ utilization project areas were identified. This information was used to design multiple, integrative resource development plans, including CO₂ storage as synergistic systems that increase efficiency of development, minimize environmental footprints, and sustain and stabilize long-term resource utilization.

Conclusions/Benefit to the State

The goals of the WY-CUSP program were to improve estimates of geological CO₂ reservoir storage capacity, to evaluate the long-term integrity and permanence of confining layers, and to manage injection pressure and produced brine at the RSU CO₂ storage site. In the process of achieving these goals, new and improved strategies and technologies have been developed to achieve the most accurate performance assessments and resultant risk reductions for detailed geologic CO₂ storage site characterization. The ultimate mission of the WY-CUSP program, managed by the University of Wyoming Carbon Management Institute (CMI) (including collaborators at the University of Wyoming, the Wyoming State Geological Survey, Los Alamos National Laboratory, Idaho National Laboratory (INL), Sandia National Laboratory, Schlumberger, and Baker Hughes) — delivery of a certified commercial CO₂ storage site in Wyoming that could be used as a surge tank for CO₂ utilization — has been accomplished.

The data gathered during this project has spurred additional advanced scientific research projects in areas such as geomechanics, fluid flow dynamics, and water-rock reactions. For instance, the rock core is currently being sampled to assist with the completion of a new \$1.5M University of Wyoming/DOE project; collaboration has begun to feature the 3-D data in the Shell 3-D Visualization Center housed in the School of Energy Resources (SER) Energy Innovation Center; INL researchers are using the brine data to extrapolate new rare earth elements (REEs) exploration methodology; and interpretations and analyses are being used in collaboration with existing Wyoming/China EOR/CCUS/gas storage projects. The results of the WY-CUSP CO₂ storage site characterization program have produced numerous scientific articles, presentations at professional meetings, a book titled “Geological CO₂ Storage Characterization: The Key to Deploying Clean Fossil Energy Technology”, and supported multiple Master and PhD degrees as well as partnerships and potential future collaborations. The WY-CUSP program has brought UW, CMI, and SER to the forefront of geological CO₂ storage research and also international recognition as leaders in carbon management.

In the process of completing this project, the WY-CUSP team has compiled all the information needed for permitting either a small-scale CO₂ injection/storage demonstration, or a full-scale commercial geological CO₂ storage project. Most importantly, the research has strived to describe the necessary methods used in approaching and solving the obstacles faced in achieving a detailed, geologic characterization of a potential geological CO₂ storage site. We offer the WY-CUSP experience for the benefit of all others and hope it helps their endeavors.

Notable detailed results from this study include:

- A database that significantly increases the understanding for two of Wyoming's most important hydrocarbon reservoirs, therein substantially reducing the uncertainty for all dynamic models of Weber/Tensleep and Madison fluid-flow and rock fluid systems.
- A novel technique to correct for geologic heterogeneity in storage capacity calculations, as well as new seismic velocity models to more accurately delineate porosity distribution, both of which strongly increase the descriptive characterization of the reservoir and substantially reduce the uncertainties of the CO₂ storage performance assessments.
- The identification of pressure management needs relative to injectivity in Wyoming basins. It is proposed that brine displacement be allowed and controlled by production at the land surface through production wells on the perimeter of the storage site. The average ratio of the amount (tonnage) of displaced brine to injected CO₂ is 1.14 at the study site.
- A detailed analysis of core from targeted reservoirs and seals that allowed researchers to fully characterize the lithology, mineralogy, depositional history, porosity, diagenetic episodes and analogs, displacement pressures, and the burial and geochemical history of the study site. These data and techniques can be successfully extrapolated to similar formations in Rocky Mountain basins.
- A defined thermal evolution of the study area relative to the Greater Green River Basin; this has been used to evaluate the timing and evolution of hydrocarbon production as well as potential flow paths.
- An ideal case study for addressing storage challenges associated with deep saline reservoirs; most CCUS projects utilized younger, shallower reservoirs
- A new, theoretical modeling approach for applicable reservoir characterization (i.e. deep, old, basinal) for high-resolution fluid flow modeling and assessment of uncertainties relative to geologic heterogeneity.
- The identification of primary stress orientations and natural fractures systems analogous to other Laramide regional folds. This has allowed researchers to determine natural fracture pathways and the potential for enhanced fluid flow during injectivity.
- The identification of slightly under-pressured reservoir systems at the study site indicating lower probabilities of meteoric recharge or hydrocarbon charging.
- Reservoir specific geochemical models that evaluate complex mineral reactions within the injection zones in the presence of multiple fluid phases, also applicable to other EOR assets in these reservoirs.

Carbon storage is vital to protecting the coal extraction industry in Wyoming, particularly as it provides a pathway for allowing the coal-fired power-generating sector of our economy to meet pending and future regulations. However, to view CO₂ storage and the WY-CUSP program solely in the context of that benefit misses the very broad context in which CO₂ storage would function: essentially, CO₂ storage could be the keystone of Wyoming's energy and water development in the twenty-first century. To sequester CO₂ from the atmosphere, to carry out the efficient recovery of stranded oil, to capture CO₂ emissions from a major coal-to-chemicals industry, to efficiently accommodate widely fluctuating natural gas demand, to supply an additional water source: all revolve around integrative management of CO₂. Consequently, we suggest that our most productive strategy rests on adopting a proactive approach to CO₂ storage and working to create a certified commercial CO₂ storage site in Wyoming.