

FACTSHEET FOR PARTNERSHIP FIELD VALIDATION TEST (Rev. 9-28-09)

Partnership Name	West Coast Regional Carbon Sequestration Partnership (WESTCARB)		
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Field Test Information: Field Test Name	Arizona Utilities CO ₂ Storage Pilot Test		
Test Location	Northeastern Arizona		
Amount and Source of CO ₂	Tons: 2000	Source: Manufactured (i.e., commercial)	
Field Test Partners (Primary Sponsors)	Arizona Electric Power Cooperative, Arizona Public Service Company, Peabody Energy, Salt River Project, Tucson Electric Power Company		
Summary of Field Test Site and Operations:			
<p>The Arizona Utilities CO₂ Storage Pilot Project was organized into three phases:</p> <ul style="list-style-type: none"> <p>Phase I. Pre-pilot planning, geologic characterization, and public outreach. The objective of Phase I was to develop a better understanding of the geologic and hydrologic characteristics of saline formations in the Colorado Plateau region of northeast Arizona and to build support for a CO₂ storage pilot test among the surrounding communities. The scope of work for Phase I consisted of reviewing available data on the area's sedimentary rock formations and groundwater salinity, identifying and screening candidate sites for CO₂ storage projects, and reviewing regional data to confirm expectations of the large CO₂ storage potential of the Colorado Plateau in Arizona. WESTCARB and Arizona utility representatives then met with community leaders, local businesses, citizens, news media, and other interested stakeholders to provide project information and to gather feedback and gain support for the project. NEPA documentation for the project was developed and submitted.</p> <p>Phase II. Site characterization, detailed pilot project planning, permitting, well drilling, and testing. The objective of Phase II is to obtain the necessary permits and to drill a well to collect preliminary site-specific data to determine if the site is suitable for CO₂ injection. To accomplish this, WESTCARB researchers analyzed data from nearby boreholes and associated water samples, developed hydrogeologic models and conducted computer simulations of CO₂ injection, formulated a field test plan, developed a well drilling plan and casing design, engaged regulators regarding CO₂ sequestration, prepared and submitted permit applications for drilling and CO₂ injection, drilled a well to a depth of approximately 3800 feet--through the target reservoir formations (Naco and Martin), extracted formation fluid samples to ascertain salinity, conducted well logs and drill stem tests to estimate porosity and permeability, and held meetings with nearby communities. Figure 1 shows the observed geologic column as determined by drilling at the test site. Researchers found very saline waters and good seal formations, as expected. If drill stem tests and logging had demonstrated that the target storage</p> 			

formations had sufficient permeability, the project would have proceeded to Phase III at this site.

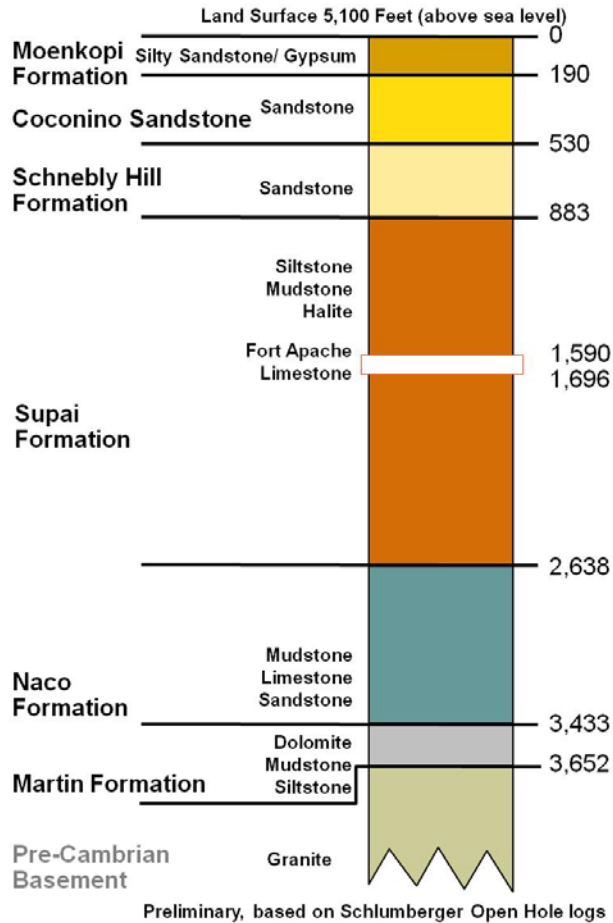


Figure 1. Schematic showing observed subsurface lithology in the test well near the Cholla power plant, west of Holbrook, Arizona. The Devonian age Martin Formation was the target storage formation, but it was found to have insufficient permeability at this location.

- Phase III. CO₂ injection, monitoring, and storage assessment.** The objective of Phase III is to procure and safely inject approximately 2000 tons of CO₂ into a target saline formation and to use monitoring tools to “see” the location of the injected CO₂, measure any water chemistry changes in the reservoir formation, and ensure compliance with environmental and health and safety requirements. Figure 2 shows a schematic of a vertical seismic profile (VSP) survey, which will be performed before and after CO₂ injection to image the CO₂ location. After completing the injection, researchers may attempt to produce the CO₂ back out of the well, which would provide additional data on subsurface behavior. The capacity of the storage formations will be assessed relative to the size of regional sources of CO₂ in northeastern Arizona. Dialogue with nearby communities will continue throughout Phase III.

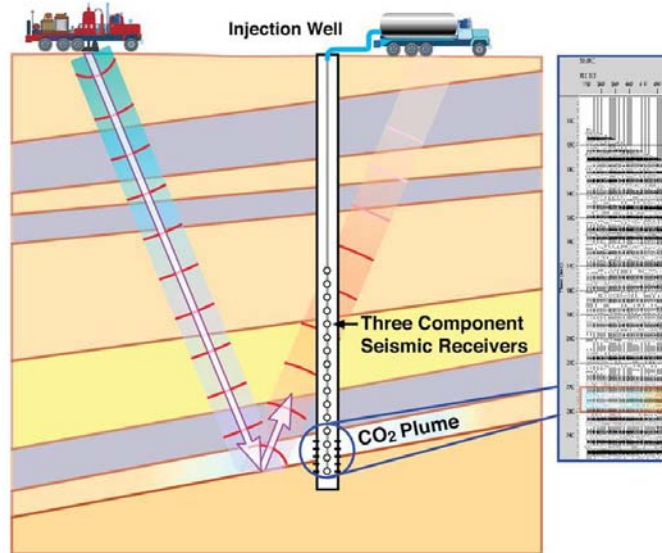


Figure 2. Schematic showing the single-well test design and vertical seismic profile survey method for tracking the location of injected CO₂. Additional CO₂ monitoring techniques are described in Table 1.

Research Objectives:

The Arizona Utilities CO₂ Storage Pilot is part of a broader North American research effort to validate scientists’ consensus opinion that geologic carbon sequestration can mitigate adverse climate change impacts by safely and permanently keeping CO₂—a greenhouse gas—away from the atmosphere. In addition, the Arizona Utilities CO₂ Storage Pilot has three specific objectives:

1. Demonstrate the safety and feasibility of CO₂ injection and storage in saline formations in the vast Colorado Plateau region of northeastern Arizona
2. Demonstrate and test methods for monitoring CO₂ storage projects in consolidated sandstone, shale, and carbonate fields
3. Gain experience with regulatory permitting and public outreach associated with geologic storage of CO₂ in a saline formation in Arizona

This pilot will investigate CO₂ storage in saline formations in the Colorado Plateau region in northeastern Arizona, which underlies four coal-fired power plants: Navajo, Coronado, and Springerville, which are operated by Salt River Project, and Cholla, which is operated by Arizona Public Service Company (APS). The magnitude of the annual CO₂ emissions in this area, the large storage potential of the saline formations of the Colorado Plateau (as well as the Black Mesa Basin), and the high degree of interest by local utility operators make this an outstanding opportunity for assessing geologic storage options associated with large sources of CO₂ in the western United States.

Summary of Modeling and Simulation Efforts:

Preliminary computer simulations were conducted by Lawrence Berkeley National Laboratory (LBNL) using TOUGH2/EOS7C to estimate the size, shape, and location of CO₂ following injection of 2000 tons into the target formation, and any pressure increase in formation fluids

associated with the injection. For a set of assumptions that “bounded” expected results, simulations for the Cholla site suggested:

- If permeability is high and uniform in the reservoir formation, the injected CO₂ could rise up to 180 feet above the injection location (approximately 3500 feet deep), but would likely stabilize before reaching the Supai Formation, the seal.
- If horizontal permeability is high and vertical permeability is low, the injected CO₂ might extend 250 feet horizontally from the well before stabilizing. To allow for a margin of error, a value of 400 feet was used in the permit application.
- With injection pressure at the well controlled to prevent fracture of the reservoir formation, the maximum pressure increase at a distance of 400 feet from the well was modeled to be just 2.2% above the background pressure.

Upon identification of one or more alternate sites by the project team, LBNL researchers will revise their geologic models and run new simulations of CO₂ injection in Colorado Plateau saline formations.

A comprehensive set of hydrologic and geophysical monitoring techniques was evaluated in the process of selecting those for use in the project. The subsurface and surface measurements listed in Table 1 is believed to be the most effective set for meeting the objectives of the pilot project.

Table 1. Measurement Technologies Proposed for the Arizona Utilities CO₂ Storage Pilot

Measurement technique	Measurement parameters	Application
Injection and flowback of CO ₂ Fluid sampling before, during, and after CO ₂ injection with a U-tube system Use of tracers in CO ₂	CO ₂ dissolved in formation brine Brine salinity, alkalinity, pH, and chemical composition	Estimate residual saturation (capillary) trapping Quantifying CO ₂ -water-rock interactions, solubility, and mineral trapping
Subsurface pressure	Reservoir pressure Annulus pressure in injection well	Control of formation pressure below fracture gradient Wellbore and injection tubing condition
Well logs	Gamma, SP, resistivity Brine salinity Sonic velocity Reservoir saturation tool (RST) before and after CO ₂ injection	Lithology Tracking CO ₂ movement in and above storage formation Tracking migration of brine if it reaches shallow aquifers Calibrating seismic velocities for VSP surveys
Time-lapse vertical seismic profiling	P and S wave velocity Reflection horizons Seismic amplitude attenuation	Detecting distribution of CO ₂ in the storage formation

Accomplishments to Date:

Progress on the pilot project proceeded according to plan through downhole testing at the Cholla site. In particular, the following activities were accomplished:

- Five industry partners—Salt River Project, Arizona Public Service, Tucson Electric Power, Arizona Electric Power Cooperative, and Peabody Energy—joined together to pledge more than \$1.1 million in financial support for the WESTCARB pilot project.

- WESTCARB engaged experienced Arizona geologists to assist with site selection and characterization. Favorable geology with saline formation waters was identified near Holbrook, Arizona. APS offered host the pilot test on its property just west of Holbrook, near the Cholla power plant.
- Public meetings were held in Holbrook, Arizona, in August 2007 and November 2008 to inform the community of the proposed project and invite their questions and involvement.
- Business and community leaders in the greater Holbrook area embraced the pilot concept and were supportive of the project. The Navajo County Board of Supervisors and North Arizona Council of Governments both issued statements of endorsement.
- The project team identified all necessary state and federal permits for well drilling and CO₂ injection, and the site owner, APS, secured the permits from the responsible agencies.
- WESTCARB received NEPA clearance for the project from DOE's NEPA Examiner.
- APS prepared the site for field activities by grading access roads and a drilling pad area, running power lines to the site, and establishing work procedures to assure safety and environmental protection.
- WESTCARB's technical project site manager oversaw drilling of a 3800-foot oil and gas type well at the site along with associated mudlogging analyses, wireline logging, core sample collection, and drill stem tests (of formation permeability).

Summarize Target Sink Storage Opportunities and Benefits to the Region:

Four coal-fired power plants in the Colorado Plateau region of Arizona generate about 40 million tons of CO₂ each year. Growing electricity demand could result in the development of new generating units and additional sources of CO₂. The geologic setting of northeastern Arizona provides thick (up to 10,000 feet) sedimentary sequences with simple, near-horizontal stratigraphy and few faults. Multiple candidate storage reservoirs and overlying seal units exist in the area. This project will assess the CO₂ storage potential for high-salinity sandstone and/or carbonate formations representative of the northeastern Arizona region.

Cost:

Total Field Project Cost: \$5,686,856

DOE Share: \$ 4,579,470 (80.5%)

Non-DOE Share: \$1,107,386 (19.5%)

Field Project Key Dates:

Receipt of Permits: 11/08 to 3/09

Drilling at Cholla Site: 7/09 to 8/09

Testing and Data Analysis at Cholla: 8/09 to 9/09

Alternate Site/Characterization Program Selection: 9/09 to 11/09

Permit Resubmittal, CO₂ Injection, and MMV: TBD