the ENERGY lab

PROJECT FACTS

Carbon Sequestration

Southeast Regional Carbon Sequestration Partnership—Development Phase

Background

As part of a comprehensive effort to assess options to reduce greenhouse gas emissions, and to concurrently use fossil fuels, the U.S. Department of Energy has selected seven regional partnerships, through its Regional Carbon Sequestration Partnership (RCSP) initiative, to determine the best approaches for capturing and permanently storing carbon dioxide (CO_2). CO_2 is a greenhouse gas (GHG) which can contribute to global climate change. The partnerships are made up of state agencies, universities, private companies, national laboratories, and nonprofit organizations that form the core of a nationwide network helping to establish the most suitable technologies, regulations, and infrastructure needs for carbon sequestration. Altogether, the RCSPs include more than 500 organizations (up from 350 in the previous Field Validation Phase), spanning 43 states, two Indian Nations and four Canadian provinces.

The RCSP initiative is implemented in three phases. The Characterization Phase began in September 2003, with the seven partnerships working to identify sources and to assess suitable locations for CO_2 storage. In June 2005, work transitioned to the Validation Phase, a four-year effort focused on validating promising CO_2 sequestration opportunities through a series of small-scale field tests in the seven regions. Presently, activities in the Development Phase (2008-2017) are proceeding as an extension of the work completed to date and will demonstrate that CO_2 capture, transportation, injection, and storage can be achieved safely, permanently, and economically at a large scale. These tests will promote understanding of injectivity, capacity, and containment of CO_2 in the various geologic formations identified by the partnerships. Results and assessments from these efforts will help in the commercialization efforts for future sequestration projects in North America.

The Southeast Regional Carbon Sequestration Partnership (SECARB), led by the Southern States Energy Board (SSEB), represents the 11 southeastern states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia, and counties in Kentucky and West Virginia. SECARB is comprised of more than 100 partners and stakeholders. The partnership estimates that 31 percent of the Nation's CO_2 stationary source emissions come from the SECARB region. SECARB's deep saline formations offer significant safe and permanent storage capacity for these emissions. Moreover, SECARB, along with the other RCSPs, continues to develop best practices to support the wide-scale transfer and advancement of information and technology derived from its projects.

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PARTNERS AND STAKEHOLDERS

Advanced Resources International
AGL Resources
Alabama Oil & Gas Board
Alawest
Alpha Natural Resources
American Coalition for Clean Coal Energy
American Electric Power
Amvest Gas Resources
Applied Geo Technologies
ARCADIS
Arch Coal
Arkansas Oil and Gas Commission
Association of American Railroads
Augusta Systems, Incorporated
Baker Hughes Incoporated

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U.S. DEPARTMENT OF ENERGY

PARTNERS AND STAKEHOLDERS (cont.)

Big Rivers Electric Corporation
Blue Source
BP America
Buchanan Energy Company of Virginia, LLC
Buckhorn Coal Company
CDX Gas, LLC
CEMEX
ChevronTexaco Corporation
Clean Coal Technology Foundation of Texas
Clean Energy Systems, Inc.
Clemson University
CO_2 Capture Project
Composite Technology Corporation
CONSOL Energy, Inc.
Core Laboratories
CSX Gas
Dart Oil & Gas Corporation
Denbury Resources, Inc.
Dominion
Duke Energy
Eastern Coal Council
Edison Electric Institute
Electric Power Research Institute (EPRI)
Entergy Services, Inc.
Equitable Resources
Exxon Mobile
Florida Municipal Electric Association
Florida Power & Light Company
Geological Survey of Alabama
GeoMet, Inc.
Georgia Environmental Facilities Authority
Georgia Forestry Commission
Georgia Power Company
Halliburton
Integrated Utility Services, Inc.
International Coal Group
Interstate Oil and Gas Compact Commission
Kentucky Geological Survey
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Louisiana Department of Environmental Quality
Louisiana Geological Survey
Marshall Miller & Associates
Massachusetts Institute of Technology
McJunkin Appalachian Oil Field Supply Company
Mississippi Power Company
Mississippi State University
National Coal Council
National Mining Association
Natural Resource Partners

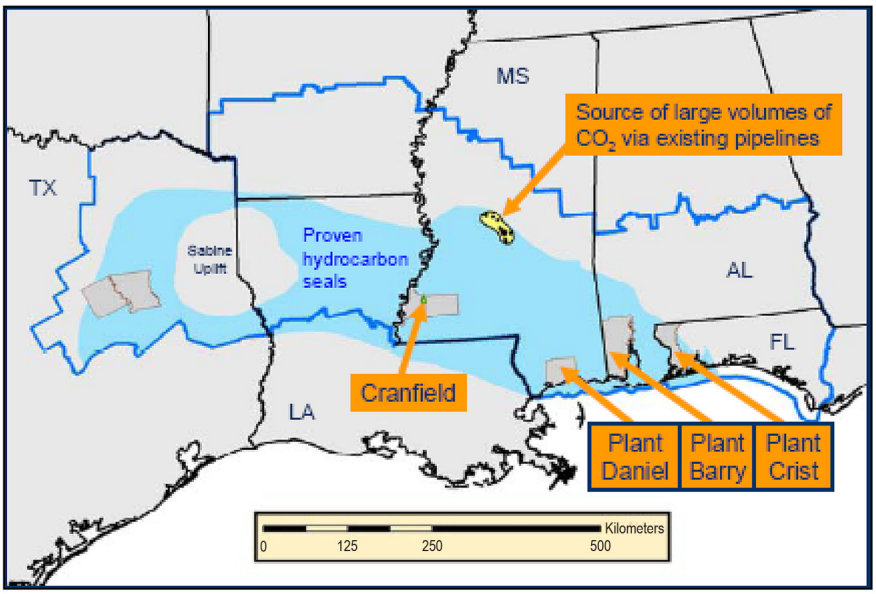
Project Description

Project Summary

SECARB is conducting a two-step, large-volume injection test in the lower Tuscaloosa Formation and Paluxy Formation, a key component of a larger, regional group of similar formations, called the Gulf Coast Wedge. The first step, or "Early Test," began to inject 1.5 million metric tons (1.65 million tons) of CO_2 per year into the lower Tuscaloosa Formation. The Early Test began in October 2009 and is scheduled to continue injection for 18 months. The CO_2 comes from a naturally occurring source. The second step, or "Anthropogenic Test," will inject 125,000 to 150,000 metric tons (137,500 to 165,000 tons) of CO_2 per year for four years into the Paluxy Formation at a different site. The CO_2 will be supplied by a pilot unit capturing CO_2 from flue gas produced from a Southern Company power plant located near the injection site.

Injection Site Description

The Early Test is focused on the down dip "water leg" of the Cranfield Unit, operated by Denbury Resources, Inc. in Adams and Franklin Counties, Mississippi, about 15 miles east of Natchez, Mississippi, and one and one-half miles north of Cranfield. The area selected for the Early Test is immediately north of SECARB's Validation Phase "Stacked Storage" study underway in the oil rim field. The Anthropogenic Test will be conducted approximately 10 miles northwest of Southern Company's Plant Barry in a saline formation within the Citronelle Oilfield in Mobile County, Alabama. CO_2 would be transported to the Citronelle Field from a capture unit located at Plant Barry via a pipeline that Denbury Resources has proposed for construction.



Geographic Location of SECARB's Development Phase Activities

Description of Geology

The lower Tuscaloosa Formation is one of the named stacked sandstone formations of the Gulf Coast Wedge. It is a Cretaceous-age, sandstone saline formation that occurs in the subsurface along the Gulf of Mexico Coastal Plain from western Florida to Texas (where it is defined as the Woodbine Formation). The Tuscaloosa Formation contains an upper section of alternating shales and

sands and a basal section, the Massive Sand Unit, which contains a thick layer of clean, coarse-grained sand. The formation was deposited during a major period of global sea level rise, and its deposition has been interpreted as an upward gradation from fluvial and deltaic sedimentation (the Massive Sand) to shelf deposition (alternating sands and shales). The Massive Sand was deposited in a wave-dominated, shallow coastal barrier environment. The well-sorted, clean, coarse-grained nature of the Massive Sand, a result of this environment, makes it an ideal candidate for CO_2 injection due to its high permeability and porosity. As the sea level continued to rise, the shelf depositional environment gave way to a deep marine environment, during which the overlying middle (Marine) Tuscaloosa Formation was deposited. This formation consists of about 500 feet (152 meters) of low-permeability shale, providing an excellent caprock and primary seal for CO_2 injection into the lower Tuscaloosa Formation.

System	Series	Stratigraphic Unit	Sub-Units	Hydrology
Tertiary	Miocene	Misc. Miocene Units	Pascagoula Fm.	Freshwater Aquifers
			Hattiesburg Fm.	
			Catahoula Fm.	
	Oligocene	Vicksburg		Saline Reservoir
			Red Bluff Fm.	Minor confining unit
	Eocene	Jackson		Saline Reservoir
		Claiborne		Saline Reservoir
		Wilcox		Saline Reservoir
	Paleocene	Midway Shale		Confining unit
Cretaceous	Upper	Selma Chalk	Navarro Fm.	Confining unit
			Taylor Fm.	
		Eutaw	Austin Fm.	Confining unit
			Eagle Ford Fm.	Saline Reservoir
		Tuscaloosa Group	Upper Tusc.	Minor Reservoir
			Marine Tusc.	Confining unit
			Lower Tusc.	Saline Reservoir
	Lower	Washita – Fredrickburg	Dantzler Fm.	Saline Reservoir
			"Limestone Unit"	

General Southeastern Mississippi Stratigraphic Column

Shale also characterizes the lower portion of the Tuscaloosa Formation acting as a barrier to the vertical migration of substrates. Deposition that occurred during the early Cretaceous Period was based on a cycle of marine and delta sedimentation and deposition. The high porosity and permeability of the sandstones in the region are due to the cycles of deposition throughout time. An oceanic retreat deposited the target of SECARB's Proposed Anthropogenic Project, the Paluxy Formation. Following this deposition was another marine transgression, which deposited the shales, limestones, and sandstones that are known as the Washita-Fredericksburg Shale. This shale would be the primary

PARTNERS AND STAKEHOLDERS (cont.)

Norfolk Southern
North American Coal Corporation
North Carolina State Energy Office
Nuclear Energy Institute
Oak Ridge National Laboratory
Old Dominion Electric Cooperative
Peabody Energy
Penn Virginia Corporation
Phillips Group, The
Pine Mountain Oil & Gas, Inc.
Pocahontas Land Corporation
Powell River Project
Praxair
Progress Energy
QEA, LLC
Rentech, Inc.
RMB Earth Science Consultants
RMS Strategies
SCANA Energy
Schlumberger
Shell Oil Company
Smith Energy
South Carolina Department of Agriculture
South Carolina Electric & Gas Company
South Carolina Public Service Authority/Santee Cooper
Southern Company
Southern Natural Gas/El Paso
Southern States Energy Board
Susan Rice and Associates, Inc.
Tampa Electric Company
Tennessee Valley Authority
Texas Bureau of Economic Geology
TXU Corporation (Luminant Energy)
United Company, The
University of Alabama
University of British Columbia
Virginia Center for Coal and Energy Research
Virginia Department of Mines, Minerals and Enegy
Walden Consulting
Winrock International

COST

Total Project Value
$93,689,241

DOE/Non-DOE Share
$64,949,078 / $28,740,163

confining seal for carbon dioxide sequestered in the Paluxy Formation. The porosity of the formation is believed to have an average of 23% and a permeability of 130 millidarcies. Specific measurements of the Paluxy Formation at the Citronelle Dome are not available, but estimates have been made based on the logs of two wells that are approximately four miles from the site of SECARB's Proposed Project.

Source of CO_2

The naturally occurring CO_2 for the Early Test will be provided by Denbury Resources' CO_2 pipeline from the Jackson Dome near Jackson, Mississippi. The source is commercially available, high purity, highly reliable, and low cost. The CO_2 for the Anthropogenic Test will be supplied from a pilot unit capturing CO_2 from flue gas using amine capture technology from a 25 megawatt (MW) slipstream of Southern Company's Plant Barry (Bucks, Alabama) power plant near the injection site. The expectation is that this pilot unit will be capable of producing 125,000 to 150,000 metric tons of CO_2 per year.

Injection Operations

Injections will occur at a scale sufficient to successfully address issues of injection rate and cumulative injection impacts that may be factors in the design of future large-scale, commercial sequestration deployments. During the Early Test, 1.5 million metric tons (1.65 million tons) of CO_2 is currently transported through the commercial Denbury Sonat pipeline (a former gas pipeline that Denbury retrofitted for CO_2 transport in 2007) from a natural source at Jackson Dome to Cranfield, Mississippi, over 18 months. Distribution lines and compression have been developed by Denbury to bring CO_2 from the pipeline head to at least four injection wells for storage in the down dip "water leg" of the Cranfield Unit. CO_2 injection for the Early Test commenced in October 2009. For the Anthropogenic Test, the CO_2, once captured, will be dehydrated and compressed to approximately 2,000 pounds per square inch gauge (psig). It will be transported over a short distance (~10 miles) via carbon steel pipe to the Citronelle, Alabama, injection site.

Simulation and Monitoring of CO_2

SECARB will adhere to a vigorous monitoring, verification, and accounting (MVA) program during the 10-year Development Phase project. Each site will be well instrumented with multiple sensor arrays. In the Early Test, sweep efficiency will be monitored by saturation measurements along well bores, crosswell measurements, and vertical seismic profiling (VSP) and/or surface seismic methods. Proposed monitoring activities for the Anthropogenic Test will include: well bore integrity assessed through Ultrasonic Imaging Tool (USIT) logging, annular pressure monitoring, and tracer injection; assessment of areal extent of the plume through drilling and monitoring up-gradient wells, seismic surveys (3-D and VSP), and Reservoir Saturation Tool (RST) logs in observation wells; monitoring for formation leakage through RST logging and using the VSP geophones to map and trace potential CO_2 leakage; and potential CO_2 seepage through shallow subsurface monitoring for CO_2, carbon isotopes, and tracers. To help predict plume movement and assess the ultimate fate of the injected CO_2, the project team will utilize two types of simulation models – GEM simulation software and TOUGHREACT.

Goals and Objectives

SECARB's overall goal is to validate the efforts of the public outreach, research, and field activities implemented under the Characterization and Validation Phases. Specific objectives include:

- Conducting a large-volume, high-pressure injection test that benefits from existing CO_2 infrastructure and reasonable CO_2 costs.
- Assessing the viability and logistics of injecting 1 million metric tons (1.1 million tons) of CO_2 per year into a regionally significant saline formation in the Gulf Coast.
- Achieving a more thorough understanding of the science, technology, regulatory framework, risk factors, and public opinion issues associated with large-scale injection operations.
- Executing a sequestration test that covers all aspects of capture, separation, and storage, while fulfilling technical, regulatory, social, and economic considerations.
- Refining capacity estimates of the formation using results of the test.

Accomplishments to Date

- CO_2 injection for the Early Test commenced in October 2009 and is scheduled to continue for one and a half years at a rate of one million metric tons per year.
- Southern Energy's Plant Barry was selected as the CO_2 source for the Anthropogenic Test.
- Site characterization activities for the Citronelle Field (host site for Anthropogenic test) commenced in August 2009.

Benefits to the Region

The lower Tuscaloosa Formation, which is representative of the Gulf Coast geology, could be used to store 50 percent of the CO_2 produced in the SECARB region during the next 100 years—an estimated 50 billion metric tons (55 billion tons). The Gulf Coast Wedge includes the largest saline sinks (in terms of areal extent and capacity) for the SECARB region, as well as the United States. Annual stationary point source emissions of CO_2 have been estimated to be 1 billion metric tons (1.2 billion tons). Using the range of reported capacity, the Gulf Coast Wedge can accommodate these emissions for approximately 300 to nearly 1,200 years, using capture and storage technologies. These volumes are sufficient to support commercialization of this CO_2 sink and demonstrate that CO_2 capture and sequestration can be a viable option for mitigating the region's GHG emissions.