the ENERGY lab

PROJECT FACTS

Carbon Storage – RCSP

Midwest Regional Carbon Sequestration Partnership—Validation Phase

Background

The U.S. Department of Energy Regional Carbon Sequestration Partnership (RCSP) Initiative consists of seven partnerships. The purpose of these partnerships is to determine the best approaches for permanently storing carbon dioxide (CO_2) in geologic formations. Each RCSP includes stakeholders comprised of state and local agencies, private companies, electric utilities, universities, and nonprofit organizations. These partnerships are the core of a nationwide network helping to establish the most suitable technologies, regulations, and infrastructure needs for carbon capture, utilization, and storage (CCUS). The RCSPs include more than 400 distinct organizations, spanning 43 states and four Canadian provinces, and are developing the framework needed to validate carbon storage technologies. The RCSPs are unique in that each one is determining which of the numerous CCUS approaches are best suited for their specific region of the country and are also identifying regulatory and infrastructure requirements needed for future commercial deployment. The RCSP Initiative is being implemented in three phases, the Characterization Phase, Validation Phase, and Development Phase. In September 2003, the Characterization Phase began with the seven partnerships working to determine the locations of CO_2 sources and to assess suitable locations for CO_2 storage. The Validation Phase (2005–2013) focused on evaluating promising CO_2 storage opportunities through a series of small scale field tests in the seven partnership regions. Finally, the Development Phase (2008-2020) activities are proceeding and will continue evaluating how CO_2 capture, transportation, injection, and storage can be achieved safely, permanently, and economically at large scales. These tests are providing tremendous insight regarding injectivity, capacity, and containment of CO_2 in the various geologic formations identified by the partnerships. Results and assessments from these efforts will assist commercialization efforts for future carbon storage projects in North America.

The primary objective of the DOE's Carbon Storage Program is to develop technologies to safely and permanently store CO_2 and reduce Greenhouse Gas (GHG) emissions without adversely affecting energy use or hindering economic growth. The Programmatic goals of Carbon Storage research are: (1) estimating CO_2 storage capacity in geologic formations; (2) demonstrating that 99 percent of injected CO_2 remains in the injection zone(s); (3) improving efficiency of storage operations; and (4) developing Best Practices Manuals (BPMs).

CONTACTS

Traci Rodosta
Carbon Storage Program 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

Dawn Deel
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-4133
dawn.deel@netl.doe.gov

Darrell Paul
Project Manager
Midwest Regional Carbon Sequestration Project
Battelle
505 King Avenue
Columbus, OH 43201
614-424-5890
paul@battelle.org

PARTNERS

AJW Inc.
American Electric Power
AMP-Ohio
ArcelorMittal
Baard Energy LLC
Babcock & Wilcox
Battelle Memorial Institute
BP Products North America
Center for Energy and Economic Development (CEED)
Chicago Climate Exchange
CONSOL Energy

NATIONAL ENERGY TECHNOLOGY LABORATORY

Albany, OR • Anchorage, AK • Morgantown, WV • Pittsburgh, PA • Sugar Land, TX

Website: www.netl.doe.gov

Customer Service: 1-800-553-7681

U.S. DEPARTMENT OF ENERGY

PARTNERS (CONT.)

Constellation Energy
Consumers Energy
Core Energy
Dominion
DTE Energy
Duke Energy
Edison Mission
Exelon
FirstEnergy
Indiana Consumer Counsel
Indiana Geological Survey
Kentucky Geological Survey
Maryland Geological Survey
National Rural Electric Cooperative Association
New Jersey Department of Environmental Protection
New York State Energy Research and Development Authority
New York State Museum Institute
Ohio Coal Development Office within the Ohio Air Quality Development Authority
Ohio Consumers' Counsel
Ohio Corn Marketing Program
Ohio Division of Geological Survey
Ohio Environmental Council
Ohio Soybean Growers
Pennsylvania Geological Survey
Praxair
Rutgers University
RWE
Schlumberger
Stanford University
The Keystone Center
The Ohio State University
University of Maryland
West Virginia Geological Survey
West Virginia University
Western Michigan University

COST

Total Project Value
$28,801,838

DOE/Non-DOE Share
$22,304,933 / $6,496,905

Description

The Midwest Regional Carbon Sequestration Partnership (MRCSP) has been established to assess the technical potential, economic viability, and public acceptability of CCUS within a region consisting of nine contiguous states: Indiana, Kentucky, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, and West Virginia. A group of leading universities, state geological surveys, non-governmental organizations and private companies, led by Battelle Memorial Institute, have been assembled to carry out this research.

The MRCSP's Validation Phase research program advanced economic growth and environmental protection in the Midwest Region. The MRCSP conducted a series of validation tests in the locations identified in the MRCSP's Characterization Phase (2003-2005). Specifically, the MRCSP demonstrated the safety and effectiveness of geological storage by conducting three small-scale CO_2 injection field tests in the region's deep geologic formations. The MRCSP also conducted four terrestrial storage field validation tests to show how naturally stored carbon can be measured and monitored and how carbon credits could be traded in voluntary GHG markets. The MRCSP continued work initiated in the Characterization Phase to further map and define the storage potential of the region. Potential locations for geologic storage in the MRCSP states extend from deep rock formations in the broad sedimentary basins and arches in the western portion of the region to the offshore continental shelf in the east. Research and testing has established many promising geologic units for CO_2 storage in deep saline rock formations, depleted oil and gas fields, organic shale layers, and coalbeds. The MRCSP also continued their efforts to understand key regulatory issues and engages and informs stakeholders about CCUS.

Primary Project Goal

The primary goal of the MRCSP's Validation Phase is to establish the best methods for capturing and permanently storing carbon dioxide in the geological formations best suited to injecting and storing CO_2 emissions. The MRCSP is designed to assess the technical potential, economic viability, and public acceptability of CCUS within the region.

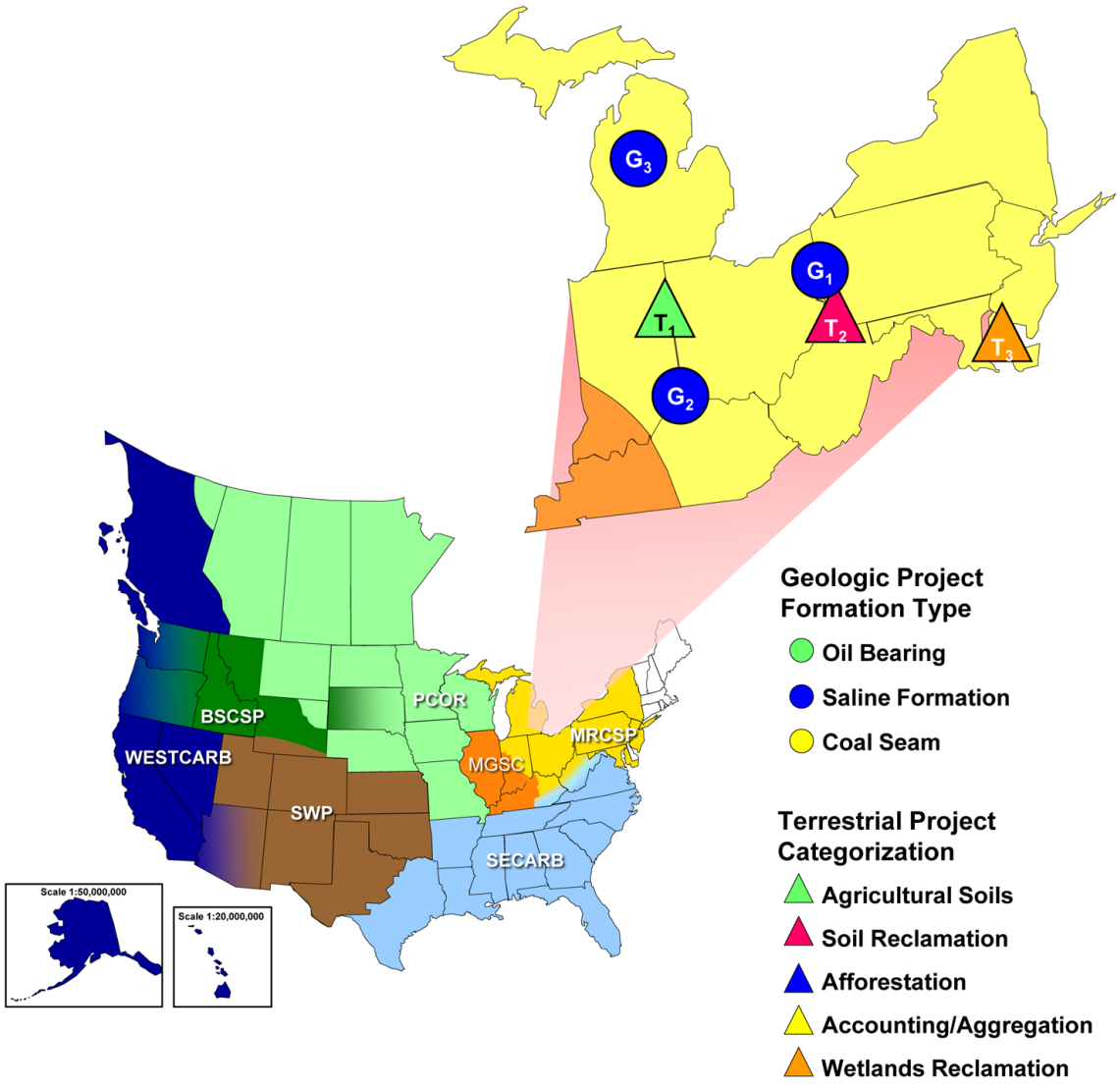
Objectives

The primary objective is to identify the technical, economic, and social considerations associated with geologic and terrestrial CO_2 storage and create viable pathways for its deployment. The MRCSP Validation Phase conducted the following:

- Identified, characterized, and mapped CO_2 sources and assess the viability and cost of capturing and storing emissions.
- Continued to characterize and estimate the region's potential geologic and terrestrial storage capacity.
- Engaged public and elected officials at all levels in dialogue on issues affecting implementation and the potential benefits associated with geologic and terrestrial CO_2 storage.
- Validated the potential for geologic storage in the region by conducting several small-scale CO_2 injection field tests (Validation Phase) in selected deep geologic reservoirs to demonstrate the safety and effectiveness of geologic storage systems.

- Validated the potential for terrestrial storage in the region by conducting three small-scale terrestrial field tests to demonstrate enhanced carbon uptake and validate measurement techniques used to quantify terrestrial carbon storage.
- Linked options for capture, transportation, and geological storage within the environmental and regulatory framework.
- Identified factors that might contribute to enhanced public acceptance of CCUS.

Field Projects

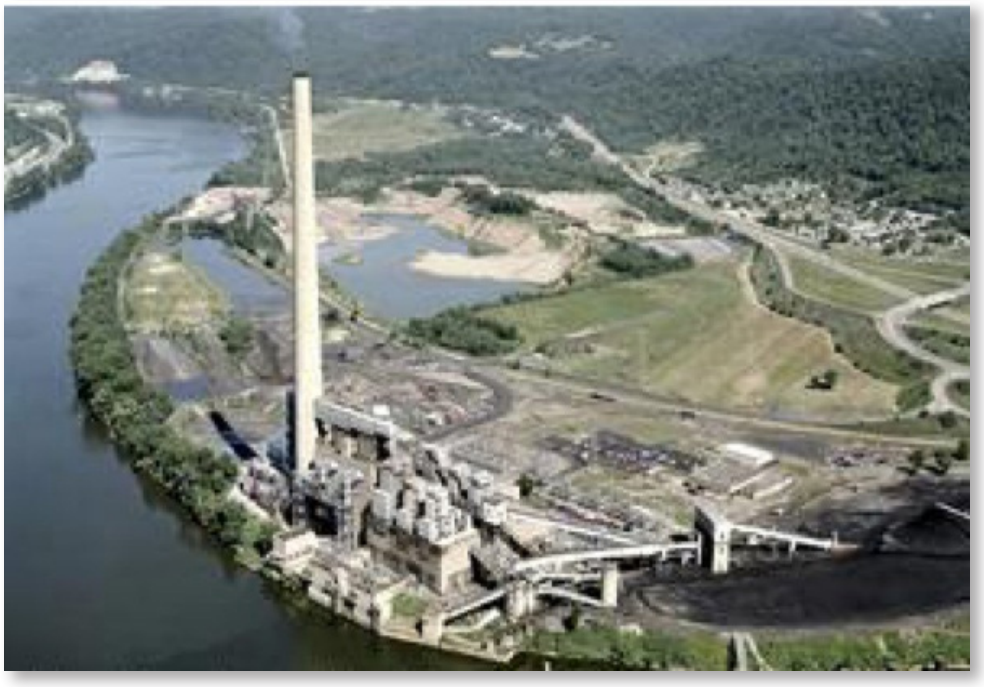


Geologic Storage Opportunities

MRCSP's research estimated up to approximately 229 billion metric tons total of potential CO_2 storage resource in the region's oil and natural gas fields, unmineable coal seams, organic rich shales, and saline formations. This CO_2 storage resource is estimated to accommodate hundreds of years of current CO_2 emissions from the region's large point sources, such as power plants, cement plants, and refineries. The MRCSP's research further estimates the above total to be distributed as 16.8 billion metric tons of potential storage resource in existing depleted oil and natural gas fields (which could lead to hundreds of millions of barrels of additional oil production), 1 billion metric tons of potential unmineable coal bed storage, 30 billion metric tons of storage potential in organic rich shales, and up to 183 billion metric tons of storage potential in deep saline formations. The MRCSP has completed three small scale geologic storage projects, which are summarized below as part of its Validation Phase.

Appalachian Basin Geologic Test (G1)

This project provided an opportunity to evaluate the feasibility of injecting CO_2 into three different deep rock formations at depths between 5,900 and 8,300 feet. These formations, the Oriskany, Salina, and Clinton/Medina, are representative of formations that are pervasive cross the Appalachian Valley, a part of the MRCSP region that contains many of the major coal-fired power plants in the region, and the United States in general. The test was conducted at FirstEnergy's R.E. Burger Power Plant near Shadyside, Ohio.



FirstEnergy's R.E. Burger Plant

Accomplishment Highlights:

- Site characterization, well design, a two-dimensional (2-D) seismic survey, and the drilling of a test well of just over 8,300 feet depth was completed by February 2007. A collaborative, regional geologic assessment was developed by the Ohio, Pennsylvania, and West Virginia Geological Surveys, describing the regional geologic setting and target storage rock formations.
- Results of the formation evaluation indicate that porosity, void space, and permeability of target formations were lower than expected, strengthening the importance of extensive drilling, formation evaluation, and characterization efforts to identify suitable formations for the geologic storage of CO_2 in more complex basins such as the Appalachian.
- Significant outreach was conducted at this site, including preparation of information materials (fact sheets, briefings, and posting of project snapshots on the MRCSP web site); assistance to Annenberg Media in developing an educational video of the drilling program as part of their teacher education program on energy; conduct site tours for senior management from DOE, industry and state government; and organization of an informal public educational meeting, as well as participation at the Ohio EPA UIC permitting hearing.
- CO_2 injection tests in the Oriskany Sandstone, the Salina Carbonate, and the Clinton/Medina Sandstone were completed in fall 2008, utilizing a commercial source of CO_2 for the tests. Although less than 50 metric tons of CO_2 was injected, the test results will help to develop best practices and better understand the regional geology for its storage potential.
- Injection tests provided useful information on rock properties and formation behavior, and aided in establishment of familiarity with CO_2 injection operations at active power plants.

Cincinnati Arch Geologic Test (G2)

This saline formation project aimed to demonstrate carbon storage in the Mt. Simon Sandstone, a major CO_2 storage target in the MRCSP region. Results of the injection testing and monitoring at this site, located on Duke Energy's East Bend Power Plant (located near Rabbit Hash, Kentucky), can be applied to similar power plants in this region. This project successfully injected approximately 1,000 metric tons of CO_2 at depths between 3,200 and 3,600 feet into the Mt. Simon Sandstone in the Cincinnati Arch region. The source of CO_2 was a commercial supplier and the CO_2 was delivered to the site via tanker trucks.

Duke Energy's East Bend Facility

Accomplishment Highlights:

- CO_2 injection activities resulting in injection and storage of approximately 910 metric tons of CO_2 were completed in September 2009. An injection rate of 1,200 metric tons per day was achieved and porosity estimates for the injection zone range from 5 to 15 percent. The overlying Eau Claire formation exhibited good caprock characteristics. Overall results indicate that the formation can accept and contain CO_2.
- The Underground Injection Control (UIC) permitting process was completed in the spring of 2009 with receipt of a UIC injection permit from U.S. EPA Region 4.
- Test well was drilled and characterized in July 2009. Geologic characterization included about 90 feet of full core, wireline logging, and various sidewall cores.
- Outreach activities included preparation of a fact sheet and other informational materials, two open houses for plant neighbors, and in-person as well as email briefings to local area officials.
- Post-injection site monitoring continued through September 2011 to monitor ground water in the area and, thus, help ensure safe CO_2 storage. To date, no issues have been identified that would indicate an adverse impact to groundwater.

Michigan Basin Geologic Test (G3)

This project involved total injection of approximately 60,000 metric tons of CO_2 into the Bass Islands Dolomite, a saline formation between depths of 3,400 to 3,500 feet. Injection rates of 600 metric tons per day were sustained throughout injection. The test location is the Charlton 30/31 field in Otsego County, Michigan, site of an enhanced oil recovery (EOR) operation managed by MRCSP partner, Core Energy. The site, located in the northern part of the Michigan Basin, is in the vicinity of natural gas processing plants operated by MRCSP partner DTE Energy and others, which currently provide CO_2 for the EOR operations. The captured CO_2 from the nearby gas processing plants, combined with the EOR operation, provides available infrastructure for testing CO_2 storage in adjacent saline formations. Geology in this region was well-characterized, due to oil and natural gas exploration in the area, with many available well logs.

Injection well at Michigan site

Accomplishment Highlights:

- Initial injection of approximately 10,000 metric tons of CO_2 into the Bass Islands Dolomite was completed in March 2008. A media day briefing was held during the first injection test in February 2008.

- Secondary injection of an additional 50,000 metric tons of CO_2 was injected during the summer of 2009. Outreach efforts include informational materials (including posting of regular project updates on the website); a public informational meeting with regular follow-ups to local stakeholders, as requested; and on-going briefings to key officials and community opinion leaders.
- A new test/injection well was drilled, and an existing EOR well was redeveloped as a monitoring well in the fall of 2006. Core samples were acquired and analyzed in the Bois Blanc-Bass Islands interval during drilling.
- Completed post-injection monitoring, including a combination of cross-well seismic, hydraulic monitoring, PFT tracers, microseismic array, and wireline logging. Analysis of post-injection MVA data was conducted. Results indicate no CO_2 leakage from the intended target formation.
- MRCSP conducted extensive seismic monitoring operations in order to quantify any subsurface response to CO_2 injection. No significant seismic events relating to CO_2 injection were detected.

Terrestrial Storage Opportunities

Terrestrial ecosystems in the MRCSP states offer a viable opportunity for carbon storage because of the extensive farmlands, wetlands, minelands, and forests in the region. There are over 22 million hectares (or 88,000 square miles) of land in the MRCSP region that could be utilized for enhanced carbon storage. Terrestrial storage research was focused on five land use categories: 1) non-eroded prime croplands; 2) eroded prime croplands; 3) marginal lands such as forest, pasture, and severely eroded croplands; 4) minelands; and 5) wetlands. The region's total terrestrial storage potential for these five land use classes is estimated to be 144 million metric tons of CO_2 per year, the majority of which would come from conversion of marginal lands to forest (99 million metric tons CO_2/year), followed by wetlands (14 million metric tons CO_2/year), non-eroded croplands (14 million metric tons CO_2/year), eroded croplands (11 million metric tons CO_2/year), and mineland restoration (6 million metric tons CO_2/year). Ancillary, non-climate benefits associated with terrestrial storage within the MRCSP region include improved soil quality, reduced erosion and sedimentation, bio-filtration of pollutants, and decreased rates of CO_2 emissions. Adoption of recommended management practices may enhance crop yield in some soils by one to two percent annually, decrease the magnitude of soil erosion and non-point source pollution by 70 to 80 percent, and reduce the transport of pesticides and heavy metal runoff and percolation water by 70 to 80 percent.

Terrestrial Storage Field Test: Croplands (T1)

This project employs monitoring, verification, and accounting (MVA) protocols, and technologies of multiple cropland plots over the MRCSP region, primarily in the states of Ohio, Indiana, and Michigan. Soil sample analyses are being used to determine the actual rate of storage and potential for the region's farmlands to adopt "no-till" or reduced-tillage practices to increase the amount of carbon stored in agricultural soils. The potential benefit over a 20 year period could result in an estimated 250 million metric tons of additional CO_2 stored. The stored carbon may be sold as CO_2 offset credits, which would provide additional profit to the landowners in the region.

Accomplishment Highlights:

- Thirteen sites in 2006 from 12 Major Land Resource Areas (MLRA's), 11 sites in 2007 from 11 MLRA's, five sites in 2008 from five MLRA's, and 10 sites in 2009 of the MRCSP region were selected to collect soil samples from three predominant land uses, namely till, no till and woodlot.
- Soil samples, such as structural stability, plant available water, texture, shrinkage, soil compaction, soil hydraulic properties, and soil aggregate properties, were collected and analyzed from five different depths.
- Three Ohio sites based on different parent material: Glacial Till (Coshocton), Till Plain (Delaware), and Glacial Lake Plain (Henry County) were selected to assess the historic carbon loss by cultivation. An additional 144 soil samples and 24 plant residue samples were collected and analyzed for additional soil physical properties.
- Geospatial analysis and pedometrics were conducted with the aim to predict soil carbon stock in relation to readily available data, such as land use, digital elevation model, soil reflectance, and weather data (temperature and precipitation) for the entire MRCSP region.
- A Digital Elevation Model (DEM) of the study area has been prepared using data from the USGS. Once integrated, the model will provide the 30-year average annual temperature and precipitation data collected for the seven states.

- A public outreach meeting was held in the winter of 2008 with selected farmers from across the region. Issues related to global climate change, terrestrial storage in croplands, geologic storage, and work being conducted by DOE were discussed and feedback was obtained.
- Residence time of carbon stored in soil depends on soil properties (clay vs. sand), depth, land use, and management. The soil carbon pool is maintained or enhanced as long as no-till system and other best management practices are used.

Terrestrial Storage Field Test: Minelands (T2)

Soil samples from five mined sites reclaimed to grass and legumes in Monongalia County, West Virginia were collected and analyzed to assess soil carbon accumulation. The Waynesburg coal seams for all five mine sites were contour mined beginning as early as 1982 and as late as 2007 using front end loaders. Overburden material placed on the disturbed land consisted of 70 to 80 percent sandstone, with shale making up the remaining 20 to 30 percent. Mining operations ceased at different times for each of the sites (1990, 1998, 2000, 2005, and 2007), which allowed comparison across reclaimed mine sites over time. Soil sample collection began in 2006 and continued annually to assess the change in soil carbon accumulation over time. In addition to measuring soil carbon stocks on reclaimed mine lands, the project is performing economic analyses to assess the trade-offs between existing land management activities and those that enhance carbon storage. The analysis involves estimating the difference in soil carbon accumulation rates in soils on sites reclaimed to grass/legumes and forest, which capture carbon in above ground (biomass) and below ground (soil) systems. The objective is to assess the economic viability of using the carbon accumulation on reclaimed mine sites as a GHG mitigation activity.

Accomplishment Highlights:

- Collected and analyzed 1,105 soil samples for carbon and nitrogen content from five reclaimed mine sites in Monongalia County, West Virginia.
- Completed bulk density measurements for the soil samples collected from the recently reclaimed mine site and the Skousen, Dent's Run, Mylan Park, and New Hill reclaimed sites.
- Completed selective dissolution techniques to separate recalcitrant and/or labile soil organic carbon (SOC) on 75 soil samples.
- Utilized UV-Vis (ultraviolet-visible spectroscopic) and fluorescence spectroscopic methods to investigate the degree of humification of SOC molecules. In general, the greater the degree of humification, the greater the aromatic nature and degree of substitution, the greater the stabilization of SOC and, therefore, potential for SOC storage on reclaimed mine land. FT-IR (Fourier Transform Infrared) Spectroscopy was used to investigate the types of principal functional groups attached to the SOC molecules.
- Analyzed mining permit data to determine the area and date reclaimed mine sites in West Virginia satisfied: Phase 1 (re-contouring), Phase 2 (vegetative cover established to control for soil erosion), and Phase 3 (vegetative cover density, which satisfies bond requirements five year after reclamation).
- Developed carbon storage rate estimates that result from forestry activities using the DOE Energy Information Administration's Voluntary Reporting of Greenhouse Gases (1605b) Program and the Carbon On-Line Estimator (COLE). Estimates of the potential costs savings from reclamation with the Forest Reclamation Approach (FRA), recommended by Appalachian Regional Reforestation Initiative (ARRI), were used to estimate the minimum carbon prices and to encourage reforestation in the MRCSP research region. West Virginia University determined that the rate of soil carbon storage in the near surface for mine lands reclaimed to pasture or grassland ranged between 0 to 3 Mg carbon per ha-1 yr-1. Furthermore, reclaiming mined land to forest increases the amount of carbon stored significantly due to carbon accumulation in aboveground biomass, litter layer, and soils.
- Estimates of the potential costs savings from reclamation with the Forest Reclamation Approach (FRA) recommended by the ARRI were used to develop a map of the minimum carbon process necessary to encourage reforestation in the MRCSP research region.
- The average soil organic carbon (SOC) rate of accumulation for the MRCSP study observed in the 0 – 12 cm depth range when applied to all reclaimed U.S. mine sites would provide a potential storage capacity of 3 million tons (3.2 million tons) per year.

Terrestrial Field Test: Wetland- Blackwater Wildlife Refuge (T3)

This project monitored the carbon storage rates in tidal marshes at the Blackwater National Wildlife Refuge. The project area is near Cambridge, Maryland, where up to 20,000 acres of lost tidal marsh is being restored using clean dredged material. The results of this study are being used to estimate carbon storage rates in restored marshes over time, evaluate the extent to which various management practices influence this process, and develop a sampling protocol for CO_2 validation in restored marshes.

Accomplishment Highlights:

- Established project transects, laid down marker horizons, and conducted first and second year sampling data collection.
- Completed laboratory analyses on soil samples, plant sample analysis, and completed soil data analysis.
- Conducted ongoing public outreach, including preparation of informational materials (fact sheets and an exhibit) for placement in the Visitors' Center, conducted a site tour for DOE officials, and contributed to the Center's community educational programs.
- The restored and natural marsh at the Blackwater National Wildlife Refuge are storing carbon at an above-average rate versus the national average based solely on surficial accumulation, which is likely an underestimate.
- At a rate of 3.4 Mg carbon per ha-1 yr-1 of surficial carbon storage, the proposed 8,000 ha restoration would store about 24,550 metric tons (27,000 tons) of carbon per hectare per year.

Terrestrial Storage Field Test: Forested Wetlands (T4)

Additional field validation tests have been conducted to help identify ways to enhance the natural storage capacity of forested wetlands. This work involved obtaining empirical data from pilot demonstration sites in New Jersey. Forested wetlands, the focus of this field demonstration, constitute the majority of New Jersey's freshwater wetland resource. These wetlands currently occupy ~10% of New Jersey's land area. Restoring forested wetland on previously drained agricultural area may provide a useful conjunction of carbon management and wetland mitigation practices.

Accomplishment Highlights:

- The study areas was selected and are located on restored forested wetlands on previously drained agricultural land, which will permit quantification of carbon stores and carbon flux rates.

Benefits

The Validation Phase projects have provided the first steps toward demonstrating the feasibility of storing CO_2 in geologic formations. The results are providing the knowledge base for stakeholders to develop robust carbon mitigation strategies to store CO_2.

MRCSP's Validation Phase geologic field tests involved CO_2 injection into selected deep saline formations, a storage type that represents the most significant geologic storage potential for the United States. Results showed prospective storage resource available to permanently store hundreds of years of CO_2 emission from the region. MRCSP field tests also determined that oil-and-gas fields have a high potential for enhanced oil and gas production associated with CO_2 storage. Additionally, in the Appalachian Basin of the MRCSP region, using CO_2 for enhanced coalbed methane recover also shows potential for storing CO_2.

Validation Phase terrestrial field tests showed that the MRCSP region can potentially store, terrestrially, approximately 15 percent of the region's annual CO_2 emissions from large point sources, such as power plants. In particular, Validation Phase tests confirmed that no-till agriculture is a valuable carbon storage strategy with the added benefit of improved soil quality and agronomic productivity.

NT42589-P2, December 2012