



the **ENERGY** lab

## PROJECT FACTS

### Carbon Sequestration

# Big Sky Carbon Sequestration Partnership—Validation Phase

## Background

The U.S. Department of Energy (DOE) has selected seven partnerships, through its Regional Carbon Sequestration Partnership (RCSP) initiative, to determine the best approaches for capturing and permanently storing carbon dioxide (CO<sub>2</sub>), a greenhouse gas (GHG) which can contribute to global climate change. The RCSPs are made up of state and local agencies, coal companies, oil and gas companies, electric utilities, universities, private companies, and nonprofit organizations that form the core of a nationwide network helping to establish the most suitable technologies, regulation, and infrastructure needs for carbon sequestration. More than 350 organizations, spanning 43 states and four Canadian provinces, are included in the partnership. A framework needed to validate and deploy carbon sequestration technologies is being developed by the RCSPs. The RCSPs will determine which of the numerous sequestration approaches are best suited for their specific regions of the country and identify regulatory and infrastructure requirements that will be needed should policy and economics indicate that sequestration be deployed on a wide scale. The RCSP initiative is being implemented in three phases. The Characterization Phase began in September 2003 with the seven partnerships working to develop the necessary framework to validate and potentially deploy carbon sequestration technologies. The Validation Phase of the RCSP effort (2005–2009) is focused on evaluating promising CO<sub>2</sub> sequestration opportunities through a series of field tests in the seven partnership regions. Presently, activities in the Development Phase (2008–2017) are proceeding and will continue the validation process to determine that CO<sub>2</sub> 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 storability of CO<sub>2</sub> in the various geologic formations identified by the partnerships. Results and assessments from these efforts will assist commercialization efforts for future sequestration projects in North America.

## Description

The Big Sky Carbon Sequestration Partnership is building on the work conducted in the Characterization Phase with a focus on geologic and terrestrial field verification tests that assess the relative efficiency of alternative sequestration options, prove the environmental efficacy and sustainability of sequestration, verify regional CO<sub>2</sub> sequestration capacities, and satisfy field test permitting and regulatory requirements. Data from Validation Phase tests will be integrated into a geographical information system (GIS) tool that will assist industry and regional planners to optimize energy development strategies. The Big Sky Partnership will also conduct extensive public outreach and education and training opportunities for students and young professionals.

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## PARTNERS

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Nez Perce Tribal Council  
Norwegian Univ. of Science and Technology  
Oregon State University  
PacifiCorp  
Portland General Electric (PGE)  
Power Procurement Group

Carbon sequestration will play a paramount role in developing this sustainable future by enabling the region to cleanly utilize its abundant fossil energy resources (nearly 40 percent of total U.S. coal reserves) and sequestration sinks to support future energy demand and economic growth. The Big Sky Partnership region has abundant geologic and terrestrial sink opportunities available, including areas of mafic volcanic rocks (flood basalts), reactive carbonate reservoirs (e.g., the Madison formation), and Powder River basin coals.

## Primary Project Goal

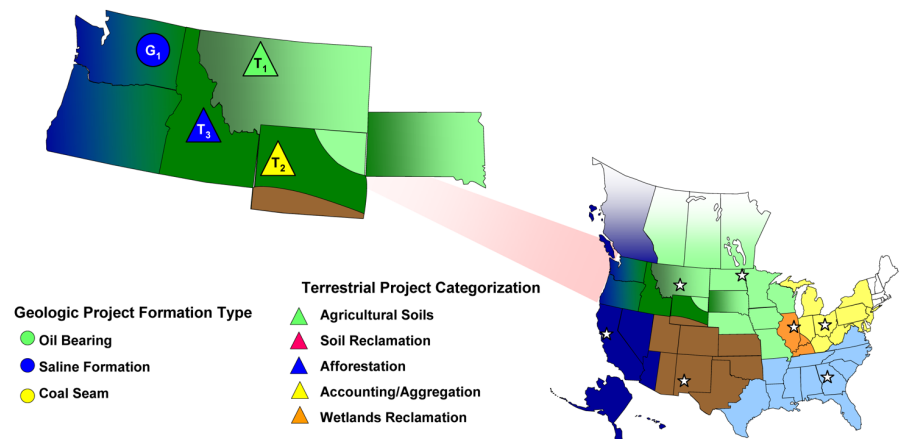
The overarching goal of the partnership is to promote the development of a regional framework and infrastructure required to verify and deploy sequestration technologies. To achieve this, the Validation Phase focuses on the most promising geologic and terrestrial field tests coupled with market assessments, economic analysis, and regulatory and public outreach.

## Objectives

In the Validation Phase, the Big Sky Partnership will develop regional solutions for CO<sub>2</sub> sequestration and provide insight critical to others involved in GHG management throughout the United States and the world by:

- Conducting field tests in prominent geological formations that are located throughout the region—mafic rock formations, such as basalts, and sedimentary rock-hosted saline formations.
- Conducting terrestrial field tests to demonstrate the technical and economic feasibility of carbon storage in the major terrestrial carbon sinks, implementing monitoring and verification protocols, and assessing the impacts to existing ecosystems.
- Developing a national mafic rock atlas and assessing the sequestration potential of these rocks through modeling studies, laboratory testing, and insights developed from the basalt pilot project.
- Addressing and assessing the technical and economic potential for and implications of carbon sequestration in the region.
- Establishing the Big Sky Energy Future Coalition that brings together industry, academia, environmental non-governmental organizations, and regulatory and governmental officials biennially to discuss the role that carbon sequestration can play in providing a technological solution to the region's energy requirements.

## Field Projects



*Big Sky Carbon Sequestration Partnership Validation Phase Field Tests*

## Geologic Sequestration Opportunities

The partnership's primary geologic effort is to demonstrate carbon storage in mafic/basalt rock formations, a geology not yet well-characterized, but with significant long-term storage potential in the region and in other parts of the world. For example, the region's Columbia River Basalt Group covers approximately 164,000 km<sup>2</sup> (63,320 square miles), with CO<sub>2</sub> storage capacity of basalt formations

in the region range estimated at 36–148 billion tons (33–134 billion metric tons). Although the basalts have inherently low porosity and permeability, it is believed that significant CO<sub>2</sub> injectivity and storage capacity can be obtained by one or several brecciated zones between major basalt flows. Furthermore, preliminary calculations show that rapid conversion of injected CO<sub>2</sub> to carbonate minerals can occur in basalt formations, with complete conversion of fluid phase CO<sub>2</sub> to solid phase carbonate minerals in a few hundred years. If these laboratory-based estimates can be verified in the field, basalt formations may offer a unique geologic medium for long-term, secure carbon sequestration.

### Basalt Field Validation Test (G1)

This field test will involve injection of approximately 1,000 tons of supercritical CO<sub>2</sub> into a deep basalt formation (Grande Ronde Basalt) in western Walla Walla County in eastern Washington State. The test will assess the mineralogical, geochemical, and hydrologic impact of injected CO<sub>2</sub> within a basalt formation and incorporate site monitoring and verification activities. Initial injection of CO<sub>2</sub> is currently scheduled to begin in July 2009.

#### Accomplishment Highlights:

Simulations of CO<sub>2</sub> injection for two basalt flows were completed.

- Two shallow soil gas probes were installed in the vicinity of the injection well. Gas samples have been collected on a monthly basis to detect any anomalous gas composition readings and establish background concentrations for CO<sub>2</sub> and other gases.
- Seismic survey was completed in December 2007.
- Underground Injection Control Class V Well Registration packet was prepared and submitted to Washington Department of Ecology.
- Land use agreement was signed with Boise White Paper, LLC.
- Drilling of pilot injection well was completed in April 2009; the final hole depth was ~4,000 feet.

### Reactive Carbonate Reservoir Investigation

The Madison Formation, a reactive carbonate reservoir, has regions (on the Moxa Arch) that have been exposed to CO<sub>2</sub> for millions of years in a naturally occurring gas reservoir. The objective of the current investigation is to determine changes in rock properties resulting from CO<sub>2</sub> exposure and conduct a geologic reservoir analysis that could provide the foundation for a future demonstration to evaluate monitoring, verification, and accounting (MVA) performance at commercial-scale.

#### Accomplishment Highlights:

- The mineralogy of public-domain core samples from the Madison Formation was determined by X-ray diffraction on rock and clay separate samples and verified by examination of thin sections prepared from the cores. The results show that the Madison Formation was composed of dolomite, quartz, and calcite with minor amounts of illite, anhydrite, analcime, epsomite and natronite.

### Enhanced Coalbed Methane Recovery and CO<sub>2</sub> Sequestration

This investigation will determine the technical and economic issues associated with injecting a pure CO<sub>2</sub> stream into a coal seam versus an unseparated flue gas stream. It will also evaluate the effects of coal swelling on coalbed permeability and incorporate these effects into a coal bed reservoir simulator.

#### Accomplishment Highlights:

- Coal samples for the study were collected from two Colorado mines (Colowyo and Trapper) and two North Dakota mines (Falkirk and Beulah).

### Terrestrial Sequestration Opportunities

The Big Sky Partnership region provides tremendous potential for GHG offsets through terrestrial carbon sequestration in forests, rangelands, and agricultural croplands. Currently, the partnership has the most comprehensive terrestrial

## PARTNERS (cont.)

PPL Montana  
Puget Sound Energy (PSE)  
Ramgen Power Systems, Inc.  
Research Council of Norway  
Ruckelshaus Institute for Environment & Natural Resources (University of Wyoming)  
Russian Academy of Sciences  
Sage Resources  
Schlumberger  
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Wageningen University (The Netherlands)  
Western Governors' Association  
Wyoming Carbon Sequestration Advisory Committee  
Wyoming Department of Environmental Quality  
Wyoming State Governor's Office  
Yellowstone Ecological Research Center

## COST

### Total Project Value

\$21,455,308 (includes work performed by DOE National Laboratories)

### DOE/Non-DOE Share

\$16,405,089 (National Labs: \$2,046,000) / \$5,050,219

sequestration program in the nation. The Big Sky Partnership has designed cropland, rangeland, and forestland field validation tests to advance the partnership's Characterization Phase market-based carbon storage methods and verification protocols to demonstrate the viability of emerging pilot carbon markets. The results of this activity could be one of the largest market-based carbon trades in the country that is nationally recognized and in compliance with the reporting requirements of the DOE Energy Information Administration's Voluntary Reporting of Greenhouse Gases (1605b) Program. Furthermore, the partnership will integrate results from the field tests into its economic assessment framework.

### **Cropland Field Validation Test (T1)**

The objectives of this test are to: 1) quantify and determine cropland management practices that optimize carbon sequestration in semi-arid Montana; 2) develop MVA protocols to evaluate carbon sequestration for farms enrolled in carbon trading; and 3) investigate satellite image analysis as an alternative to the on-site verification of National Carbon Offset Coalition carbon contract compliance and as a means to remotely obtain cropland data used in predicting farmland soil carbon sequestration. Existing field trials at six controlled benchmark sites address the first objective by testing the effects of tillage vs. no-tillage and fallow-wheat vs. lentil-wheat crop rotations. The second objective is being addressed by an enrolled site component to develop and test MVA technologies and protocols. The MVA methods being compared to estimate soil carbon content are: 1) lab-based and "on-the-go" visible and near-infrared (VisNIR) spectroscopy; 2) laser-induced breakdown spectroscopy (LIBS); and 3) conventional laboratory methods. The third objective is being addressed via a remote sensing study that relies primarily upon analysis of Landsat Thematic Mapper (Landsat 5) satellite imagery.

#### ***Accomplishment Highlights:***

##### *Controlled study*

- First round of samples from multiple fields collected and analyzed.
- Completed the 2008 soil and vegetation sampling at all controlled site locations, and initiated analysis.

##### *Enrolled site proximal soil sensing MVA*

- Completed study of proximal soil sensing using "on-the-go" VisNIR. Results show that lab-based spectroscopy provided more accurate predictions than "on-the-go" VisNIR. "On-the-go" VisNIR did show potential for mapping soil properties with some potential limitations. Findings suggest that "on-the-go" VisNIR may be best applied to mapping fields or regions with relatively high SOC and clay content variability.
- Completed initial simulated in situ soil organic carbon measurements using LIBS. Results show LIBS analysis of soil cores is a valuable tool for measuring soil carbon in situ. It is a more rapid approach and more cost effective than standard analyses.

##### *Remote sensing study*

- Completed study, and results indicate the separation of no-till from conservation tillage management through spectral and textural-based satellite mapping is unlikely given the current technology and similarities in surface residue coverage.

### **Rangeland Sequestration Potential Assessment (T2)**

Continuing a study which began in 1982, this field test will focus on determining best management practices for carbon sequestration on rangelands. The test includes soil and biomass sampling at two long-term rangeland sites in eastern Wyoming to determine the sequestration effects of grazing intensity and seasonality of grazing on native northern mixed-grass prairie and improvement practices on degraded northern mixed-grass prairie. An assessment of sink potential for these rangelands will be performed, including potential benefits to ranchers. Findings from this field test are expected to be relevant to rangelands in Montana and eastern Colorado.

#### ***Accomplishment Highlights:***

- Completed literature review and synthesis of findings on carbon sequestration in rangelands.
- Expanded studies initiated in 1982 on the effect of grazing intensity (320 soil samples analyzed).
- Results indicate that grazing can significantly affect carbon dynamics and plant community composition of rangeland ecosystems, with grazing at proper stocking rates enhancing soil carbon and the potential for soil carbon sequestration.

### **Forestry Field Validation Test (T3)**

This forestry field test will use remote sensing to identify changes in forest management for enrolled forestry sequestration sites in the Northern Rocky Mountains. This remote sensing will complement contractual, ground-based, random plot sampling and allometric measurements. The primary objective is to quantify sequestration potential in forests through understanding the effects of forest management on different carbon pools in forests.

### **Benefits**

The Big Sky Partnership's efforts will benefit the United States by providing a comprehensive assessment of the sources and potential sinks for CO<sub>2</sub> in the Big Sky region, which includes the northern Rockies and Great Plains, as well as the inland Pacific Northwest area. Preliminary estimates of CO<sub>2</sub> storage potential of the storage of the mafic/basalt rock formations in the region's Columbia River Basalt group range from 36–148 billion tons (33–134 billion metric tons) of CO<sub>2</sub>, which is enough capacity for over 20 years of storage of all U.S. coal-fired power plant emissions of CO<sub>2</sub>. Additional storage potentials exist in the deep saline formations, in depleted oil reservoirs, and in coalbed methane fields in the Powder River Basin area. These areas, together with the basalt formations, have the potential to store up to an estimated 603 billion tons (547 billion metric tons) of CO<sub>2</sub>. This information on sources and sinks is being integrated with the data from other partnerships to provide a comprehensive database covering the entire nation. This effort will also provide information to evaluate potential pilot sequestration projects in the Big Sky region with respect to the effectiveness, efficiency, and permanence of the sequestered carbon. The projects will promote cooperation among stakeholders and help ensure public acceptance of CO<sub>2</sub> sequestration.