September 30, 2005

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2006-0054, "Plains CO_2 Reduction Partnership–Phase II"

The goal of the PCOR Partnership is to develop market-based solutions to carbon management issues that have the potential to benefit both the region's economy and environment. By developing these technologies and monetizing the carbon credits that result, it is the position of the PCOR Partnership that we can avoid GHG regulations in favor of incentives for our industrial partners. Phase I work has shown that our region has an abundance of geologic and terrestrial sinks for CO_2 sequestration and that this provides a competitive advantage to the energy industries in our region. By performing the proposed work, we will ensure that North Dakota's lignite industry will continue to lead the world in providing advanced technologies for the utilization of this abundant and critical resource.

Enclosed are the original and seven copies of the subject proposal. Also enclosed is the $100 application fee.

If you have any questions or comments, please contact me by phone at (701) 777-5279 or by e-mail at esteadman@undeerc.org.

Sincerely,

Edward N. Steadman
Senior Research Advisor

ENS/cs

Enclosures

c/enc: Harvey Ness, Lignite Research Council

PLAINS CO_2 REDUCTION PARTNERSHIP –PHASE II

EERC Proposal No. 2006-0054

Submitted to:

Ms. Karlene Fine

North Dakota Industrial Commission
State Capitol
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Proposal Amount: $720,000

Submitted by:

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Research Development and Compliance

September 2005

PLAINS CO_2 REDUCTION PARTNERSHIP–PHASE II

ABSTRACT

The Energy & Environmental Research Center (EERC) was selected to receive U.S. Department of Energy (DOE) Phase II funding for the "Plains CO_2 Reduction (PCOR) Partnership." The goal of the PCOR Partnership is to enhance the regional economy by providing our partners with opportunities related to carbon management. The partnership is pursuing a market-based approach and is developing technological solutions designed to provide technically and economically viable solutions for carbon management. The diverse PCOR Partnership team, led by the EERC with assistance from over 40 industrial partners, has the expertise, experience, facilities, and capabilities to fulfill project goals.

The goals of the PCOR Partnership Phase II program are to validate technologies and develop opportunities for our industry partners to capture, market, and monetize credits for CO_2. The long-range goal is to mitigate risk to the coal-based power industry by taking a market- and incentive-based approach to carbon management. The PCOR Partnership will accomplish this by:

- Continuing to assess regional sequestration opportunities.
- Performing field validation tests that provide the information needed to monetize carbon credits.
- Evaluating the feasibility of selected commercial-scale carbon sequestration technologies.
- Assessing the economics, risk, public acceptance, and societal and monetary cobenefits of CO_2 sequestration.
- Providing outreach and education for CO_2 sequestration stakeholders and the general public.

The PCOR Partnership Phase II program will last 4 years (October 2005–September 2009). The total cost of the project is $21,487,892, which includes cash contributions of $14,300,000 from DOE; $395,000 from industrial stakeholders; $500,000 from the North Dakota Industrial Commission Oil and Gas Research Program, and this request for $720,000 from the North Dakota Industrial Commission Lignite Research, Development, and Marketing Program. The remaining $5,572,892 represent the in-kind contributions of various team members.

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PROJECT SUMMARY

The Plains CO_2 Reduction (PCOR) Partnership Phase II program will develop regional solutions to carbon management issues and provide our industrial partners with opportunities for market-based solutions to greenhouse gas (GHG) issues. The proposed work involves four technology validation field trials and two investigations of commercially available sequestration concepts. The field trials will demonstrate the potential for the expansion of enhanced oil and gas recovery opportunities similar to the Dakota Gasification Company (DGC)/EnCana Corporation project, which provides a substantial revenue stream to DGC, and validate the potential of terrestrial sequestration options. The field trials will include a full suite of monitoring, mitigation, and verification (MMV) and regulatory compliance that will be used to develop protocols for the monetization of carbon credits. These activities, along with continued regional characterization and integration with other regional partnerships, will provide a firm foundation for future large-scale deployments of sequestration technologies and identify potential pathways for CO_2 recovery from existing and planned additional lignite-based development in our region, thereby enhancing opportunities for the use of North Dakota lignites in the future.

Field validation tests will demonstrate four sequestration scenarios that are of significant scale and are designed to verify the proposed concepts for eventual commercial application. PCOR Partnership Phase I results have indicated enormous potential for value-added CO_2-based oil and gas recovery as well as sequestration within the region. Enhanced oil recovery (EOR) and enhanced coalbed methane (ECBM) recovery projects are especially compelling as field validation concepts since our regional opportunity is so large and the economics are seemingly favorable. The lessons to be learned in sink capacities and permanence, MMV, transport, economics, risk, public acceptance, and societal cobenefits that will be provided by the proposed sequestration CBMR/EOR projects are vital to the long-term opportunities for the lignite industry in North Dakota.

The injection of CO_2 into economically unminable lignite seams in North Dakota will assess the potential for these strata as both CO_2 sequestration sinks and targets for ECBM recovery. Investigating these lignites will lead to new information about the sequestration potential of these abundant resources that are proximal to our lignite-powered electrical utilities so vital to our state, regional, and national economy.

Two sequestration/EOR projects are planned for Phase II. Sequestration/EOR injection of CO_2 will be investigated in an Amerada-Hess operated oil field in western North Dakota. This project will inject CO_2 for sequestration and EOR into strata approximately twice as deep as injected previously. The geochemical and geophysical implications of this deep injection of CO_2 are profound. This is especially significant because the injection zone conditions are similar to those found in many areas in western North Dakota that could be opportunities for EOR from lignite-based CO_2 sources. The other sequestration/EOR project involves acid gas injection into a pinnacle reef system in cooperation with Apache Canada Ltd. This activity is compelling for several seasons: pinnacle reefs are common in the deeper sedimentary basins in the Williston Basin in western North Dakota; pinnacle reefs are stratigraphically isolated, which gives them a high potential for permanence; the acid gas to be injected will provide information about the chemical and geochemical effects of nonpure CO_2 injection for sequestration and EOR; and the resulting information will be critical as our utility partners assess the technical feasibility and economics of separating CO_2 from flue gas for commercial sale.

A terrestrial field trial will investigate the enormous unlocked sequestration potential of Prairie Pothole Region wetlands. This vast regional wetland network provides a unique setting for the development of carbon offsets that could benefit all of the region’s electrical power plants that may be looking at noncapture options for CO_2 management in the future. In addition, the feasibility of using wind power to offset compression penalties for DGC will be determined. Finally, an assessment of CO_2 management options will be developed for a planned integrated gasification combined cycle plant in northern Minnesota.

PROJECT DESCRIPTION (additional detail found in Appendix A, U.S. Department of Energy Proposal 2005-0200)

Introduction

In response to U.S. Department of Energy (DOE) Program Solicitation "Regional Carbon Sequestration Partnerships (RCSP)," the Energy & Environmental Research Center (EERC) has developed and is coordinating the PCOR Partnership, an international activity to identify the major CO_2 sequestration opportunities in the Great Plains region and develop field validation tests of CO_2 sequestration technologies.

This region, which includes North Dakota, South Dakota, Minnesota, Iowa, Nebraska, Missouri, Wisconsin, and portions of Montana and Wyoming as well as the Canadian provinces of Manitoba, Saskatchewan, and Alberta (see Figure 1), was chosen based on a synergy between low-rank (lignite and subbituminous) coal users, geologic sinks, current CO_2 activities, terrestrial sinks, and existing industry

Figure 1. PCOR Partnership region.

collaborations. The PCOR Partnership is working to fully realize the United States' vision of reducing carbon intensity, increasing efficiency, and achieving carbon sequestration as expressed in the "Carbon Sequestration Technology Roadmap and Program Plan (1)." The PCOR Partnership will work to strengthen and expand its membership and technical base over the course of the program, and all activities will be conducted in consideration of affordably meeting U.S. energy demand and environmental concerns.

Objectives

The objectives of the proposed work are to develop regional solutions for the capture, transport, and storage of anthropogenic CO_2 in the PCOR Partnership region, particularly with respect to ensuring the safe and economical storage of CO_2 in geologic formations and terrestrial ecosystems. With respect to the North Dakota lignite industry, the objectives of the PCOR Partnership Phase II efforts are 1) to refine the technical and economic analyses of emerging CO_2 capture technologies for regional applications; 2) to match regional CO_2 sources with appropriate economically viable geologic sinks in North Dakota (i.e., tertiary EOR and/or ECBM projects); and 3) to develop a means by which a carbon credit market for geologic sequestration of CO_2 can be established, thereby enhancing and extending the economic life of the region's coal, oil, and gas fields. There are a number of complementary PCOR Partnership Phase II activities that are not specifically discussed herein. Among them are further regional characterization; research into safety, regulatory, and permitting issues; and public outreach and education. As shown in Figure 2, the goals of this program will be implemented through a management task (Task 1) and nine technical tasks (Tasks 2, 3, 4, 5, 6, 7, 8, 9, 10).

Methodology

The PCOR Partnership Phase II objectives that most directly match the goals of the North Dakota Industrial Commission (NDIC) Lignite Research Council (LRC) will be accomplished through three technology validation projects that focus on geologic sequestration and one terrestrial sequestration activity.

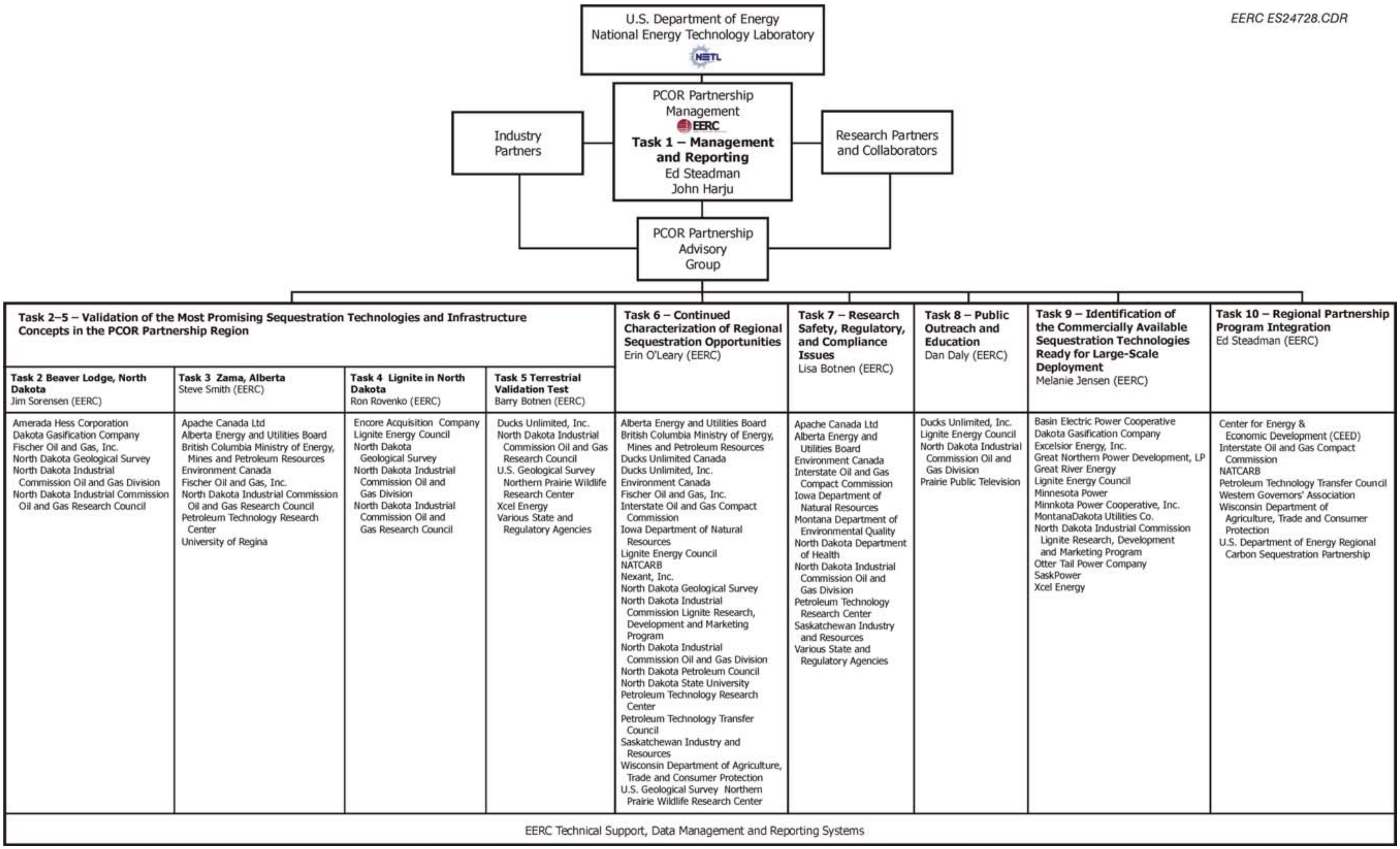


Figure 2. PCOR Partnership organizational chart.

In additions two investigations of commercially available sequestration technologies will be performed. The concept of using wind energy to meet a portion of the electrical demands for CO_2 compression for the DGC pipeline to Weyburn will be investigated. This will reduce the potential carbon credit penalty for CO_2 capture and compression in preparation for the monetization of geologic carbon credits. We will also develop potential CO_2 management options for a planned Excelsior Energy, Inc., integrated gasification combined cycle (IGCC) power plant to be constructed in Northern Minnesota in the 2010 to 2012 time frame. This will provide information needed to assess the technological and economic potential for carbon management for planned advanced power systems in our region.

The field demonstration activities at North Dakota locations include the incremental recovery of oil through tertiary operations in carbonate reservoirs in the Beaver Lodge Field and ECBM recovery through injection of CO_2 into the Harmon lignite seam in southwestern North Dakota. In addition, the terrestrial sequestration activity with Ducks Unlimited, Inc., will include North Dakota locations. The geologic sequestration field validation tests will be accomplished through a systematic 4-year design package. The objectives of the field validation tests are to establish the technical and economic feasibility of commercial-scale deployment of the sequestration activities. Methods of accomplishing these objectives for each validation test project include the following:

- Technical and economic analyses of emerging CO_2 capture technologies
- Continued regional source and sink matching activities
- Preinjection baseline site characterization
- Development and implementation of appropriate MMV protocols
- Public outreach activities

Anticipated Results

With respect to CO_2 sequestration markets, there is currently no well established carbon credit trading market for CO_2 sequestration in geologic formations. The key hurdles to establishing such a market are proving that 1) the injected CO_2 can be monitored and verified in manners that are technically accurate and cost- effective and 2) the injection and storage processes are safe. Using data generated by the field demonstrations, a Regional Technology Implementation Plan will be developed that will support the establishment of a carbon credit trading market for geologic sequestration of CO_2. The development of such a market will preserve and enhance the economic potential for North Dakota lignite by providing economic incentives for our partners and potentially avoiding burdensome and unnecessary regulation in the future.

With respect to matching regional CO_2 sources to EOR and ECBM projects in the PCOR Partnership Region, other PCOR Partnership Phase II tasks are focused on identifying potential new CO_2 providers. Under Phase II, the PCOR Partnership will further enhance working relationships with the lignite industry in North Dakota, as well as ethanol plants, cement plants, and other large CO_2 point sources in the PCOR Partnership region. Another PCOR Partnership Phase II task that will develop valuable information for the North Dakota energy industry will focus on the concept of utilizing wind energy to meet a portion of the electrical demands of CO_2 compression for the DGC pipeline. Data will be gathered and compiled for an investigation using wind power to support the energy requirements of two CO_2 compressors at DGC to enable additional CO_2 compression for resale and subsequent use in other EOR projects. This would allow the CO_2 producer to take credit for additional CO_2 reduction. CO_2 management options will be determined for a planned IGCC plant in Northern Minnesota. This will quantitatively evaluate the technical and economic factors associated with CO_2 sequestration from advanced power systems.

The PCOR Partnership partners are critical to the project’s success and will contribute through working groups focused on key topical areas. The EERC will manage and coordinate all project activities to ensure effective and timely reporting to LRC, collaboration with other RCSPs, and outreach to the public and the technical community.

PCOR Partnership Team

As shown in Table 1, the PCOR Partnership features a diverse, multipartner team under EERC leadership that brings together the key government, private sector, technical, and outreach groups needed to undertake the activities in the eight performance tasks. The PCOR Partnership team is well suited to assess the regional baseline and infrastructure and to involve stakeholders in developing commercially viable demonstration activities in Phase II. The PCOR Partnership team includes 1) industry sponsors that provide cost share and serve as advisors; 2) research partners that are funded under the PCOR Partnership venture; and 3) collaborators that, in most cases, provide in-kind support. The industry sponsors have significant and active operations in all nine states of the U.S. region and Canada. The knowledge base, expertise, and hands-on experience of the PCOR Partnership research team encompass the entire region.

PCOR Partnership Facilities and Capabilities

The EERC and its PCOR Partnership partners bring a unique combination of capabilities and facilities to the PCOR Partnership program. The EERC's 210,000 square feet of laboratory, technology demonstration, and office space, located on the University of North Dakota (UND) campus, house state-of-the-art facilities for analysis, fabrication, and laboratory-to pilot-scale testing and verification. All facilities are available for PCOR Partnership and RCSP Phase II activities. In addition, the EERC has the

Table 1. PCOR Partnership Team, Phase II

University of North Dakota Energy & Environmental Research Center (EERC)	Great River Energy	North Dakota Industrial Commission Oil and Gas Division
Alberta Energy and Utilities Board	Interstate Oil and Gas Compact Commission	North Dakota Industrial Commission Oil and Gas Research Council
Amerada Hess Corporation	Iowa Department of Natural Resources	North Dakota Natural Resources Trust
Apache Canada Ltd.	Lignite Energy Council	North Dakota Petroleum Council
Basin Electric Power Cooperative	Minnesota Power	North Dakota State University
British Columbia Ministry of Energy, Mines, and Petroleum Resources	Minnkota Power Cooperative, Inc.	Otter Tail Power Company
Center for Energy and Economic Development (CEED)	Montana–Dakota Utilities Co.	Petroleum Technology Transfer Council
Dakota Gasification Company	Montana Department of Environmental Quality	Prairie Public Television
Ducks Unlimited Canada	Natural Resources Canada	Saskatchewan Industry and Resources
Ducks Unlimited, Inc.	Nexant, Inc.	SaskPower
Eastern Iowa Community College District	North Dakota Department of Health	Wisconsin Department of Agriculture, Trade and Consumer Protection
Encore Acquisition Company	North Dakota Geological Survey	U.S. Department of Energy
Environment Canada	North Dakota Industrial Commission Department of Mineral Resources, Oil and Gas Division	U.S. Geological Survey Northern Prairie Wildlife Research Center
Excelsior Energy Inc.	North Dakota Industrial Commission Lignite Research, Development and Marketing Program	Western Governors' Association
Fischer Oil and Gas, Inc.		Xcel Energy
Great Northern Power Development, LP		

facilities, equipment, and experienced personnel to undertake 1) relational database design, 2) geographic information system (GIS) programming, 3) database applications and decision support tools, and 4) predictive modeling. The PCOR Partnership's industrial sponsors and collaborative partners have sites and facilities that will be used for the demonstration of CO_2 separation, transportation and capture technologies, and indirect and direct (disposal and value-added) sequestration during RCSP Phase II activities.

Environmental and Economic Impacts While Project is Under Way

The economic and environmental impacts of this project are profound. Because the PCOR Partnership region (and the Williston Basin of North Dakota in particular) is blessed with abundant opportunities for EOR and ECBM that are located near many of our lignite power production facilities, carbon management may prove to be more economical for North Dakota lignites than for competing fossil fuel-fired facilities. Because the Williston Basin has such a large potential sequestration capacity, our region is better poised for long-term fossil fuel-fired electrical generation than areas without these opportunities. Environmentally, we can be part of the solution to concerns over GHG emissions. Economically, the benefits to our state and region may be even greater. The EOR and ECBM activities investigated by the proposed work may extend the lifetime of our existing oil fields by as much as 30 years. These technologies can also facilitate the development of new oil and gas fields. Oil and gas production is very important to our state's economy and provides vital primary sector and tax revenue. Oil and gas activities are an increasingly important part of the overall electrical demand in the rural western counties of North Dakota, while the oil and gas industry needs the abundant affordable electricity that North Dakota's lignite generating stations provide; so partnerships between these two vital sectors of our economy are critical.

CO_2 is a GHG. In 2003, the Bush Administration, through DOE, launched an initiative to achieve reductions in CO_2 emissions in the United States through a variety of means, including sequestration in geological formations and terrestrial applications. The establishment of CO_2 EOR operations in North

Dakota could ultimately lead to the sequestration of millions of tons of CO_2 a year into deep geological formations. With respect to local impacts from project activities, each technology validation test will be designed and implemented according to applicable state and federal regulations to ensure that the environmental impact of the project activities are minimal. MMV activities will be conducted at each technology validation test site to ensure that shallow groundwater resources and the surface environment are not significantly impacted by the injection activities.

Ultimate Technological and Economic Impacts of Project

The activities within this project will support existing and future opportunities to derive value from the management of CO_2. A clear understanding of the opportunities for cost-effective carbon management options will be critical to expanding the lignite-based energy industry in North Dakota. The overall focus of this project is the development of market-based CO_2 sequestration options that are technically and economically feasible and ensure that lignite maintains its current role and enhances its future role as a critical part of North Dakota's economy.

The results of these field validation tests will be used to 1) refine the technical and economic analyses of emerging CO_2 capture technologies for regional applications, 2) demonstrate the feasibility of using captured CO_2 to enhance the production of hydrocarbons in North Dakota reservoirs, 3) exhibit the cost-effective use of North Dakota oil reservoirs and lignite coal seams for safe storage of CO_2, 4) establish a means by which a carbon credit market can facilitate economic carbon management, 5) evaluate terrestrial sequestration of CO_2 in wetland areas, 6) evaluate the use of wind energy for offsetting additional CO_2 emitted via CO_2 compression, and 7) evaluate CO_2 management options for a planned IGCC plant.

STANDARDS OF SUCCESS

The overall success of this project will be determined through the successful implementation of the plant. Phase II field validation tests and their subsequent commercial application within the PCOR Partnership region. This strategy is based on identifying the best candidate opportunities and addressing and solving the economic, technical, environmental, and regulatory concerns facing those opportunities. Ultimately, the goal of the PCOR Partnership is to develop market-based strategies for carbon management that are commercially viable in our region. Communication with a broad spectrum of stakeholders in this program will also be essential for its long-term success and will be at the forefront throughout the project.

BACKGROUND

Introduction

Phase I of the PCOR Partnership largely focused on characterizing the CO_2 sources and sinks in the region. The regional characterization activities conducted under Phase I confirmed that the numerous large stationary CO_2 emission sources are critical to our regional economy and that the region also has tremendous capacity for CO_2 sequestration through EOR and ECBM. EOR and ECBM are technologies that provide economic benefits to our industrial partners and enhance the regional economy. The variable nature of the sources and sinks reflects the geographic and socioeconomic diversity of the region. In North Dakota, large coal-fired power plants, ethanol plants, gas processing plants, and the refinery were identified as being significant CO_2 sources.

Several sinks already considered to be capable of sequestering large volumes of CO_2 were identified in North Dakota, including oil reservoirs, lignite coal seams, saline aquifers, and terrestrial sinks in the grasslands and Prairie Pothole Region. PCOR Partnership Phase II will focus on sequestration of CO_2 through injection into oil reservoirs and lignite coal seams for EOR and ECBM and restoration of Prairie Pothole Region wetlands. CO_2-based ECBM and EOR are value-added sequestration technologies that have the potential for future large-scale deployment in the region if pilot projects demonstrate their technical and economic feasibility. It is these near-term opportunity source–sink pairings that have been most closely scrutinized under Phase I and from which the field-based validation projects have been selected to be conducted under Phase II (see attached PCOR Partnership Prospectus in Appendix B).

The PCOR Partnership Phase I evaluations found that oil fields, coal seams, and saline aquifers evaluated to date in the PCOR Partnership region could sequester an estimated 230 billion tons of CO_2. This tremendous sequestration capacity enhances opportunities for the utilities in our region when compared to other areas, which lack such capacity. Among the region's largest CO_2 sources are coal-fired power plants located in western North Dakota that emit a total of 45 million tons of CO_2 each year. PCOR Partnership Phase I evaluations suggest that 79 years' worth of CO_2 emissions from those sources could be stored in western North Dakota's petroleum reservoirs as a result of EOR activities alone. Phase I results also suggest that coal seams in the region have significant CO_2 storage capacity. For example, the effective CO_2 storage capacity of the Harmon coal seam is estimated at 328 million tons (5.6 tcf). These lignite deposits have four key attributes that warrant their evaluations as a geologic CO_2 sequestration sink. First, they underlie or are located in close proximity to eight coal-fired power plants. Second, compared to higher-rank coals, the lignite deposits have a higher relative affinity for the sorption of CO_2 than methane. Third, unpublished data indicate that coalbed methane may be present in some of the Williston Basin coal seams, in which case the injection of CO_2 could result in commercially viable ECBM production. Fourth, the shallow depths and low temperatures of the low-rank coalbed reservoirs place them in the gas-phase area of the CO_2 phase diagram. This makes these sinks suitable for direct injection of CO_2 stripped from power plant flue gas streams without the energy and cost penalty requirements for compression to supercritical conditions.

PCOR Partnership Region Definition and Attributes

The PCOR Partnership region, shown in Figure 1, was defined on the basis of similarities in large stationary CO_2 sources, similarities in geologic and terrestrial CO_2 sinks, transport considerations for direct CO_2 sequestration, and the presence of two major value-added, anthropogenic CO_2–EOR sequestration projects. This combination of regional attributes, detailed below, makes the PCOR Partnership region well suited to successfully complete the demonstration activities leading to a far better understanding of CO_2 sequestration options for this region.

CO_2 Sources

In 2000, the PCOR Partnership region generated nearly 911 million tons of anthropogenic CO_2, about 13.1% of the U.S. and Canadian total. Table 2 shows that, for the region as a whole, electric utilities contributed a greater share of the emissions than other stationary sources.

Emissions from the transportation sector made up slightly less than one-fourth of the total. During the Phase I activities, more than 1,300 major individual stationary CO_2 sources were identified within the region. Table 3 summarizes the emissions of the largest of these major stationary sources and shows that while about two-thirds of regional CO_2 emissions result from electricity generation, other major point sources are significant and may provide key emission reduction opportunities, depending on quality, proximity to sinks, and economic viability.

Table 2. CO_2 Emissions in Million Tons of CO_2 for the PCOR Partnership Region During 2000

State/Province	Electric Utilities	Other Stationary	Transportation	Total
Iowa	38.47	27.59	20.60	86.66
Minnesota	35.13	32.28	38.33	105.74
Missouri	69.26	24.60	43.39	137.25
Montana	0.4[a]	26.09[a]	8.30	34.79
Nebraska	20.62	10.97	13.38	44.97
North Dakota	35.11	10.76	6.11	51.98
South Dakota	4.16	4.99	6.40	15.55
Wisconsin	47.15	38.20	32.68	118.03
Wyoming	47.53	12.75	8.70	68.98
Alberta	55.89	106.59	29.32	191.80
Manitoba	1.08	5.71	6.88	13.67
Saskatchewan	15.87	16.37	9.20	41.44
U.S. PCOR Partnership	297.83	188.23	177.89	663.95
Canada PCOR Partnership	72.84	128.67	45.40	246.91
PCOR Partnership	**370.67**	**316.90**	**223.29**	**910.86**
Canada Total (2)				**631.62**
U.S. Total (3)				**6305.85**

[a] Based on 1990–1999 data, it appears that the majority of the electric utility emissions during 2000 in Montana were considered to have emanated from the industrial sector, which is a subset of “Other Stationary” on this table. It is not possible to determine the fraction of the industrial sector that comprises electric utilities.

Table 3. Summary of Major Stationary CO_2 Sources in the PCOR Partnership Region

Source Type	Quantity	% of All Sources	CO_2 Emissions, million tons/yr	% of All CO_2 Emissions
Electricity Generation	170	12.2	370.67	65.7
Paper and Wood Products	141	10.1	35.40	6.3
Petroleum and Natural Gas Processing	32	2.3	28.94	5.1
Chemical and Fuels Production	43	3.1	24.16	4.3
Ethanol Production	63	4.5	16.43	2.9
Petroleum Refining	21	1.5	16.01	2.8
Cement/Clinker Production	16	1.1	13.94	2.5

Geological Sinks

The PCOR Partnership region has abundant geologic sink opportunities. Under PCOR Partnership Phase I, key reservoir characterization data were gathered for over 1500 oil fields in the oil-producing states and provinces of the region. Three saline aquifer systems that cover large portions of the region were evaluated under Phase I, and several more have been identified for evaluation under Phase II. Coal fields in the region were shown in Phase I to have significant CO_2 storage capacity.

Terrestrial Sinks

The PCOR Partnership region also contains many opportunities for terrestrial sequestration of CO_2. Terrestrial sequestration provides opportunities for sequestration that can occur without much further technological development. Terrestrial sequestration opportunities can be considered stop-gap or short-term solutions to carbon management. Terrestrial sinks include agricultural lands (e.g., croplands, grasslands, and range lands), forest lands, wetlands, and peat bogs. The PCOR Partnership region includes more than 302 million forested acres, more than 402 million agricultural acres (both farm- and rangeland), and more than 106 million peat bog acres. The Prairie Pothole Region includes 30.9 million acres of wetlands. While the amount of carbon that can be sequestered terrestrially is species- or location-dependent, gross estimates of sequestration capacity have been made by applying average sequestration rates to the available acreages.

Sequestration Infrastructure

Current sequestration infrastructure such as injection wells, MMV equipment, and pipelines for CO_2 delivery is available at varying degrees in the PCOR Partnership region. The oil and gas fields in North Dakota contain thousands of petroleum-related wells, many of which could potentially be utilized during CO_2 sequestration operations, especially as part of EOR.

A 12-in. CO_2 pipeline stretches for 204 miles from the DGC plant in Beulah, North Dakota, to the CO_2 flood EOR and sequestration demonstration project at Weyburn, Saskatchewan. The pipeline passes over some of the region's best geological sinks (i.e., North Dakota and Saskatchewan oil and coal fields, the Madison Saline Aquifer, and other potentially suitable saline aquifers) and could potentially provide CO_2 during sequestration demonstrations.

GHG Storage Capacity and Value-Added Benefits in the PCOR Partnership Region

The sequestration capacities estimated to date for the various sink types in the PCOR Partnership region are listed in Table 4. These data indicate that the geologic sinks evaluated to date can sequester roughly 75 billion tons of CO_2. This capacity could sequester all of the region's stationary CO_2 emissions for more than 100 years if the rate of emission were constant each year. The region's terrestrial sinks can sequester over 1 billion tons of CO_2 per year for at least the next 50 years, which is more than six times the region's annual transportation-related CO_2 emissions.

The sequestration options available in the PCOR Partnership region offer potential benefits to the lignite industry by continuing the operation of numerous oil and gas fields in EOR and/or ECBM recovery modes and enhancing the public's perceptions of lignite as a clean fuel that is critical to our present-day and future economy. An estimated 280 million barrels of oil could be recovered during EOR activities in western North Dakota alone. At a price of $51/bbl, these EOR activities would produce a salable product worth $14.2 billion while sequestering more than 5 billion tons of CO_2. The Wyodak–Anderson coal field in Wyoming and Montana could produce as much as 15.8 tcf of methane during

Table 4. Estimated Sequestration Capacity of Major CO_2 Sinks Evaluated To Date in PCOR Partnership Phase I

Sink Type	Sequestration Capacity, million tons CO_2	Sequestration Capacity, million tons CO_2/yr[a]
Saline Aquifers	220,000	
Powder River Basin Coal Seams	6800	
EOR in Selected Oil Fields	700	
North Dakota Lignite Deposits	380	
Forests		1044
Wetlands		149
Agricultural Lands (cropland, rangeland, and grasslands)		65
Peat Bogs		47
Regional Total	**227,880**	**1305**

[a] These values are estimates of total CO_2 sequestration potential. They were calculated by multiplying the rate of sequestration by acreage.

ECBM production. At the Henry Hub natural gas price of $6.33/mcf, the methane resulting from sequestration activities would bring $100 billion, while sequestering nearly 7 billion tons of CO_2. In addition to the primary sector and tax benefits to the state that this additional oil recovery will provide, the oil and gas production sector is an important customer for the electricity provided by North Dakota's lignite industry.

Terrestrial sequestration results from land management practices that promote carbon buildup in biomass and soils. These practices also have positive environmental effects and include adopting conservation tillage, which reduces soil erosion and minimizes soil disturbance; using buffer strips along waterways; enrolling land in conservation programs; restoring and better managing wetlands; restoring degraded lands; converting marginal croplands to wetlands or grasslands; eliminating summer fallow using perennial grasses and winter cover crops; and fostering an increase in forests. Participation in terrestrial sequestration projects will elevate the lignite industry's stature as responsible stewards of North Dakota's resources.

Based on carbon data on wetlands in cropland collected during 1997 by the U.S. Geological Survey (USGS) and the 1997 National Resources Inventory, restoration of cropland wetlands would result in the sequestration of more than 79 million tons of soil organic carbon in the U.S. Prairie Pothole Region. This preliminary estimate is conservative and does not account for carbon stores in wetland vegetative communities or for other GHG offsets associated with reduction in methane and nitrous oxide emissions; both GHG benefits are expected to be significant.

QUALIFICATIONS

The EERC has the proven ability to develop and lead multiyear, multidisciplinary, multiclient programs, including many public–private and stakeholder-based partnerships like the PCOR Partnership. The EERC was established in 1949 as a federal research facility under the U.S. Bureau of Mines and later became the lead laboratory for low-rank coals under DOE. The center was defederalized in 1983 and became a business unit of UND. The EERC currently has contract awards of $29 million, covering 405 active contracts, with 83% from the private sector. Since 1987, the EERC has worked with over 850 clients in all 50 states and in 47 countries. The EERC's multidisciplinary staff of more than 270 has maintained its leading role in coal research and has expanded its expertise and partnerships in a broad spectrum of energy and environmental programs. The EERC has successfully completed projects involving geological characterization of subsurface resources, experimental design, analytical methods development, groundwater quality, biomass-based energy, advanced power systems, atmospheric emission controls, reclamation of disturbed lands, disposal and value-added waste management, disposal site characterization, site remediation for oil and gas, cleanup of the federal weapons complex and industry sites, and training activities from a local to international scope.

The EERC's success has been supported by its long-standing partnership with the fossil fuel industry and DOE through the National Energy Technology Laboratory (NETL). The North Dakota LRC has been a particularly strong and valuable partner. Our success has been closely linked with the effective participation of the LRC. Our mutual goals of providing timely, practical results that benefit both the public and private sector have helped to keep North Dakota lignite a reasonably priced, reliable source of electricity. There have been many projects involving LRC–industry–government partnerships under the Jointly Sponsored Research Program (1988 to present) that have attracted more than $30 million of industrial cash support. The EERC has projects and strong working relationships with a number of other state and federal agencies including the U.S. Department of Defense, Department of the Interior, Environmental Protection Agency (EPA), Department of Agriculture, Geological Survey, and Agency for International Development.

Key personnel for the PCOR Partnership Phase II activities include select administrative and technical staff from all of the PCOR Partnership research partners, representing a broad range of scientific and engineering disciplines and real-world experience. Indeed, the success of Phase I was due to the commitment of our industry partners who are even more critical to the success of Phase II. Relevant EERC expertise includes project management; data management and GIS programming; geological characterization and assessment; permitting and regulation compliance; and public outreach. The PCOR Partnership members bring technical expertise in sources, systems, permitting and regulations, transportation, reservoir engineering, EOR, CO_2 sequestration (including value-added applications), and outreach.

VALUE TO NORTH DAKOTA

A vibrant and growing lignite industry is critical to the long-term economy of our state and region. Lignite provides a reliable low-cost source of electricity and reduces our dependence on foreign oil. The Great Plains Gasification Plant has pioneered alternative technologies for lignite utilization that may become even more critical in a future in which carbon management becomes a more important part of the complex interplay between energy and the environment. The Great Plains Gasification Plant has also provided a model for the commercial use of anthropogenic CO_2 for EOR. The DGC/EnCana Corporation EOR project has shown that carbon management can be a positive in terms of both the environment and the economic well-being of the industries involved. Even better news is that this type of progress was made without imposing regulatory pressure on the energy industries that provide so much to our quality of life.

The goal of the PCOR Partnership is to develop market-based solutions to carbon management issues that have the potential to benefit both the region's economy and environment. By developing these technologies and monetizing the carbon credits that result, it is the position of the PCOR Partnership that we can avoid GHG regulations in favor of incentives for our industrial partners. Phase I work has shown that our region has an abundance of geologic and terrestrial sinks for CO_2 sequestration and that this provides a competitive advantage to the energy industries in our region. By performing the proposed work, we will ensure that North Dakota's lignite industry will continue to lead the world in providing advanced technologies for the utilization of this abundant and critical resource.

The window of opportunity to take advantage of converging market forces to make carbon management an economic positive for our region is likely to be a small one. North Dakota's lignite industry has a history of seizing opportunities and leading in new technology development. We anticipate carbon management will be another opportunity in this regard.

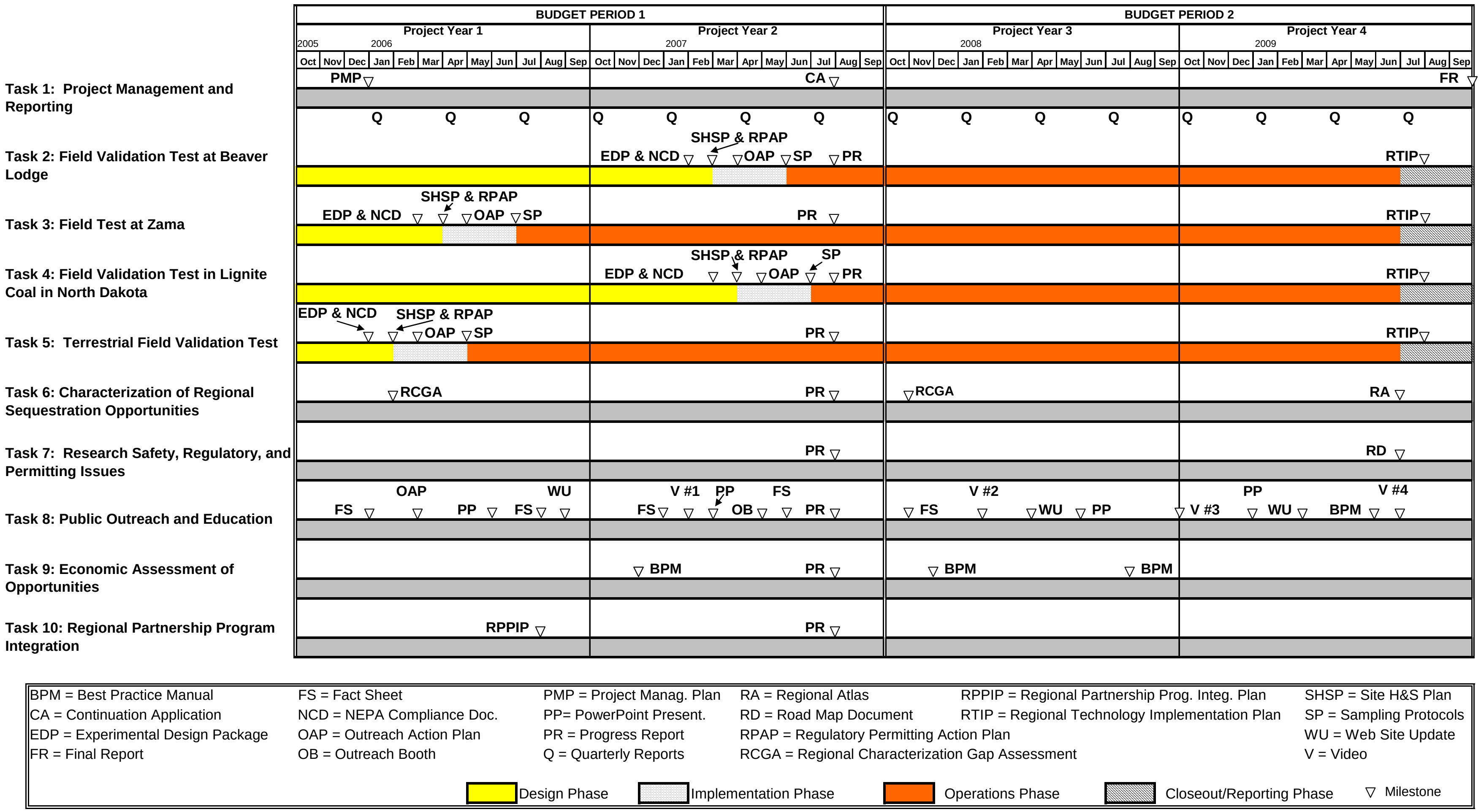
MANAGEMENT

Mr. Ed Steadman, EERC Senior Research Advisor, will serve as Project Manager of the Phase II PCOR Partnership. He will have overall responsibility for the contract and will interface regularly with the PCOR Partnership partners, principal investigators, and EERC senior management. He will be responsible for regular reporting to Lignite Research, Development and Marketing Program management and timely dissemination of information to other project partners. Other members of the project management team will include Mr. John Harju, EERC Associate Director for Research, and Dr. Michael Jones, EERC Senior Research Advisor. The project management team will focus on providing timely completion of milestones; timely, high-quality deliverables; and effective communication between the PCOR Partnership and the Lignite Research, Development and Marketing Program . Regular project review meetings (annual or as otherwise directed) between representatives of the PCOR Partnership and the Lignite Research, Development and Marketing Program will be scheduled.

TIMETABLE

Table 5 shows the project schedule for PCOR Partnership Phase II activities over a 4-year time frame. Only Tasks 2–5 are discussed in detail within this proposal.

Table 5. PCOR Partnership Phase II Project Schedule



BUDGET

The EERC is requesting $720,000 from the Lignite Research, Development and Marketing Program for PCOR Phase II. Additional cost share of $20,767,892 is shown in Table 6.

Cash commitments have been received from many industrial partners including Otter Tail Power Company, Xcel Energy, Great River Energy, Excelsior Energy, Inc., Great Northern Power Development, LP, and SaskPower. Additional cash support is anticipated from Montana–Dakota Utilities Co., Minnesota Power, Minnkota Power Cooperative, Inc., and Encore Acquisition Company. We further anticipate participation from additional industry sponsors as Phase II progresses. Their contributions, as well as funding from the Lignite Research, Development and Marketing Program, are critical to the success of this project, which is focused on using CO_2 from North Dakota lignite-fired facilities in technically, environmentally, and economically viable demonstration activities.

In-kind contributions from our partners total $5,572,892. Without these contributions the field validation testing would not be possible. The total project budget is necessary to adequately address the concerns surrounding the market-based management of CO_2 in North Dakota. The level of Lignite Research, Development and Marketing Program funding is critical to adequately represent the perspective of the North Dakota lignite industry in this project. Funding of a lesser amount is inadequate to demonstrate a serious commitment to considering the use of regional CO_2 resources for tertiary EOR projects in North Dakota. In funding Phase II of the PCOR Partnership, DOE assumes the Lignite Research, Development and Marketing Program will monetarily support the program as outlined in a letter from the Lignite Research, Development and Marketing Program to the EERC (see Appendix D). The scope of work developed for overall project funding assumes funding is received from the LRDMP. A detailed budget is provided in Appendix E.

Table 6. PCOR Partnership Cost Share

	Cash Cost Share					In-Kind Cost Share					Grand Total
Organization	Year 1	Year 2	Year 3	Year 4	Total	Year 1	Year 2	Year 3	Year 4	Total	
US DOE	$2,300,000	$4,000,000	$4,000,000	$4,000,000	$14,300,000						$14,300,000
NDIC-LRC	$180,000	$180,000	$180,000	$180,000	$720,000						$720,000
NDIC-OGRC	$125,000	$125,000	$125,000	$125,000	$500,000						$500,000
Excelsior	$15,000	$50,000	$15,000	$15,000	$95,000						$95,000
Great River Energy	$15,000	$15,000	$15,000	$15,000	$60,000						$60,000
Otter Tail Power	$15,000	$15,000	$15,000	$15,000	$60,000						$60,000
SaskPower	$15,000	$15,000	$15,000	$15,000	$60,000						$60,000
Xcel Energy	$15,000	$15,000	$15,000	$15,000	$60,000						$60,000
Great Northern Power	$15,000	$15,000	$15,000	$15,000	$60,000						$60,000
NDIC-OGD						$38,375	$38,599	$39,645	$40,689	$157,308	$157,308
NDGS						$34,532	$34,571	$35,493	$36,414	$141,010	$141,010
PPTV						$74,500	$77,338	$74,500	$49,850	$276,188	$276,188
NDSU						$12,478	$18,711	$18,711	$18,711	$68,611	$68,611
Ducks Unlimited						$44,800	$53,323	$55,462	$47,174	$200,759	$200,759
EUB						$153,486	$146,662	$143,561	$127,339	$571,048	$571,048
Apache Canada						$263,056	$1,098,094	$1,086,614	$710,204	$3,157,968	$3,157,968
Amerada Hess						$150,000	$350,000	$350,000	$150,000	$1,000,000	$1,000,000
TOTAL	**$2,695,000**	**$4,430,000**	**$4,395,000**	**$4,395,000**	**$15,915,000**	**$771,227**	**$1,817,298**	**$1,803,986**	**$1,180,381**	**$5,572,892**	**$21,487,892**

[1] Oil and Gas Research Council.
[2] Oil and Gas Division.
[3] North Dakota Geological Survey.
[4] Prairie Public Television.
[5] North Dakota State University.
[6] Energy and Utilities Board.

MATCHING FUNDS

Matching funds being provided to the PCOR Partnership Phase II program are detailed in Table 6.

TAX LIABILITY

The EERC—a research organization within UND, which is an institution of higher education within the state of North Dakota—is not a taxable entity.

CONFIDENTIAL INFORMATION

No confidential information is included in this proposal.

PATENTS AND RIGHTS TO TECHNICAL DATA

It is anticipated that no patents will be generated by PCOR Partnership Phase II activities. The rights to the technical data generated by this project will be held jointly by the EERC and the sponsoring partners.

REFERENCES

1. U.S. Department of Energy Office of Fossil Energy, National Energy Technology Laboratory. *Carbon Sequestration – Technology Road Map and Program Plan*, May 2005. http://www.netl.doe.gov/coal/Carbon%20Sequestration/pubs/2005%20roadmap_for%20web_revised_08022005.pdf.
2. Environment Canada. Canada's Greenhouse Gas Inventory 1990–2002. htt://www.ec.gc.ca/pdb/ghg/1990_02_report/cl_e.cfm (accessed Feb 2005).
3. Energy CO_2 Inventories. http://yosemite.epa.gov/oar/globalwarming.nsf/ UniqueKeyLookup/SVDN5SZKKA/$File/state_co2_ffc. pdf (accessed Jan 2005).

APPENDIX A

U.S. DEPARTMENT OF ENERGY PROPOSAL 2005-0200 – STATEMENT OF PROJECT OBJECTIVES

STATEMENT OF PROJECT OBJECTIVES
The Plains CO_2 Reduction Partnership

A. OBJECTIVES

The overall goal of the proposed work of Phase II of the Plains CO_2 Reduction (PCOR) Partnership is to validate the most promising sequestration technologies and infrastructure concepts that were identified in Phase I activities and to refine the regional characterization efforts started in Phase I.

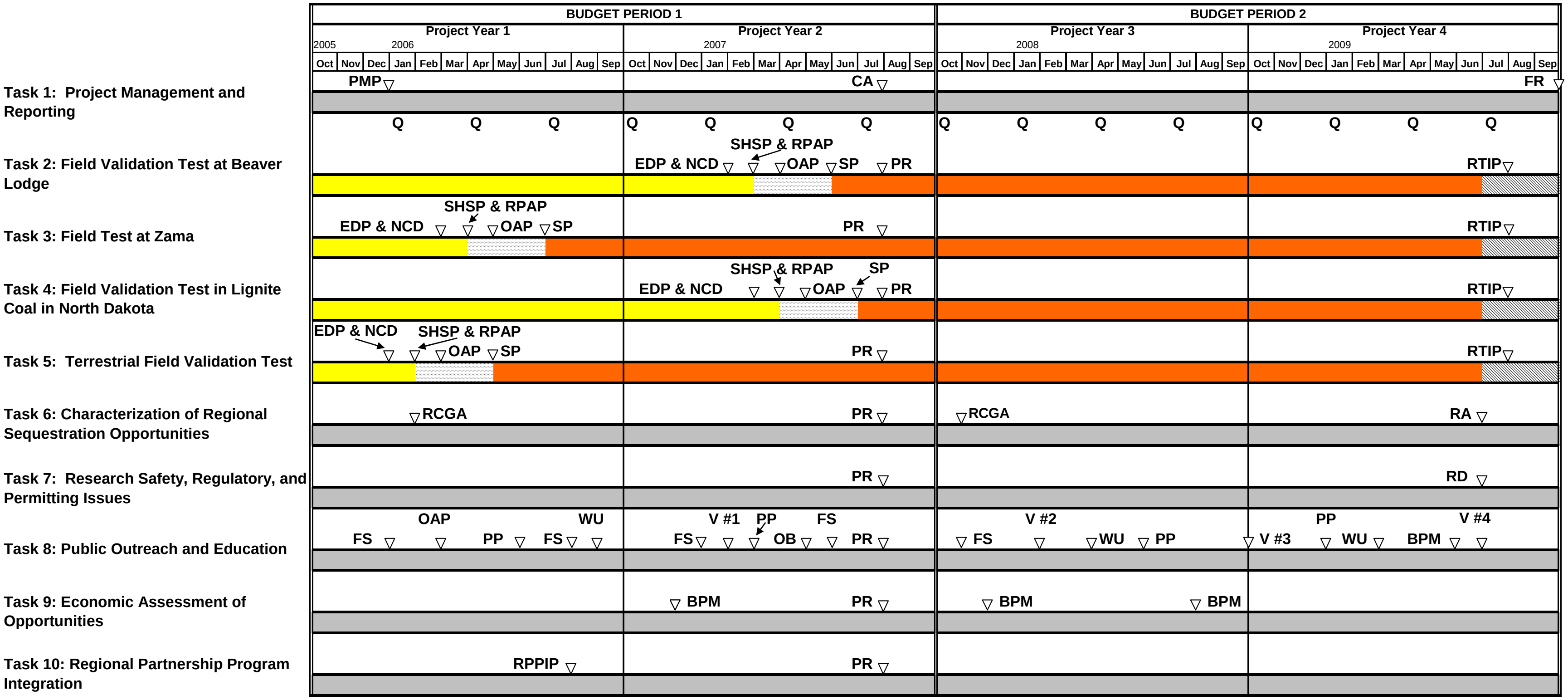
B. SCOPE OF WORK

The scope of work in Phase II is organized into ten tasks and two budget periods (Table 1). Deliverables include a continuation application, an outreach booth, a PowerPoint™ presentation, a regional atlas, road map documents, regulatory permitting action plans, regional permitting implementation outlines, four videos, an updated Web site, quarterly reports, design packages, sampling protocols, outreach action plans, progress reports, site health and safety plans, a regional characterization gap assessment, National Environmental Policy Act (NEPA) Compliance forms, project management plans, fact sheets, a Regional Partnership Program Integration Plan, and a Phase II final report that summarizes the results of the project.

C. TASKS TO BE PERFORMED

Ten tasks will be performed. Task 1 will consist of overall project management and development and distribution of required project reports. Tasks 2–5 are field validation tests. These field validation tests will assess the technical and economic feasibility of CO_2 sequestration options in the PCOR Partnership region. The ultimate goal of each of the field validation tests is to develop and evaluate monitoring, mitigation, and verification (MM&V) technologies and protocols for CO_2 sequestration. Task 6 will refine the characterization of the region with respect to CO_2 sinks and sources. Task 7 will satisfy project permitting requirements for all field validation activities and other regional sequestration opportunities. Task 8 will develop and implement carbon sequestration education and outreach mechanisms. Task 9 will assess the regional availability of commercial sequestration technologies ready

Table 1. PCOR Partnership Phase II Gantt Chart



BPM = Best Practice Manual	FS = Fact Sheet	PMP = Project Manag. Plan	RA = Regional Atlas	RPPIP = Regional Partnership Prog. Integ. Plan	SHSP = Site H&S Plan
CA = Continuation Application	NCD = NEPA Compliance Doc.	PP= PowerPoint Present.	RD = Road Map Document	RTIP = Regional Technology Implementation Plan	SP = Sampling Protocols
EDP = Experimental Design Package	OAP = Outreach Action Plan	PR = Progress Report	RPAP = Regulatory Permitting Action Plan		WU = Web Site Update
FR = Final Report	OB = Outreach Booth	Q = Quarterly Reports	RCGA = Regional Characterization Gap Assessment		V = Video

Design Phase | Implementation Phase | Operations Phase | Closeout/Reporting Phase | ▽ Milestone for large-scale deployment. Task 10 will ensure that the PCOR Partnership activities are integrated with other National Energy Technology Laboratory (NETL) Regional Carbon Sequestration Partnerships (RCSPs).

TASK 1.0 PROJECT MANAGEMENT AND REPORTING

Task 1 will include all project management and reporting activities.

1.1 Design Project Management and Reporting Plan

A project management plan will be delivered and submitted for U.S. Department of Energy (DOE) approval during the first quarter of the project.

1.2 Perform Project Management

1.2.1 Submit Quarterly PowerPoint™ Presentations

The PowerPoint presentations will summarize project status, results, budget, papers, and presentations.

1.2.2 Develop and Update Project Fact Sheets

The fact sheets will be developed and updated as requested by the DOE contracting officer's representative (COR).

1.2.3 Send Monthly E-Mail Updates on PCOR Partnership Activities

The monthly e-mail updates will be sent on or before the fifth of every month

1.2.4 Provide COR Briefings

The DOE COR will be provided with progress reports and briefings, as requested.

1.2.5 Prepare Technical Papers for Contractors' Review Meetings

1.2.6 Complete Continuation Application

A continuation application will be completed 60 days prior to the end of Budget Period 1.

1.2.7 Earned Value Management

Earned Value Management (EVM) principles will be applied to track project budgets and progress. EVM reports will be submitted to the DOE COR on a quarterly basis.

1.3 Develop PCOR Partnership Phase II Final Report

Task and subtask reports will be integrated and compiled into a comprehensive PCOR Partnership Phase II final report.

TASK 2.0 – CARBON SEQUESTRATION AND EOR FIELD VALIDATION TESTS AT BEAVER LODGE, NORTH DAKOTA

Activities will be conducted in the Beaver Lodge oil field in northwestern North Dakota to evaluate the potential for geological sequestration of CO_2 in a deep carbonate reservoir for the dual purpose of CO_2 sequestration and enhanced oil recovery (EOR). Phase I studies indicated that the Beaver Lodge Field may have up to 212 million tons of CO_2 storage capacity. The target injection zone for the project will be the Duperow Formation, which is located at a depth of between 10,000 and 10,500 ft.

2.1 Project Design

This task will involve developing an experimental design package and designing the safety, regulating, and permitting activities associated with the Beaver Lodge Field validation.

2.1.1 Experimental Design Package Focused on the Validation of CO_2 Sequestration in the Beaver Lodge Field

This package will be submitted to the DOE COR at least 30 days prior to commencing field work. The experimental design will include the following:

- NEPA compliance document
- Defined goals of the field test
- Identification of infrastructure requirements
- Baseline characterization design
- CO_2 flood design
- MM&V operations design for both surface and subsurface (monitoring wells)
- Data acquisition and evaluation of sequestration and EOR potential
- Closeout procedures

2.1.2 Safety, Regulatory, and Permitting

Permitting action plans will be designed in accordance with relevant local, state/provincial, and federal regulatory agencies for the validation project, as follows.

- Prepare and submit applications for permits required for the Beaver Lodge Field validation test to the appropriate local, state/provincial, and federal regulatory agencies.
- Develop courses of action to address key safety and regulatory issues identified under Task 7.
- Develop a health and safety plan describing potential hazards (both physical and chemical), listing emergency numbers, and outlining precautions to take while at the site.

2.2 Project Implementation

2.2.1 Public Outreach and Education

An outreach action plan will be designed and implemented to raise awareness among the public and other stakeholders about the activities and goals of the Beaver Lodge Field validation test. This plan will be submitted to the DOE COR for approval. Public outreach materials, such as a fact sheet describing the activities and results of the test, will be distributed. The following deliverables will be accomplished in Task 8:

- Videos produced by Prairie Public TV (PPTV) that describe sequestration methods, including, in part, geologic sequestration of the type being tested at Beaver Lodge Field, will be aired on local public television stations.
- A fact sheet that specifically describes the activities at the Beaver Lodge Field will be prepared and disseminated.
- Discussion with industrial partners will be conducted to assist them in developing public outreach plans, if so desired.
- Public outreach and education portions of the Regional Technology Implementation Plan (RTIP) will be provided.

2.2.2 Conduct Baseline Site Characterization

Baseline site characterization efforts for the Beaver Lodge Field validation test will include reservoir simulation modeling, calculations to estimate the expected storage capacity, and laboratory tests to predict possible interaction of the injected gases/fluids with the reservoir rock and fluids. Below is a list of general parameters that will be characterized.

- Surface characteristics
- Soil
- Groundwater
- Ecosystem
- Population
- Reservoir characteristics

2.2.3 Develop Sampling Protocols

A review of sampling requirements will be conducted to develop a sampling protocol to be submitted to the DOE COR.

2.2.4 Install or Gain Access to Injection Well(s)

Amerada Hess Corporation will provide the research team with access to the CO_2 injection well site.

2.2.5 Monitoring Wells

Amerada Hess Corporation will provide access to wells that may serve as monitoring wells. The following steps will be taken:

- Monitoring well locations will be selected.
- Where possible, existing wells will be utilized for MM&V activities. New wells may be drilled if existing wells are not suitable for MM&V activities.
- Monitoring wells will be instrumented with appropriate MM&V technologies. Specific technologies will be selected jointly by the research team and Amerada Hess Corporation.

2.2.6 Install Surface/Shallow Surface Monitoring Equipment

Appropriate equipment will be installed to monitor surface and shallow subsurface conditions. Parameters to be monitored include air quality, soil vapor gas composition, and shallow groundwater pH.

2.2.7 Determine Preinjection Reservoir Characteristics

Amerada Hess Corporation will provide a detailed analysis of the pre-injection reservoir conditions.

2.3 Project Operations

2.3.1 Injection of CO_2 into Reservoir

Amerada Hess Corporation plans to purchase CO_2 from the Dakota Gasification Company (DGC) and transport it via pipeline to the Beaver Lodge Field where it will be injected into the target reservoir. A minimum of 3000 tons of CO_2 will be injected over the course of the validation test.

2.3.2 Monitoring of Injection Data

- The dynamic response of the reservoir fluids to CO_2 injection will be monitored. Field-based activities will be conducted to monitor pressure, pH, resistivity, changes in bulk fluid density, and volume.
- Wellbore integrity will be conducted. Laboratory analyses of the stability and reactivity of cements and/or casings in response to CO_2 and modified formation fluids will be performed. Additional assessments (i.e., bond logs) of the integrity of the injection well and other wells in the vicinity may be performed.

2.3.3 Monitoring of Reservoir

Stress regimes and geochemical properties will be monitored. The dynamic response of the injection zone and bounding rocks at the injection site will be monitored for changes over the course of the project. Seismicity within the reservoir may also be monitored.

2.3.4 Monitoring of Surface and Subsurface to Ensure Containment

Surface and shallow subsurface conditions will be monitored on a regular basis to ensure that the injected CO_2 is being contained. Parameters to be monitored include air quality, soil vapor gas composition, and shallow groundwater pH.

2.3.5 Sampling Strategy

A sampling strategy will be developed and employed to measure and mitigate leakage from existing wells in the field.

2.4 Closeout and Reporting

Closeout and reporting activities will be conducted.

2.4.1 Progress Reports

Quarterly reports will be provided throughout Task 2. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

2.4.2 Postinjection Monitoring and Assessment

The following parameters will be included in a suite of activities used to assess the condition of the reservoir with respect to CO_2 sequestration and EOR effectiveness:

- Reservoir pressure data
- Downhole temperature
- pH
- Resistivity
- Changes in bulk fluid density and volume within the reservoir

2.4.3 Summarize Results from Testing, Sequestration Potential, and EOR Recovery

Preinjection predictions regarding the nature of CO_2 in the target reservoir will be compared to postinjection reservoir conditions as monitored over the duration of the study period. The goals of this subtask will be to determine 1) the reliability of the preinjection modeling predictions and calculations, 2) the fate of injected CO_2 within the target reservoir, and 3) the effectiveness of the injected CO_2 for enhancing oil recovery from the reservoir. Reliability of the preinjection modeling predictions and calculations with respect to CO_2 sequestration potential will be assessed using material balances, by determination of the percentage of effective utilization of the available storage capacity, and through evaluation of the postinjection reservoir conditions. The long-term fate of the injected CO_2 will be determined through monitoring activities. The impact on EOR will be determined by quantifying the incremental oil recovery associated with CO_2 injection.

2.4.4 Develop Regional Technology Implementation Plan

The results of this field validation test will be used to develop an RTIP. The plan will provide technical guidance on approaches for conducting baseline surveys, MM&V, and assessing the overall success of injecting CO_2 into deep oil reservoirs for the purpose of simultaneous CO_2 sequestration and EOR.

TASK 3.0 – CARBON SEQUESTRATION AND EOR FIELD TEST AT ZAMA, ALBERTA

The field validation test conducted in the Zama Field of Alberta will evaluate the potential for geological sequestration of CO_2 as part of a gas stream that also includes high concentrations of H_2S. The acid gas will be injected for the concurrent purposes of CO_2 sequestration, H_2S disposal, and EOR. The results of the Zama activities will provide insight regarding the impact of high concentrations of H_2S (30% or greater) on sink integrity (i.e., seal degradation), MM&V, and EOR success within a carbonate reservoir. The acid gas will be obtained from the Zama gas-processing plant and injected into a pinnacle reef at a depth of approximately 4900 feet.

3.1 Project Design

This task will involve developing an experimental design package and designing the safety, regulating, and permitting activities associated with the Zama Field validation test.

3.1.1 Experimental Design Package Focused on the Validation of CO_2 Sequestration in the Zama Field

This package will be submitted to the DOE COR at least 30 days prior to commencing field work. The experimental design will include the following:

- NEPA compliance document
- Defined goals of the field test
- Identification of infrastructure requirements
- Baseline characterization design
- Reservoir modeling
- CO_2 flood design
- MM&V operations design for both surface and subsurface (monitoring wells)
- Data acquisition and evaluation of sequestration and EOR potential
- Closeout procedures

3.1.2 Safety, Regulatory, and Permitting

Permitting action plans will be designed in accordance with relevant local, state/provincial, and federal regulatory agencies for the validation project as follows:

- Prepare and submit applications for permits required for the Zama Field validation test to the appropriate local, state/provincial, and federal regulatory agencies.
- Develop courses of action to address key safety and regulatory issues identified under Task 7.
- Develop a health and safety plan describing potential hazards (both physical and chemical), listing emergency numbers, and outlining precautions to take while at the site.

3.2 Project Implementation

3.2.1 Public Outreach and Education

An outreach action plan will be designed and implemented to raise awareness among the public and other stakeholders about the activities and goals of the Zama Field validation test. This plan will be submitted to the DOE COR for approval. Public outreach materials, such as a fact sheet describing the activities and results of the test, will be distributed. The following deliverables will be accomplished in Task 8:

- Videos produced by PPTV that describe sequestration methods, including, in part, geologic sequestration of the type being tested at Zama Field, will be made available to the general public in Alberta.
- A fact sheet that specifically describes the activities at the Zama Field will be prepared and disseminated.
- Discussion with industrial partners will be conducted to assist them in developing public outreach plans, if so desired.
- Public outreach and education portions of the RTIP will be provided.

3.2.2 Conduct Baseline Site Characterization

Baseline site characterization efforts for the Zama Field validation test will include reservoir simulation modeling, calculations to estimate the expected storage capacity, and laboratory tests to predict possible interaction of the injected gases/fluids with the reservoir rock and fluids. Below is a list of general parameters that will be characterized:

- Surface characteristics
- Soil
- Groundwater
- Ecosystem
- Population
- Reservoir characteristics
- Seismic characteristics
- Reservoir simulation

3.2.3 Sampling Protocols

A review of sampling requirements will be conducted to develop a sampling protocol to be submitted to the DOE COR.

3.2.4 Access to Injection Well(s)

Apache Canada Ltd. will provide the research team with access to the acid gas injection well site.

3.2.5 Monitoring Wells

Apache Canada Ltd. will provide access to wells that may serve as monitoring wells. The following steps will be taken:

- Monitoring well locations will be selected. Where possible, existing wells will be utilized for MM&V activities. New wells may be drilled if existing wells are not suitable for MM&V activities.
- MM&V instruments will be installed.

- Monitoring wells will be instrumented with appropriate MM&V technologies. Specific technologies will be selected jointly by the research team and Apache Canada Ltd.

3.2.6 Surface/Shallow Surface Monitoring Equipment

Appropriate equipment will be installed to monitor surface and shallow subsurface conditions. Parameters to be considered for monitoring include air quality, soil vapor gas composition, and shallow groundwater pH.

3.2.7 Preinjection Reservoir Characteristics

Apache Canada Ltd. will provide a detailed analysis of the preinjection reservoir conditions.

3.3 Project Operations

3.3.1 Injection of Acid Gas into Reservoir

Apache Canada Ltd. plans to utilize acid gas from the Zama gas plant, which is owned and operated by Apache Canada Ltd., and transport it via pipeline to the Zama Field where it will be injected into the target reservoir. Approximately 250,000 tons of CO_2 will be injected over the course of the validation test.

3.3.2 Monitoring of Injection Data

- The dynamic response of reservoir fluids to acid gas injection will be monitored. Field-based activities will be conducted to monitor pressure, pH, resistivity, changes in bulk fluid density, and volume.
- Wellbore integrity will be conducted. Laboratory analyses of the stability and reactivity of cements and/or casings in response to acid gas and modified formation fluids will be performed. Additional assessments (e.g., bond logs) of the integrity of the injection well and other wells in the vicinity may be performed.

3.3.3 Monitoring of Reservoir

Stress regimes and geochemical properties will be monitored. The dynamic response of the injection zone and bounding rocks at the injection site will be monitored for changes over the course of the project. Seismicity within the reservoir may also be monitored.

3.3.4 Monitoring of Surface and Subsurface to Ensure Containment

Surface and shallow subsurface conditions will be monitored on a regular basis to ensure that the injected acid gas is being contained. Parameters to be monitored include air quality, soil vapor gas composition, and shallow groundwater pH.

3.3.5 Sampling Strategy

A sampling strategy will be developed and employed to measure and mitigate leakage from existing wells in the field.

3.4 Closeout and Reporting

Closeout and reporting activities will be conducted.

3.4.1 Progress Reports

Quarterly reports will be provided throughout Task 3. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

3.4.2 Postinjection Monitoring and Assessment

The following parameters will be included in a suite of activities used to assess the condition of the reservoir with respect to CO_2 sequestration and EOR effectiveness:

- Downhole temperature
- Pressure
- pH
- Resistivity
- Changes in bulk fluid density and volume within the reservoir

3.4.3 Summary of Results from Testing, Sequestration Potential, and EOR Recovery

Preinjection predictions regarding the nature of acid gas in the target reservoir will be compared to postinjection reservoir conditions as monitored over the duration of the study period. The goals of this subtask will be to determine 1) the reliability of the preinjection modeling predictions and calculations, 2) the fate of injected acid gas within the target reservoir, and 3) the effectiveness of the injected acid gas for enhancing oil recovery from the reservoir. Reliability of the preinjection modeling predictions and calculations with respect to acid gas sequestration potential will be assessed using material balances, by determination of the percentage of effective utilization of the available storage capacity, and through evaluation of the post injection reservoir conditions. The long-term fate of acid gas injection with respect to on-site conditions will be evaluated through monitoring activities. The impact on EOR will be determined by quantifying the incremental oil recovery associated with acid gas injection.

3.4.4 Regional Technology Implementation Plan

The results of this field validation test will be used to develop an RTIP. The plan will provide technical guidance on approaches for conducting baseline surveys, MM&V, and assessing the overall success of injecting acid gas into deep oil reservoirs for the purpose of simultaneous CO_2 sequestration, EOR, and acid gas disposal.

TASK 4.0 – CARBON SEQUESTRATION AND ECBM RECOVERY FIELD VALIDATION TEST IN LIGNITE IN NORTH DAKOTA

The effectiveness of lignite seams to act as sinks for CO_2 during simultaneous CO_2 sequestration and enhanced coalbed methane (ECBM) production will be evaluated in the Williston Basin. CO_2 from an undetermined source will be injected into the Harmon coal seam to examine whether long-term contact with CO_2 affects the physical stability and gas storage capacity properties of lignite. Preliminary estimates of the potential coalbed methane reserves and effective CO_2 storage capacity of the Harmon coal seam have been tabulated under PCOR Partnership Phase I. The total coalbed methane gas in place for the Harmon coal seam is approximately 4.4 tcf, and the effective storage capacity is estimated at 5.6 tcf (328 million tons). Together, these calculations support the conclusion that further evaluation of the Harmon coal seam is desirable.

4.1 Project Design

This task will involve developing an experimental design package and designing the safety, regulating, and permitting activities associated with the lignite field validation test.

4.1.1 Experimental Design Package Focused on the Validation of CO_2 Sequestration in the Williston Basin Lignite Field

This package will be submitted to the DOE COR at least 30 days prior to commencing field work. The experimental design will include the following:

- NEPA compliance document
- Defined goals of the field test
- Identification of infrastructure requirements
- Baseline characterization design
- CO_2 flood design
- MM&V operations design for both surface and subsurface (monitoring wells)
- Data acquisition and evaluation of sequestration and ECBM production
- Closeout procedures

4.1.2 Safety, Regulatory, and Permitting

Permitting action plans will be designed in accordance with relevant local, state/provincial, and federal regulatory agencies for the validation project as follows:

- Prepare and submit applications for permits required for the lignite field validation test to the appropriate local, state/provincial, and federal regulatory agencies.
- Develop courses of action to address key safety and regulatory issues identified under Task 7.
- Develop a health and safety plan describing potential hazards (both physical and chemical), listing emergency numbers, and outlining precautions to take while at the site.

4.2 Project Implementation

4.2.1 Public Outreach and Education

An outreach action plan will be designed and implemented to raise awareness among the public and other stakeholders about the activities and goals of the lignite field validation test. This plan will be submitted to the DOE COR for approval. Public outreach materials, such as a fact sheet describing the activities and results of the test, will be distributed. The following deliverables will be accomplished in Task 8:

- Videos produced by PPTV that describe sequestration methods, including, in part, geologic sequestration of the type being tested in the lignite field, will be aired on local public television stations.
- A fact sheet that specifically describes the activities at the lignite field will be prepared and disseminated.
- Discussion with industrial partners will be conducted to assist them in developing public outreach plans, if so desired.
- Public outreach and education portions of the RTIP will be provided.

4.2.2 Baseline Site Characterization

Baseline site characterization efforts for the lignite field validation test will include reservoir simulation modeling, calculations to estimate the expected storage capacity, and laboratory tests to predict possible interaction of the injected gases/fluids with the reservoir rock and fluids. Below is a list of general parameters that will be characterized:

- Surface characteristics
- Soil
- Groundwater
- Ecosystem
- Population
- Reservoir characteristics

4.2.3 Sampling Protocols

A review of sampling requirements will be conducted to develop a sampling protocol to be submitted to the DOE COR.

4.2.4 Access to Injection Well(s)

A commercial partner will provide the research team with access to the CO_2 injection well site.

4.2.5 Monitoring Wells

The commercial partner will provide access to wells that may serve as monitoring wells. The following steps will be taken:

- Monitoring well locations will be selected. Where possible, existing wells will be utilized for MM&V activities. New wells may be drilled if existing wells are not suitable for MM&V activities.
- MM&V instrumentation will be installed. Monitoring wells will be instrumented with appropriate MM&V technologies. Specific technologies will be selected jointly by the research team and the commercial sponsor.

4.2.6 Surface/Shallow Surface Monitoring Equipment

Appropriate equipment will be installed to monitor surface and shallow subsurface conditions. Parameters to be monitored include air quality, soil vapor gas composition, and shallow groundwater pH.

4.2.7 Preinjection Reservoir Characteristics

The research team will provide a detailed analysis of the preinjection reservoir conditions.

4.3 Project Operations

4.3.1 Injection of CO_2 into Reservoir

The commercial partner will purchase CO_2 from an undesignated commercial vendor of CO_2 and transport it via truck to the lignite coal field where it will be injected into the target reservoir. A minimum of 500 tons of CO_2 will be injected over the course of the validation test.

4.3.2 Monitoring of Injection Data

The dynamic response of reservoir fluids to CO_2 injection will be monitored. Field-based activities will be conducted to monitor pressure, pH, and hydraulic conductivity of the reservoir.

4.3.3 Monitoring of Reservoir

Stress regimes and geochemical properties of the reservoir and bounding rocks will be monitored. The dynamic response of the injection zone and bounding rocks at the injection site will be monitored for changes over the course of the project.

4.3.4 Monitoring of Surface and Subsurface to Ensure Containment

Surface and shallow subsurface conditions will be monitored on a regular basis to ensure that the injected CO_2 is being contained. Parameters to be monitored include air quality, soil vapor gas composition, and shallow groundwater pH.

4.3.5 Sampling Strategy

A sampling strategy will be developed and employed to measure and mitigate leakage from existing wells in the field.

4.4 Closeout and Reporting

Closeout and reporting activities will be conducted.

4.4.1 Progress Reports

Quarterly reports will be provided throughout Task 4. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

4.4.2 Postinjection Monitoring and Assessment

The following parameters will be included in a suite of activities used to assess the condition of the reservoir with respect to CO_2 sequestration and EOR effectiveness:

- Downhole temperature
- Pressure
- pH
- Resistivity
- Changes in bulk fluid density and volume within the reservoir

4.4.3 Results from Testing, Sequestration Potential, and EOR Recovery

Preinjection predictions regarding the nature of CO_2 in the target reservoir will be compared to postinjection reservoir conditions as monitored over the duration of the study period. The goals of this subtask will be to determine 1) the reliability of the preinjection modeling predictions and calculations, 2) the fate of injected CO_2 within the target reservoir, and 3) the effectiveness of the injected CO_2 for ECBM recovery from the reservoir. Reliability of the preinjection modeling predictions and calculations with respect to CO_2 sequestration potential will be assessed using material balances, by determination of the percentage of effective utilization of the available storage capacity, and through evaluation of the postinjection reservoir conditions. The long-term fate of the injected CO_2 will be determined through monitoring activities. The impact on ECBM will be determined by quantifying the incremental methane recovery associated with CO_2 injection.

4.4.4 Regional Technology Implementation Plan

The results of this field validation test will be used to develop a RTIP. The plan will provide technical guidance on approaches for conducting baseline surveys, MM&V, and assessing the overall success of injecting CO_2 into lignite coal reservoirs for the purpose of simultaneous CO_2 sequestration and ECBM.

TASK 5.0 – TERRESTRIAL FIELD VALIDATION AND QUANTIFICATION – PRAIRIE POTHOLE WETLANDS

The objective of the terrestrial field validation is to develop the technical capacity to systematically identify, develop, and apply alternate land use management practices to the prairie pothole ecosystem (at both a local and regional scale) that will result in greenhouse gas (GHG) reductions. These reductions will include emission removals achieved by defining best management practices for sequestering carbon and reducing GHGs, including restoring the wetland/grassland complexes. The overarching research will result in the quantification of the amount of carbon sequestered in restored grassland systems such as Conservation Reserve Program (CRP), and provide a standardized estimate of carbon sequestered under various grassland management regimes throughout the project area. The following task structure is designed to effectively validate and quantify carbon sequestration potential in the PCOR Partnership region and determine the economic feasibility of terrestrial sequestration offsets based on the socioeconomic drivers affecting land use change.

5.1 Project Design

This task will involve developing an experimental design package including the safety, regulating, and permitting required for this field validation test.

5.1.1 Experimental Design Package Focused on the Validation of Terrestrial CO_2 Sequestration Methods

This package will be submitted to the DOE COR at least 30 days prior to commencing field work. Experimental design activities will include the following:

- NEPA compliance document
- Defined goals of the field test
- MM&V operations design

5.1.2 Compiling Design Criteria

Spatial geographic information system (GIS) and empirical data will be compiled to determine sample distribution and strata. These data may include soil type, existing land use, crop history, land values, etc. Ducks Unlimited, Inc., will obtain spatial layers for soils, native grasslands, cropland, wetlands, and other land cover classifications for this area. These activities will be coordinated with, and supported by, ongoing field research being performed by the U.S. Geological Survey (USGS) and Ducks Unlimited Canada. These data will be used to select sequestration/price discovery trial sites in proximity to monitoring and research stations.

5.1.3 Developing and Implementing a Web-Based Landowner Outreach Strategy

This Web site will serve as the reference resource and primary communication outlet to inform, engage, and solicit participation in the carbon offset feasibility element of this project. The site will address the options for sequestration practices, the carbon sequestration potential of the practices, and best management practices for retaining sequestered carbon. By providing site-specific information on their property, landowners can evaluate alternative carbon sequestration scenarios in an interactive environment.

5.1.4 Safety, Regulatory, and Permitting

Action plans will be designed in accordance with relevant local, state/provincial, and federal regulatory agencies for the validation project as follows:

- Prepare and submit applications for permits required for the validation project to the appropriate local, state/provincial, and federal regulatory agencies.
- Develop courses of action to address key safety and regulatory issues identified under Task 7.
- Develop a health and safety plan describing potential hazards (both physical and chemical), listing emergency numbers, and outlining precautions to take while at the site.

5.2 Project Implementation

This portion of the project will provide the necessary background materials that will facilitate project operations.

5.2.1 Preparation and Distribution of Informational Materials to Solicit Participation in the Carbon Offset Feasibility Study

Printed and electronic communications will be used to determine landowner interest in adopting land use management practices for carbon offsets. Feasibility will be determined by completing trend analysis on past and current land use practices and developing a price discovery survey for establishing the costs for effecting land use change on privately owned properties. Printed materials will complement and reinforce the Web site content and provide information for landowners interested in restoring grasslands and wetlands that will sequester carbon.

5.2.2 Transactions

Ducks Unlimited, Inc., staff will complete grassland and wetland complex restoration on one or more properties in the project area in order to establish baseline carbon levels and monitoring stations for prairie grassland carbon sequestration rates. Detailed information on the carbon sequestration project sites will be entered and tracked in Ducks Unlimited, Inc.'s carbon offset system in accordance with DOE guidelines that recommend accurate and complete accounting of GHG emissions and activities that reduce, avoid, and sequester GHG emissions. Terrestrial sequestration projects also require data-tracking consistency and transparency across project types to enhance the credibility of the offset projects portfolio with stakeholders and investors.

5.2.3 Public Outreach and Education

An outreach action plan will be designed and implemented to raise awareness among the public and other stakeholders about the activities and goals of the terrestrial feasibility research. This plan will be submitted to the DOE COR for approval. Public outreach materials, such as a fact sheet, describing the activities and results of the test will be distributed. The following deliverables will be accomplished:

- Videos produced by PPTV that describe sequestration methods, including, in part, the terrestrial sequestration of the type being tested will be aired on local public television stations.
- A fact sheet that specifically describes the activities at the terrestrial field validation test sites will be prepared and disseminated.
- Discussions with industrial partners will be conducted to assist them in developing public outreach plans, if so desired.
- Public outreach and education portions of the RTIP will be provided.

5.3 Project Operations

5.3.1 Survey Data Compilation and Analysis

Data will be collected, reviewed, and analyzed to quantify the carbon offsets realized in three main elements of stratification: 1) previous cultivation history on-site, 2) soil type, and 3) age of restored grassland stand. Cost efficacy from both the carbon investor and landowner perspective will be compared to cropland rental rates and Farm Bill CRP payments by state/county, since these define the alternative competing uses of the land base. Statistical analyses will be conducted resulting in a regional, willingness-to-sell price point analysis that may include commodity prices/trends and other drivers for land conversion in the region.

5.3.2 GIS Modeling to Extrapolate Site-Specific Survey Information to the Region

Land values and rental rates vary markedly across the PCOR Partnership region. Thus, from an economic standpoint, carbon sequestration potential must be balanced with the cost of easement acquisition and grassland/wetland restoration expense. To evaluate this tradeoff, estimated carbon price point values will be overlaid with spatial data on carbon sequestration potential to conduct a cost-benefit, spatial analysis. This modeling effort will result in map products that depict the estimated carbon sequestration potential per unit cost, thereby identifying the most profitable areas in which to implement an operational terrestrial carbon sequestration program.

5.3.3 Indirect Benefits

Other economic incentives that may result from agricultural land restoration, such as water quality, erosion control, flood buffering, and recreational and wildlife benefits, will be identified and, when possible, quantified. Emerging nutrient credits (nitrogen, phosphorus, and turbidity) that would provide incremental environmental returns will be considered. Potential restoration sites will be compared to existing decision support models or restoration priorities in the region.

5.3.4 Regional Partnerships for CO_2 Sequestration

The carbon management community will be engaged in further defining and refining the infrastructure needs of an effective regional partnership. Agricultural landowners will also be invited to define and address issues at the on-the-ground level.

5.3.5 Business Flow Process for Carbon Credit Trading

In anticipation of market trading of offsets in the PCOR Partnership region, business flow processes will be developed to provide a transparent framework for transacting carbon credits resulting from grassland sequestration. The information resulting from Phase II will be invaluable in correlating environmental benefits, carbon offsets, and financial returns associated with wide-scale deployment of terrestrial carbon sequestration.

5.3.6 Assessment of the Economic Feasibility of Increasing Soil Carbon and Sequestering Atmospheric Carbon Through Modifying Established Practices of Land Management at the Landscape Level

This assessment will be performed by assembling information on socioeconomic drivers for land conversion, including past, current, and future (predicted) payments for government programs such as CRP as well as an evaluation of commodity prices that may compete with a carbon aggregation program. At the scale of the individual landowner, two primary issues will be addressed: 1) the effects of restoring agricultural lands on annual cash flow and net present value (NPV) of alternative income sources and

2) the level of cash payments necessary to stimulate changes to grasslands that would be needed for carbon offset sales. Recognizing that NPV calculations do not address problems associated with the unevenness of cash flow and the uncertainties of future income sources, the potential for financial intermediaries to make upfront payments in exchange for the rights to future carbon sales will be assessed.

5.3.7 Identification of Land Use Management Practices that Increase Soil Organic Material such as Those Related to Restoration or Preservation of Grassland

The impacts of grazing and other land-use management options on carbon sequestration will be synthesized. Existing research on land management and carbon sequestration rates that can be used to estimate or calculate carbon for each management practice will be compiled. This effort will be conducted in cooperation with USGS, which will monitor the carbon flux in test plots and extrapolate the results throughout the Prairie Pothole Region by comparing results with other study sites. Guidelines for management of wetland hydrology to enhance carbon sequestration potential will be developed.

5.4 Closeout and Reporting

5.4.1 Progress Report Provided to the DOE COR

Quarterly reports will be provided throughout Task 5. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

5.4.2 Regional Technology Implementation Plan

A private carbon/conservation easement legal document, with a site management plan that allows aggregation of carbon offsets, will be developed. The document will specify guidelines for land use management practices consistent with carbon sequestration and emission reduction offset and contain protocols and budgets necessary for monitoring easement compliance. Criteria for a legal document to transfer carbon to the investor will make up the final portion of the RTIP.

Task 6.0 – Continued Characterization of Regional Sequestration Opportunities

6.1 Regional Characterization Gap Assessment

At the beginning of each budget period, an assessment will be performed to identify any continued regional characterization needs. A plan to address source- and sink-related data gaps will be developed in which missing data and resources needed to complete characterization of the region will be identified.

6.2 Data Collection

New data made available to the PCOR Partnership will be incorporated into the PCOR Partnership Decision Support System (DSS), including the following:

- Major CO_2 sources that have come online since the original data were collected.
- Characterization data for potential geologic sinks from areas not previously examined within the region.
- Sequestration potential for peat bogs, riverine and lacustrine areas, and forests within the PCOR Partnership region. Data generated as a result of the validation tests.
- Confidential data will be appropriately secured for members and/or validation test team use.
- Data accumulated as a result of Task 7 (Research Safety, Regulatory, and Permitting Issues).

6.3 Improvements to the PCOR Partnership Decision Support System

An assessment of the DSS capabilities developed during Phase I will be conducted to identify areas for improvement including, but not limited to, visualization and analytical capabilities. A plan will be developed to update the PCOR Partnership DSS, with approval by the DOE COR. Data acquired will be entered into the Web-based DSS. To ensure the maximum usefulness of the DSS to project sponsors and participants, the DSS will be refined and maintained on a regular basis.

In addition to incorporating the new data generated from Phase II, the DSS will be expanded to accommodate the integration of data collected over the course of PCOR Partnership Phase I including, but not limited to the following:

- Terrestrial sequestration data

- Transportation options

The PCOR Partnership will continue to work with National Carbon Sequestration Database and Geographic Information System (NATCARB) to develop an interactive mapping system with distributed data from the PCOR Partnership database. The PCOR Partnership will actively participate in the various RCSP working groups and communicate with other partnerships at conferences and meetings so that common issues can be shared and resolved and common assessment tools can be created and distributed.

6.4 Reporting

6.4.1 Progress Reports

Quarterly reports will be provided throughout Task 6. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

6.4.2 Development of Regional Carbon Sequestration Atlas Providing Summary Information Concerning the PCOR Partnership Region's CO_2 Sources and Potential CO_2 Sinks

TASK 7.0 – RESEARCH SAFETY, REGULATORY, AND PERMITTING ISSUES

7.1 Existing Regulations Related to the Sequestration of CO_2 Identified and Tracked

Existing regulations will be identified and tracked with respect to the relevant regulatory agencies within each of the PCOR Partnership states and provinces and the relevant federal regulatory agencies of the United States and Canada.

7.2 New Regulatory Guidelines Collated for Projects Implemented and Commercially Ready Future Sequestration Projects

While working with partners like the Interstate Oil and Gas Compact Commission (IOGCC), the Western Governors' Association (WGA), and various state regulatory bodies, the regulatory framework of the PCOR Partnership region will be continually assessed.

7.3 Reporting

7.3.1 Progress Reports

Quarterly reports will be provided throughout task 7. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

7.3.2 Development of Safety, Regulatory, and Permitting Road Map Document

This document will discuss the findings of Tasks 7.1 and 7.2, as well as future regulatory requirements for sequestration projects in the PCOR Partnership region.

TASK 8.0 PUBLIC OUTREACH AND EDUCATION

The goals of this task are to provide 1) outreach and education mechanisms that raise the awareness of sequestration opportunities in the region and 2) outreach to interested stakeholders with information about existing and future sequestration efforts in the region.

In order to meet these goals, Task 8 is designed to 1) maintain and expand the outreach toolkit developed in Phase I, 2) provide materials from the public outreach toolkit that will be useful in outreach for each of the four Phase II sequestration technology field validation tests, and 3) develop the outreach portion for the RTIP that will support the future full-scale deployment of individual sequestration technologies in the region.

8.1 Outreach Planning

An action plan for Phase II outreach, addressing both general outreach and outreach in the area of the field sites and based on the proposal, will be developed early in Year 1 with input from the Partners. Specific steps include:

8.1.1 Preparation of Phase II Outreach Plan

- Designate Outreach Advisory Group.
- Draft Outreach Plan for review by EERC PCOR Partnership management and advisory group.
- Submit Outreach Plan to NETL.

8.2 Web Site

The public PCOR Partnership Web site will be updated and expanded in Year 1 and updated as appropriate thereafter. Upgrades include a monthly update on the Kyoto Protocol and other relevant developments, a quarterly news update, streaming video for the PCOR Partnership video products, and additional items as appropriate.

8.2.1 Web Site for Review by NETL

8.2.2 Annual Upgrades as Determined by EERC PCOR Partnership Managers and NETL

8.3 Outreach Booth

A booth display will be developed that gives information on carbon management, including sequestration, and the role of the RCSP program and PCOR Partnership program to address this need, with particular emphasis on the PCOR Partnership region. The booth materials will be updated as appropriate.

8.3.1 Booth Review by NETL

8.3.2 Annual Design Updates as Determined by EERC PCOR Partnership Managers and NETL

8.4 Outreach PowerPoint™

A PowerPoint™ presentation will be developed in Year 1 that provides information on carbon management, including sequestration, and the role of the RCSP program and PCOR Partnership program to address this need, with particular emphasis on the PCOR Partnership region. The presentation will be updated as appropriate, and significant revisions will prompt a review by the DOE COR.

8.5 Fact Sheets

A set of fact sheets will be developed that provide general background information of the PCOR Partnership Phase II program and each of the four field validation tests. The general fact sheet will be prepared in Year 1 and other fact sheets will be developed as appropriate.

8.5.1 Develop Phase II PCOR Partnership Fact Sheet A – Phase II General Overview

8.5.2 Develop Phase II PCOR Partnership Fact Sheet A – Validation Test 1

8.5.3 Develop Phase II PCOR Partnership Fact Sheet B – Validation Test 2

8.5.4 Develop Phase II PCOR Partnership Fact Sheet C – Validation Test 3

8.5.5 Develop Phase II PCOR Partnership Fact Sheet D – Validation Test 4

8.6 Television Programs

Four 30-minute original programs will be produced for broadcast in the PCOR Partnership region in partnership with PPTV. Program topics will include CO_2 markets, terrestrial sequestration, and geologic sequestration. The programs are intended for general outreach and will feature activities in the PCOR Partnership region. The programs will be made available in DVD format as well as on the public Web site. Once the programs have been aired on PPTV, they will be marketed to other public television stations in the PCOR Partnership region. Each video will entail the following subtasks:

- Planning meeting
- Interviews and location footage
- Edits
- Review by EERC PCOR Partnership management and outreach advisors
- Review by NETL
- Closed captioning
- DVD production (1000 DVD's and jackets)
- Broadcast on PPTV

8.6.1 Video A – Carbon Markets and Carbon Trading

8.6.2 Video B – Terrestrial CO_2 Sequestration

8.6.3 Video C – Geologic CO_2 Sequestration

8.6.4 Video D – CO_2 Sequestration and Global Warming – Overview of Phase II Results from NETL's Regional Partnership

8.7 Progress Reports

Quarterly reports will be provided throughout task 8. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

TASK 9.0 – IDENTIFICATION OF COMMERCIALLY AVAILABLE SEQUESTRATION TECHNOLOGIES READY FOR LARGE-SCALE DEPLOYMENT

9.1 Economic Assessment of Regional Sequestration Opportunities

During performance of Subtask 9.1, sequestration technologies and approaches that are suitable and available for large-scale deployment in the PCOR Partnership region will be identified, and the economic viability of these sequestration techniques will be estimated. This subtask comprises the following four activities:

9.1.1 Continued Identification and Definition of Regional Point Sources

Additional information will be gathered by periodic comparison of existing data with updated U.S. Environmental Protection Agency (EPA) and North American Commission for Environmental Cooperation data sets. EPA's Information Collection Request data set will also be mined for potential additional information about various regional electricity-generating facilities. Any additional information that is found will be incorporated into the EERC's existing point-source data set.

9.1.2 Matching of Capture and Separation Technologies with Point Sources

Potentially applicable capture and separation technologies will be matched to the point sources based on CO_2 stream conditions and composition. Matching will be performed using the EERC's Excel™ source–technology matching spreadsheet that was developed during Phase I activities.

9.1.3 Matching of Source–Technology Pairs with Sinks

Source–technology pairs will be matched with geologic sinks by utilizing the DDS to identify the nearest sinks. Matches will be made based upon the available capacity of the sink(s) and type of sequestration that could be performed (e.g., EOR, injection into a saline aquifer).

9.1.4 Economic Assessment of Representative Source–Technology–Sink Combinations

The economics of sequestration scenarios composed of representative source–technology–sink combinations will be estimated. The NETL Carbon Capture and Sequestration Systems Analysis Guidelines and associated spreadsheets will be utilized during these estimations. Capture and separation cost data will be calculated using existing data or be acquired from NETL case studies, the Integrated Environmental Control Model (IECM), vendors, EERC estimation spreadsheets, partner data, or literature. The cost of CO_2 transportation will be estimated from literature sources as well as partner data. Geological sequestration costs will be estimated using information from the PCOR Partnership partners. All of these costs will be integrated to produce cost estimates for various sequestration scenarios in the PCOR Partnership region.

9.2 New Sequestration Approaches

Subtask 9.2 will investigate new approaches to sequester CO_2.

9.2.1 Utilizing Wind Energy for CO_2 Compression

This effort will investigate the use of wind power as a means to meet a portion of the electrical demands of CO_2 compression that is otherwise met by fossil energy use, thereby reducing the CO_2 emissions penalty for CO_2 capture and storage. The proposed concept is designed to utilize the remaining CO_2 currently generated but not compressed at the DGC Great Plains Synfuels plant for resale and subsequent use in potential EOR projects. The proposed concept will study the generation and utilization of wind power to support energy requirements of two CO_2 compressors at DGC. Two subtasks will be performed: 1) data gathering and 2) data analysis and preparation of a Best Practice Manual.

9.2.2 Development of CO_2 Management Plan for Excelsior Energy

The EERC will develop a CO_2 management plan for an Excelsior Energy power plant to be constructed in northern Minnesota. As part of an agreement with DOE, Excelsior Energy must make a good-faith effort to conduct a validation test at the facility for either geologic or terrestrial carbon sequestration projects to achieve reductions in facility emissions of CO_2. The EERC will assess the sequestration opportunities that are available to Excelsior, such as indirect sequestration of CO_2 into terrestrial sinks and direct sequestration into geological sinks. This will be accomplished through evaluation of the potential of nearby terrestrial features and geologic formations and features. Sink–source pairs specific to Excelsior operations will be identified and ranked according to engineering, economic, and public-acceptance considerations. This information will be incorporated into a Best Practice Manual.

9.3 Reporting

9.3.1 Progress Reports

Quarterly reports will be provided throughout task 9. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

TASK 10.0 – REGIONAL PARTNERSHIP PROGRAM INTEGRATION

The PCOR Partnership will actively participate and provide leadership to technical working groups to identify, discuss, and resolve common issues related to the deployment of sequestration technologies. Specific subtasks in Task 10 will include the following.

10.1 Development of Regional Partnership Program Integration Plan

A plan will be designed for the integration of results achieved by the PCOR Partnership with those of other RCSP organizations, including NATCARB. Points of contact will be established for each of the RCSP's and other organizations (i.e., NATCARB), as directed by DOE, that are funded under Phase II of the RCSP.

10.2 Integration of Partnership Program Activities

Activities will include the regular participation of the PCOR Partnership in RCSP working group conference calls and meetings. The PCOR Partnership will also participate in other committees or groups (i.e., IOGCC and WGA) whose goals are complementary to the PCOR Partnership Phase II Program or as requested by DOE.

10.3 Reporting

Quarterly reports will be provided throughout task 10. A progress report will be provided 60 days prior to the end of Budget Period 1. A final report will be provided at the conclusion of the project.

Table 2. Summary of Project Tasks and Deliverables

EERC Project Tasks	EERC Program Deliverable	Budget Period Due 1	Budget Period Due 2
Task 1 – Management and Reporting			
This task will ensure that the project is performed on time and on budget and that all parties are informed of relevant project information in a timely manner.	• Project Management Plan	X	
	• Quarterly PowerPoint™ presentations summarizing project status, results, budget, papers, presentations, and EVM report	X	X
	• Continuation application for Budget Period 2	X	
	• PCOR Partnership Phase II final report		X
Task 2 – Carbon Sequestration and EOR Field Validation Tests at Beaver Lodge, North Dakota			
This task consists of the design and operation injection of CO_2 into a carbonate system.	• Experimental design package and NEPA compliance document	X	
	• Site health and safety plan	X	
	• Outreach action plan	X	
	• Regulatory permitting action plan	X	
	• Sampling protocols	X	
	• Progress report	X	
	• Regional technology implementation plan		X
TASK 3 – Carbon Sequestration and EOR Field Test at Zama, Alberta			
This task will determine the viability of acid gas.	• Experimental design package and NEPA compliance document	X	
	• Site health and safety plan	X	
	• Outreach action plan	X	
	• Regulatory permitting action plan	X	
	• Sampling protocols	X	
	• Progress report	X	
	• Regional technology implementation plan		X
Task 4 – Carbon Sequestration and ECBM Recovery Field Validation Test in Lignite Coal in North Dakota			
This task will consist of the design and operation of an ECBM and CO_2 sequestration project in lignite in the Williston Basin.	• Experimental design package and NEPA compliance document	X	
	• Site health and safety plan	X	
	• Outreach action plan	X	
	• Regulatory permitting action plan	X	
	• Sampling protocols	X	
	• Progress report	X	
	• Regional technology implementation plan		X

Continued . . .

Table 2. Summary of Project Tasks and Deliverables, Continued

EERC Project Tasks	EERC Program Deliverable	Budget Period Due 1	Budget Period Due 2
Task 5 – Terrestrial Field Validation Test			
This task will explore the potential of wetland complexes to sequester CO_2 in a manner that allows for the development of CO_2 offsets for industry.	• Experimental design package and NEPA compliance document	X	
	• Site health and safety plan	X	
	• Outreach action plan	X	
	• Regulatory permitting action plan	X	
	• Sampling protocols	X	
	• Progress report	X	
	• Regional technology implementation plan		X
Task 6 – Continued Characterization of Regional Sequestration Opportunities			
This task will ensure that the PCOR Partnership database of Greenhouse Gasses sources and sinks remains current and is readily available to interested parties via the Internet.	• Regional characterization gap assessment	X	X
	• Progress report	X	
	• Topical reports as appropriate	X	X
	• Regional atlas		X
Task 7 – Research Safety, Regulatory, and Compliance Issues			
This task will identify regulations relevant to CO_2 sequestration in the PCOR region. New regulatory guidelines will be collated for projects implemented. Knowledge gained and resources collected throughout Phase II will be compiled and synthesized into a road map document for future sequestration projects.	• Progress report	X	
	• Roadmap document		X
Task 8 – Public Outreach and Education			
This task will raise the awareness of sequestration opportunities in the region and inform stakeholders about existing and future sequestration efforts in the region.	• Fact sheets	X	X
	• Outreach action plan	X	
	• PowerPoint presentations	X	X
	• Videos	X	X
	• Web site update	X	X
	• Outreach booth		X
	• Progress report	X	
Task 9 – Identification of Commercially Available Sequestration Techniques Ready for Large-Scale Deployment			
This task will synthesize all of the information and data gathered during the technical tasks to identify the sequestration technologies and opportunities available in the PCOR Partnership region at the end of Phase II.	• Best Practice Manual – Regional Sequestration Opportunities		X
	• Best Practice Manual – Excelsior Energy, Inc.	X	
	• Best Practice Manual – Wind Energy		X
	• Progress report	X	
Task 10 – Regional Partnership Program Integration			
This task will ensure that pertinent information is shared with other partnerships and that a coordinated effort is made to provide a national overview of CO_2 sequestration activities.	• Regional Partnership Program Integration Plan	X	
	• Progress report	X	

APPENDIX B

PCOR PARTNERSHIP PHASE II PROSPECTUS

Plains CO_2 Reduction (PCOR) Partnership

Practical, Environmentally Sound CO_2 Sequestration

Phase II Prospectus

What Is the PCOR Partnership?

The PCOR (Plains CO_2 Reduction) Partnership is a diverse group of public and private sector stakeholders working together to better understand the technical and economic feasibility of capturing and storing CO_2 emissions from stationary sources of CO_2 in the central interior of North America. The PCOR Partnership is managed by the Energy & Environmental Research Center (EERC) at the University of North Dakota and is one of seven regional partnerships funded by the U.S. Department of Energy's (DOE's) Regional Carbon Sequestration Partnership Program and a broad range of project sponsors.

Phase I activities will be completed in September 2005. On June 9, 2005, the EERC was awarded a contract for Phase II, which will begin in October 2005. Phase II is a 4-year program focused on demonstration and validation of promising CO_2 sequestration opportunities in our region. The total value of Phase II is currently over $21.5 million, with two-thirds of that funding coming from DOE and the balance contributed by industry and other nonfederal partners. The EERC is currently seeking additional partners for Phase II.

What Has the PCOR Partnership Accomplished in Phase I?

The Partnership has assessed and prioritized the opportunities for sequestration in the region and helped to resolve the technical, regulatory, and environmental barriers to the most promising sequestration opportunities. At the same time, the Partnership has informed policy makers and the public regarding CO_2 sources, sequestration strategies, and sequestration opportunities. The following products are now being completed:

- A comprehensive regional assessment of CO_2 sources and sinks.
- The development of the PCOR Partnership Decision Support System (DSS), a geographic information system (GIS)-based database trust providing our sponsors with a tool to evaluate CO_2 sequestration opportunities in the PCOR Partnership region.
- Identification, ranking, and action plans for promising sequestration demonstration projects.
- Key GIS products for CO_2 sources and sinks, infrastructure, and regulatory issues.
- Recommendations for monitoring and verification systems.

EERC WP25023.TIF

PCOR Partnership Region

- Outreach materials including fact sheets on key regional sequestration topics, a Web site, and a 30-minute informational video.

> *"Joining the Plains [CO_2 Reduction] Partnership is an approach that will dovetail nicely with our own carbon management policy and other carbon sequestration projects."*
>
> —Xcel Energy Chairman and CEO Wayne Brunetti

Who Is Involved in the PCOR Partnership?

The PCOR Partnership includes many public and private sector stakeholders from the region and elsewhere that represent expertise in agriculture, forestry, economics, energy exploration and production, geology, engineering, and the environment. Our partners provide technical services to the PCOR Partnership by providing data, guidance, and practical experience with direct and indirect sequestration, including value-added projects. PCOR Partnership partners include the following:

- U.S. Department of Energy
- University of North Dakota Energy & Environmental Research Center

- Alberta Department of Environment
- Alberta Energy and Utilities Board
- Alberta Energy Research Institute
- Amerada Hess Corporation
- Apache Canada Ltd.
- Basin Electric Power Cooperative
- Bechtel Corporation
- Center for Energy and Economic Development (CEED)
- Chicago Climate Exchange
- Dakota Gasification Company
- Ducks Unlimited Canada
- Ducks Unlimited, Inc.
- Eagle Operating, Inc.
- Eastern Iowa Community College District
- Encore Acquisition Company
- Environment Canada
- Excelsior Energy Inc.
- Fischer Oil and Gas, Inc.
- Great Northern Power Development, L.P.
- Great River Energy
- Interstate Oil and Gas Compact Commission
- Iowa Department of Natural Resources – Iowa Geological Survey
- Kiewit Mining Group Inc.
- Lignite Energy Council
- Manitoba Hydro
- Minnesota Pollution Control Agency
- Minnesota Power
- Minnkota Power Cooperative, Inc.
- Montana–Dakota Utilities Co.
- Montana Department of Environmental Quality
- Montana Public Service Commission
- Natural Resources Canada
- Nexant, Inc.
- North Dakota Department of Health
- North Dakota Geological Survey
- North Dakota Industrial Commission Lignite Research, Development and Marketing Program
- North Dakota Industrial Commission Oil and Gas Division
- North Dakota Industrial Commission Oil and Gas Research Council
- North Dakota Natural Resources Trust
- North Dakota Petroleum Council
- North Dakota State University
- Otter Tail Power Company
- Petroleum Technology Research Centre
- Petroleum Technology Transfer Council
- Prairie Public Television
- Saskatchewan Industry and Resources
- SaskPower
- Tesoro Refinery (Mandan)
- University of Regina
- U.S. Geological Survey Northern Prairie Wildlife Research Center
- Western Governors' Association
- Wisconsin Department of Agriculture, Trade and Consumer Protection
- Xcel Energy

PCOR Partnership Phase II Goals and Objectives

The overall goal of PCOR Partnership Phase II is to validate technologies and identify locations in the partnership region that can support future full-scale geological and terrestrial sequestration opportunities. The PCOR Partnership will accomplish this goal by:

- Continuing to assess regional carbon sequestration opportunities.
- Developing field projects.
- Evaluating the feasibility of commercial-scale selected carbon sequestration technologies.
- Assessing sink capacity permanence, economics, risk, public acceptance, and societal and monetary cobenefits.
- Providing outreach and education for CO_2 sequestration stakeholders and the general public.

We anticipate the development of one terrestrial sequestration field trial and two or more geologic field trials in Phase II. Our Phase II partners will have a voice in determining the direction of the PCOR Partnership and early access to the results of the program. Participation in Phase II will also provide partners with unique opportunities to develop working relationships with stakeholders that represent a diverse cross-section of CO_2 producers, end users, and regulators. Specifically, one of the goals of the PCOR Partnership is to broker working relationships between industries that generate CO_2, those that can use it for value-added sequestration activities such as enhanced oil recovery, and the government agencies that oversee such activities.

Field projects and their respective key partners include:

- Injection of acid gas into a depleted oil reservoir in Alberta, Canada, for acid gas disposal, enhanced oil recovery, and carbon sequestration.
- Injection of CO_2 into a deep carbonate reservoir in North Dakota for enhanced oil recovery and carbon sequestration.
- Injection of CO_2 into a lignite coal seam for enhanced methane production and carbon sequestration.
- Restoration of prairie pothole wetlands for carbon sequestration.

How can you be involved in Phase II? We are currently seeking additional partners interested in PCOR Partnership Phase II activities. To learn more, contact:

Edward N. Steadman, Senior Research Advisor, (701) 777-5279; esteadman@undeerc.org
John A. Harju, Associate Director for Research, (701) 777-5157; jharju@undeerc.org

Visit the PCOR Partnership Web Site at www.undeerc.org/PCOR.

Sponsored in Part by the U.S. Department of Energy

APPENDIX C

CARBON SEQUESTRATION TECHNOLOGY ROADMAP AND PROGRAM PLAN 2005

United States Department of Energy • Office of Fossil Energy • National Energy Technology Laboratory

Carbon Sequestration

Technology Roadmap and Program Plan 2005

Developing the Technology Base and Infrastructure to Enable Sequestration as a Greenhouse Gas Mitigation Option

May 2005

A Message to our Stakeholders

The United States Department of Energy's (DOE) Carbon Sequestration Program continues to make progress toward its goals of lowering the cost of carbon dioxide (CO_2) capture and ensuring permanent and safe carbon storage. As sequestration technology has moved forward, the topic has attracted the interest of a wider community. These persons bring fresh perspectives, new ideas, and different expectations. The DOE welcomes these developments and is making the investment needed to accelerate the pace of technology progress. The following are highlights from the past year.

> ***Carbon management has become an increasingly important element of our coal research program. Carbon sequestration – the capture and permanent storage of carbon dioxide – has emerged as one of the highest priorities in the Fossil Energy research program.***
>
> Mark Maddox
> Principal Deputy Assistant Secretary for Fossil Energy
> March 16, 2005

- ***The Regional Carbon Sequestration Partnerships effort is progressing to Phase II.*** The first phase of the partnerships effort will end in June of 2005 as a clear success. Together the partnerships have established a national network of companies and professionals working to support sequestration deployments. They have created a carbon sequestration atlas for the United States, and have identified and vetted priority opportunities for sequestration field tests. The Phase II partnerships will build upon the Phase I effort. The Phase II solicitation, released in December of 2004, will provide up to $100 million in Federal funds over 4 years, with each partnership expected to receive between $2 million and $4 million per year. As in Phase I, each partnership will be required to provide at least 20 percent in cost-sharing over the duration of the project. More information about the Phase I partnerships is accessible through the document, "Regional Carbon Sequestration Partnerships: Phase I Accomplishments," which can be downloaded from the NETL website http://www.netl.doe.gov/coal/Carbon%20Sequestration/pubs/PhaseIAccomplishment.pdf

- ***A sustained investment in Core R&D is advancing the science.*** Three sample highlights from the last year: a more robust understanding of the full suite of mechanisms that can trap and immobilize CO_2 within geologic formations has emerged; field tests conducted at the Weyburn and Frio sites demonstrate an improved ability to "see" injected CO_2 in an underground formation and monitor its movement; and process engineering studies show that the combination of advanced amines and heat and pressure integration can reduce the steam use for amine post-combustion capture to as little at 1,200 Btu per pound of CO_2 captured. The program's project portfolio contains fact sheets and other information on a wide range of research activities. CD copies are available upon request and it can be downloaded from the NETL website http://www.netl.doe.gov/sequestration

- ***The non-CO_2 GHG control area is moving forward.*** Developments include promising laboratory-scale results for a temperature swing technology for capturing minemouth methane and a newly initiated project that will investigate the use of untreated landfill gas for enhanced coal bed methane recovery. This year's roadmap contains a separate table for non-CO_2 greenhouse gas control pathways and goals.

- ***The Program is proactively complying with environmental regulations.*** Project-level Environmental Assessments have been conducted under the National Environmental Policy Act (NEPA) for the geologic sequestration field projects at Frio, Texas and Marshall County, West Virginia. Also under NEPA, a Programmatic Environmental Impact Statement (EIS) is being conducted. In 2004 DOE hosted a series of public meetings in cities across the U.S. to explain the program's plans and goals and hear feedback from citizens. DOE released a Public Scoping Document in October 2004. Later in 2005, DOE will publish a draft EIS and then conduct a second round of public meetings. Copies of the reports and more information about the NEPA process is available at http://www.netl.doe.gov/coal/Carbon%20Sequestration/eis/index.html

- ***A global climate change curriculum is available.*** Recognizing the complexity of the Global Climate Change issue and the need to improve understanding of greenhouse gas mitigation options among the public, the Carbon Sequestration Program has funded a Global Climate Change curriculum for middle school students. Developed by the Keystone Center, the ten-day curriculum uses a variety of interesting and engaging activities to educate students on a range of topics including greenhouse gas science, the implications of day-to-day energy use choices, and the role of technology in mitigating GHG emissions. Group games, debates, and activities encourage children to consider the trade-offs among economics, social equity, and the environment. Teacher training sessions are held at National Science Teacher Association Conventions and at the Keystone Center and teachers throughout the country are using the curriculum in their classrooms. Building on the success of the middle school curriculum, a high school curriculum is currently under development. An online version of the curriculum is available at www.keystonecurriculum.org

Interaction with our stakeholders is critical to the success of the Sequestration Program. In 2005 the Program plans to engage stakeholders in a variety of ways, including the Fourth Annual Conference on Carbon Sequestration, the Annual Project Merit Review Meeting, the NEPA process, the Phase II Regional Partnerships, the educational curriculum, and the monthly carbon sequestration newsletter.

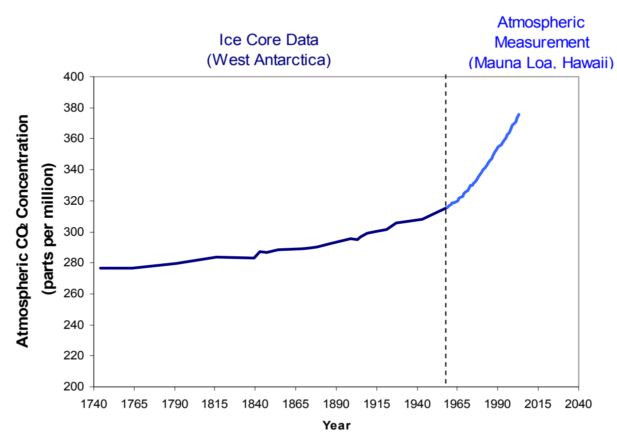
This document provides a vision of how to proceed with the development of carbon sequestration technology and is itself an important medium for engaging stakeholders. We invite readers to examine this document carefully and provide feedback to the contact persons listed on the back cover. Through a cooperative partnership of industry, academia, and government, we have the best chance of success in developing viable carbon sequestration options.

Chapter 1. Global Climate Change and the Role of Carbon Sequestration

Our modern economy and our associated quality of life – lighting, transportation, communications, heat and air conditioning – rely fundamentally on energy, and 85% of the energy consumed worldwide comes from the combustion of fossil fuels.

For nearly the first century of widespread fossil fuel use people did not pay much attention to carbon dioxide (CO_2) emissions. CO_2 was regarded, correctly, as a natural part of the Earth's atmosphere. However, sustained worldwide growth in population and economic activity have increased anthropogenic CO_2 emissions to the point where they are beginning to stress the natural carbon cycle. That is, more CO_2 is being exhausted than can be taken up by trees, grasses, and the oceans, and the excess is accumulating in the atmosphere. The concentration of CO_2 in the atmosphere is increasing at a rate of about 1-2 parts per million (ppm) per year. As shown in Figure 1, it is currently around 378 ppm, up 35% from the pre-industrial level of 280 ppm.

Figure 1. Atmospheric CO_2



Data sources: Ice core data obtained at the Siple Station, published by Friedli et al., 1986; Data from the Mauna Loa Observatory obtained from the NOAA web page.

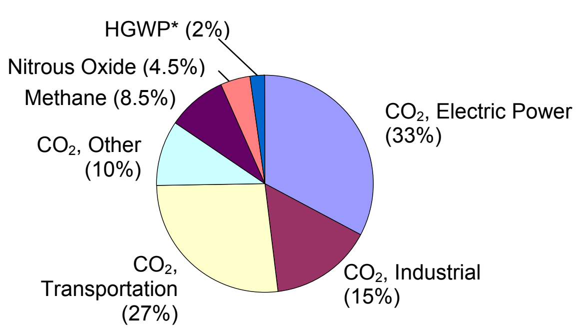
Elevated amounts of atmospheric CO_2 have two primary effects that are of concern to scientists. First, CO_2 in the atmosphere exerts a greenhouse effect that traps solar energy within the earth's ecosystem. An increased amount of greenhouse gases in the atmosphere may warm the planet overall and could cause unwelcome changes in regional climates. Second, increased CO_2 in the atmosphere causes an increased rate of CO_2 dissolution into ocean water which could make the oceans more acidic potentially causing damage to the ocean ecosystem. There is a great amount of uncertainty associated with the effects of greenhouse gas emissions and most of it centers on feedbacks. That is, how the earth's ecosystem will respond to increased atmospheric CO_2. A negative feedback pushes CO_2 back to its pre-industrial equilibrium value. For example, increased CO_2 in the atmosphere will cause trees to grow faster. Positive feedbacks are the opposite, for example increased global temperature may cause a polar tundra to thaw and release CO_2 in the atmosphere which increases the global temperature further and thaws more tundra in a spiraling effect.

Developing an understanding of the global climate, the carbon cycle, and the effects of atmospheric greenhouse gases (GHGs) is being pursued as a priority by the Administration through the U.S. Climate Change Science Program. In parallel the Administration is pursuing "transformational" technologies that provide traditional energy services (electricity, heat, transportation) without net greenhouse gas emissions or with very low greenhouse gas emissions. Carbon sequestration has emerged as a key technology option for GHG mitigation, alongside improved efficiency and non-carbon energy sources such as wind, biomass, hydro-electric, nuclear fission, and nuclear fusion. As a voluntary framework for progress, President Bush set forth the Global Climate Change Initiative (GCCI) in March of 2001. The GCCI sets a goal of an 18% reduction in the GHG intensity of the United States economy to be achieved by 2012. In 2012 an assessment will be conducted, and the DOE Carbon Sequestration Program seeks to have viable commercial options at that time that could potentially impact the GCCI reassessment.

Carbon sequestration is the capture and storage of CO_2 and other greenhouse gases that would otherwise be emitted to the atmosphere. The greenhouse gases can be captured at the point of emission, or they can be removed from the air. The captured gases can be used, stored in underground reservoirs or possibly the deep oceans, absorbed by trees, grasses, soils, and algae, or converted to rock-like mineral carbonates or other products. There are a wide range of sequestration possibilities to be explored, but a clear priority for near-term deployments is to capture a stream of CO_2 from a large, stationary emission point source and sequester it in an underground formation.

Carbon sequestration holds the potential to provide deep reductions in greenhouse gas emissions. Currently, a little less than half of total U.S. GHG emissions are large point sources of CO_2, Figure 2, and trends toward decarbonization of transportation fuels are increasing the amount of upstream CO_2 emissions. Research is ongoing to develop a clearer picture of domestic geologic sequestration storage capacity, but it is apparent that domestic formations have at least enough capacity to store several centuries worth of point source emissions. Technologies aimed at capturing and utilizing methane emissions from energy production and conversion systems fall within the definition of carbon sequestration and will reduce non-CO_2 greenhouse gas emissions. Mobile and dispersed GHG emissions can be offset by enhanced carbon uptake in terrestrial ecosystems, and research into CO_2 conversion and other advanced sequestration concepts will expand the range of sequestration further.

Figure 2. Greenhouse Gas Emissions in the United States, 2003



Roughly half of current GHG emissions are large CO_2 point sources in the power and industrial sectors that are amenable to capture and storage. Trends toward de-carbonization of transportation fuels will increase the percentage of future GHG emissions amenable to capture.

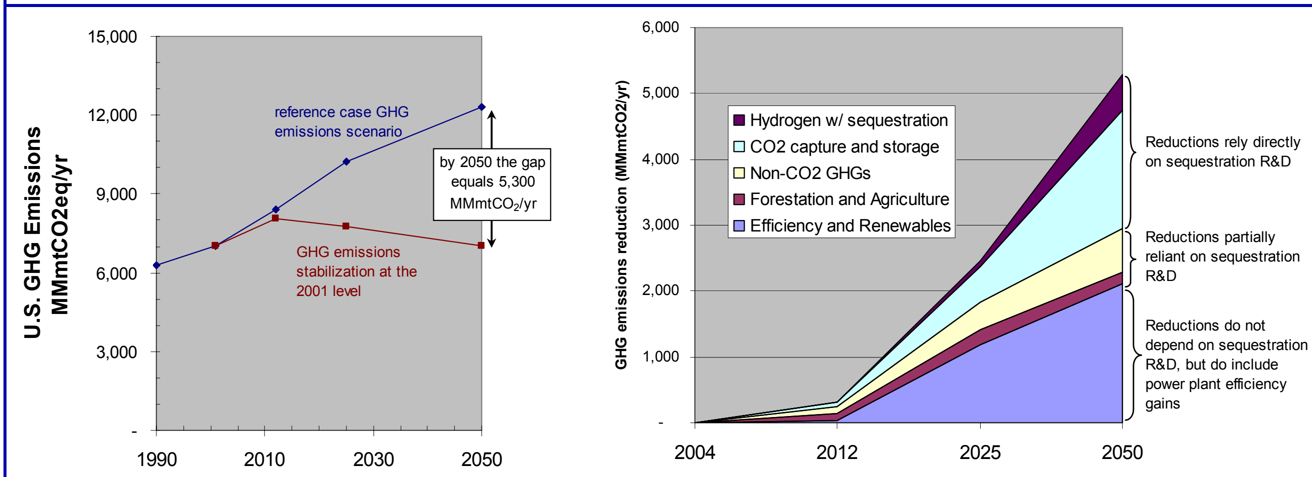
Source: DOE Energy Information Administration
Total 2003 U.S. GHG emissions were 6,891 million metrics tons CO_2 equivalent.
Methane, Nitrous oxide, and HGWPs reported in 100 year forcing CO_2 equivalents
** High global warming potential gases, e.g., certain refrigerants.*

DOE and the National Energy Technology Laboratory (NETL) have conducted analyses of energy supply and use in the United States to gauge both the need for carbon sequestration technology under a GHG emissions stabilization scenario and the ability of potential CO_2 sources and sinks to meet the need should it arise.

Figure 3 summarizes the results of that analysis. The top line on the left graphic in Figure 3 is a reference case GHG emissions scenario. It contains significant technology development for low or no-carbon fuels and improved efficiency, but no direct incentives for GHG emissions reduction. The lower line in Figure 3 is an emissions stabilization scenario. It contains accelerated improvement in GHG intensity through 2012 and then gradually reduced emissions thereafter toward a goal of stabilizing emissions at the 2001 level. The emissions reduction requirement, which equals the gap between the two scenarios, grows to 5,300 million metric tons of carbon dioxide per year by 2050. Emissions stabilization is a first step toward atmospheric concentration stabilization. Atmospheric concentration stabilization will require emissions to be reduced to 80-90 percent below current levels.

The right side of Figure 3 shows the contribution of various mitigation options needed to meet the gap under the emissions stabilization scenario. The contribution of each option has been estimated using an internal planning model that is based on cost/supply curves. The categories, "CO_2 capture and storage" and "Hydrogen with sequestration" are directly dependent on research conducted by the DOE Sequestration Program. Together, they account for 45 percent of total emissions reduction in 2050 under the emissions stabilization scenario. Terrestrial ecosystems and non-CO_2 GHG emissions control, which are being pursued by the DOE Sequestration Program in concert with other public and private partners, contribute another 15 percent. Clearly, carbon sequestration technology will play a pivotal role should GHG stabilization be deemed necessary.

Figure 3. U.S. GHG Emissions Scenarios . . . and Technologies to Fill the Gap



Chapter 2. Carbon Sequestration Technology Roadmap and Program Plan

> **VISION STATEMENT**
>
> ***To possess the scientific understanding of carbon sequestration options, and to provide cost-effective, environmentally-sound technologies that ultimately lead to a reduction in greenhouse gas intensity and stabilization of overall atmospheric concentrations of CO_2.***

Recognizing the importance of carbon sequestration, the U.S. DOE established the Carbon Sequestration Program in 1997. The Program, which is administered within the Office of Fossil Energy by the National Energy Technology Laboratory, seeks to move sequestration technologies forward so that their potential can be realized and they can play a major role in meeting any future greenhouse gas emissions reduction needs. The Program directly implements the President's GCCI, as well as several National Energy Policy goals targeting the development of new technologies. It also supports the goals of the Framework Convention on Climate Change and other international collaborations to reduce greenhouse gas intensity and greenhouse gas emissions.

This document, the 2005 Carbon Sequestration Technology Roadmap and Program Plan, identifies research pathways that lead to commercially viable sequestration systems and sets forth a plan of action for sequestration research. The information is organized into three sections:

A. ***Core R&D*** is the laboratory, pilot plant, and field work aimed at developing new technologies and new systems for GHG mitigation.

B. ***Infrastructure Development*** is the groundwork for future carbon sequestration deployments being developed through the Phase I and Phase II Regional Partnership efforts.

C. ***Program Management*** is the program's approach to R&D management: industry/government partnerships, cost-sharing, education and outreach, and environmental compliance.

Table 1 is a top-level roadmap for core R&D and infrastructure development. It shows progress toward the metrics for success achieved over the past year. The metrics and goals for CO_2 capture research are focused on reducing the cost and energy penalty because analysis shows that CO_2 capture drives the cost of sequestration systems. Similarly, the goals and metrics for carbon storage and measurement, monitoring, and mitigation (MM&V) are focused on permanence and safety. All three research areas work toward the overarching program goal of 90% CO_2 capture with 99% storage permanence at less than a 10% increase in the cost of energy services by 2012.

Table 1. Top-level Carbon Sequestration Roadmap

	Pathways	Metrics for Success		2005 Status, Progress thus Far
		2007	2012	
CO_2 Capture	• Post-combustion • Pre-combustion • Oxy-fuel	Develop at least two capture technologies that each result in less than a 20% increase in cost of energy services.	Develop at least two capture technologies that each result in less than a 10% increase in cost of energy services.	Heat and pressure integration combined with advanced amines have reduced steam consumption for post-combustion capture to 1,200 Btu/lb.
Sequestration/ Storage	• Hydrocarbon bearing geologic formations • Saline formations • Tree plantings, silvicultural practices, and soil reclamation • Increased ocean uptake	Field tests provide improved understanding of the factors affecting permanence and capacity in a broad range of CO_2 storage reservoirs.	Demonstrate ability to predict CO_2 storage capacity with +/-30% accuracy. Demonstrate enhanced CO_2 trapping at pre-commercial scale.	More robust understanding of CO_2 trapping and dissolution in saline water have been integrated into capacity estimation models.
Monitoring, Mitigation, &Verification	• Advanced soil carbon measurement • Remote sensing of above-ground CO_2 storage and leaks • Detection and measurement of CO_2 in geologic formations • Fate and transport models for CO_2 in geologic formations	Demonstrate advanced CO_2 measurement and detection technologies at sequestration field tests and commercial deployments.	CO_2 material balance greater than 99%. MM&V protocols enable 95% of stored CO_2 to be credited as net emissions reduction.	Test of time lapse (3D) seismic at Weyburn and Frio showed ability to detect volumes of CO_2 as small 2,500 metric tons within a geologic formation.
Breakthrough Concepts	• Advanced CO_2 capture • Advanced subsurface technologies • Advanced geochemical sequestration • Novel niches	Laboratory scale results from 1-2 of the current breakthrough concepts show promise to reach the goal of a 10% or less increase in the cost of energy, and are advanced to the pilot scale.	Technology from the program's portfolio revolutionizes the possibilities for CO_2 capture, storage, or conversion.	Seven awards from a competitive solicitation and a collaboration with the National Academies of Science were made in March 2004.
Non-CO_2 GHGs	• Minemouth methane capture/combustion • Landfill gas recovery	Deployment of cost-effective methane capture systems.	Commercial deployment of at least two technologies from the R&D program.	Promising lab-scale results for a temperature swing absorption process for methane/air separation.
Infrastructure Development	• Sequestration atlases • Project implementation plans • Regulatory compliance • Outreach and education	Phase II partnerships have pursued priority sequestration opportunities identified in Phase I and have conducted successful field tests.	Projects pursued by the Regional Partnerships contribute to the 2012 assessment under GCCI.	Data on CO_2 emissions point sources and sinks throughout the country are available at the NatCarb portal (www.natcarb.org). Phase II awards expected before the end of FY 2005.

A. Core R&D

The goal of the core R&D program is to advance sequestration science and develop to the point of pre-commercial deployment new sequestration technologies and approaches. The core program is a portfolio of work including cost-shared, industry-led technology development projects, research grants, and research conducted in-house at NETL. The core program is divided into the following five areas.

1. CO_2 Capture
2. Carbon Storage
3. Monitoring, Mitigation, and Verification (MM&V)
4. Non-CO_2 Greenhouse Gas Control
5. Breakthrough Concepts
6. Field Projects

The first three core research areas track the life cycle of a carbon sequestration system. That is, first CO_2 is captured, second it is stored or converted to a benign or useful carbon-based product, and third, the stored or converted CO_2 is monitored to ensure that it remains sequestered and appropriate mitigation actions are taken as needed. The fourth category, non-CO_2 greenhouse gas control, involves primarily the capture and reuse of methane emissions from energy production and conversion systems. The fifth area, breakthrough concepts, is a group of projects along the same general approach as the first four research areas, but with a higher technical uncertainty and the potential to expand the applicability of carbon sequestration beyond conventional point source emissions. Field projects are a verification of promising technologies across all areas and often involve the integration of more than one area. The goals and activities within each area are described in the pages that follow.

1. CO_2 Capture. CO_2 exhausted from fossil fuel-fired energy systems is typically either too dilute, at too low a pressure, or too contaminated with impurities to be directly stored or converted to a stable, carbon-based product. The aim of CO_2 capture research is to produce a CO_2-rich stream at pressure. The research is categorized into three pathways: post-combustion, pre-combustion, and oxyfuels. Post combustion refers to capturing CO_2 from a flue gas after a fuel has been combusted in air. Pre-combustion refers to a process where a hydrocarbon fuel is gasified to form a mixture of hydrogen and carbon dioxide and CO_2 is captured from the synthesis gas before it is combusted. Oxyfuel is an approach where a hydrocarbon fuel is combusted in pure or nearly pure oxygen rather than air, which exhausts a mixture of CO_2 and water which can easily produce pure CO_2.

Each of the three pathways has merit. Post-combustion capture applies to over 98% of current fossil fuel utilization assets, but it represents a significant technology challenge in that the CO_2 in flue gas is dilute (3-15 vol%), at low-pressure (15-25 psi), and often contaminated with traces of sulfur and particulate matter. A pre-combustion synthesis gas contains CO_2 in higher concentration (30-50 vol%), higher pressure (200-500 psi), and with less contaminants, but there are few gasification-based power systems currently in operation. Oxyfuel combustion requires roughly three times more oxygen per net kWh of power generation compared to gasification, and its efficiency is further compromised by the large amounts of flue gas that must be recycled to the combustion chamber for temperature control. However, oxyfuel does have a key advantage in that it can offer near 100% CO_2 capture. A breakthrough in membranes or chemical looping technology for oxygen delivery could dramatically change its prospects.

Table 2 presents a technology roadmap for CO_2 capture with performance goals that the Program has identified. The high partial pressure of CO_2 in synthesis gas allows for a wider range of pathways for pre-combustion. As shown in the table there are significant cross-cutting technology development areas which will enhance all CO_2 capture pathways. Table 2 also presents a set of technology performance goals identified by the program which, if achieved, provide a progression toward broad commercial viability of carbon sequestration.

The Program essentially accomplished its 2004 capture goal. American Air Liquide and Babcock & Wilcox performed oxycombustion experiments on a 1.5 MW pilot scale boiler and demonstrated a 70% reduction in CO_2 recycle per coal burned compared to a conventional 70/30 CO_2/oxygen base case.

Table 2. CO_2 Capture Roadmap

Technology Roadmap			Program Goals
CO_2 Capture Applications	**Priority Research Pathways**	**Cross Cut Pathways**	*Reduce cost and parasitic load*
Post-Combustion CO_2 capture	Chemical sorbents	Heat integration Improved base process efficiency Oxygen separation technology Gas/liquid contacting Integration of CO_2 capture with NO_x/SO_x/Hg/PM control	2004 Pilot-scale demo of 75% reduction in CO_2 recycle requirements. *GOAL MET 2007 Develop at least two capture technologies that each result in less than a 20% increase in cost of energy services. 2012 Develop at least two capture technologies that each result in less than a 10% increase in cost of energy services
Pre-Combustion CO_2 capture	Chemical sorbents Physical sorbents Membranes Water/CO_2 hydrates		
Oxyfuels	Oxygen/recycle flue gas boilers Chemical looping		

Table 3 presents a technology-centered analysis of CO_2 capture methods. In this framework CO_2 capture is divided into three sub-categories: CO_2 removal, CO_2 separation, and oxygen combustion. Each is defined as follows.

- *CO_2 removal*, bringing a CO_2-containing stream into contact with a compound that selectively captures a portion of the CO_2
- *CO_2 Separation,* the use of membranes to increase the concentration of a CO_2-containing stream
- *Oxygen combustion*, combustion of a fossil fuel with pure or highly pure oxygen to exhaust undiluted CO_2

Table 4 presents a list of projects currently being funded by the Carbon Sequestration Program, each categorized into the pathways contained in Table 3. Other programs within the Office of Fossil Energy are funding research in technologies related to CO_2 capture and those are not shown here. Table 4 presents a robust research portfolio. Links to web pages with more detailed information are provided for many of the projects.

Table 3. Technology-specific Breakdown of CO_2 Capture Options

	Technologies		Contact medium		Mechanism		Application	
CO_2 Removal	Chemical reaction	1	Aqueous solution	A	Temperature swing	1	Flue gas	F
	Dissolution	2	Hydrocarbon solution	B	Pressure Swing	2	Syngas	S
	Physical adsorption	3	Solid, fixed bed	C			Natural gas	G
	Hydrate formulation	4	Solid, moving bed	D			Other	O
			Solid, fluidized bed	E				
	Technologies		**Separation Type**		**Driving Force**		**Application**	
Separation	Permeability Difference	5	CO_2 permeate	P	Partial pressure differential	3	Flue gas	F
	Solubility Difference	6	CO_2 retentate	R	Delta pp, permeate-side reaction	4	Syngas	S
	Ion transport	7			Delta pp, retentate-side reaction	5	Natural gas	G
	Electrochemical	8					Other	O
	Technologies		**Combustion Temperature control**		**Combustion Pressure**		**Application**	
Oxygen Combustion	Cryogenic separation	9	Flue gas recycle	X	Atmospheric	6	Combustion, steam turbine	C
	O_2/N_2 membrane	10	Inert solid	Y	Medium, 50-200 psi	7	Gasification, comb. Cycle	G
	Metal oxide carrier	11			High, greater than 200 psi	8		

Table 4. CO_2 Capture Research Projects in Program Portfolio

Project Title	Performer	Roadmap categories				Web Links
Amines	Trimeric	1	A	1	F	
Sodium carbonate	CSSFA*	1	A	1	F	
Potassium carbonate	University of Texas	1	A	1	F	http://www.netl.doe.gov/publications/factsheets/project/Proj280.pdf
Supported amine	Advanced Fuel Research	1	C	1	F	
Aminated sorbents	CSSFA*	1	D	1	F	
Alkali carbonate	RTI	1	E	1	F	http://www.netl.doe.gov/publications/factsheets/project/Proj198.pdf
Microporous metal organic	UOP	3	C	1	F	
Pressure Swing Adsorption	CSSFA*	3	C	2	S	http://www.netl.doe.gov/publications/factsheets/project/Proj190.pdf
Temp. Swing Adsorption	CSSFA*	3	C	1	S	http://www.netl.doe.gov/publications/factsheets/project/Proj190.pdf
Hydrates	Nexant	4	A	1	S	http://www.netl.doe.gov/publications/factsheets/project/Proj196.pdf
Ionic liquid adsorbents	Notre Dame	3	A	1	F	
CO_2 selective membrane	Media Process Tech.	5	R	5	S	http://www.netl.doe.gov/publications/factsheets/project/Proj195.pdf
Hybrid membranes	CSSFA*	5	P	3	S	http://www.netl.doe.gov/publications/factsheets/project/Proj309.pdf
Hydrogen silica membrane	University of Minnesota	5	R	3	S	
Silica-based membrane	Sandia National Lab	5	P	4	F	
Thermally optimized	LANL, INEEL	6	R	3	F	http://www.netl.doe.gov/publications/factsheets/project/Proj194.pdf
Direct fuel cell	FuelCell Energy	8	P	3	F	
O_2-based PC boiler	Foster Wheeler	9	X	6	C	
Gasification w/ CO_2 recycle	Foster Wheeler	9	X	7	G	
O_2-fired CO_2 recycle retrofit	Southern Research Inst.	10	X	7	C	
O_2-enriched combustion	Praxair	10	X	7	C	http://www.netl.doe.gov/publications/factsheets/project/Proj197.pdf
Commercial fluidized bed	Alstom	11	Y	6	C	http://www.netl.doe.gov/publications/factsheets/project/Proj201.pdf
Novel fluidized bed	Alstom	11	Y	6	G	http://www.netl.doe.gov/publications/factsheets/project/Proj201.pdf

* Carbon Sequestration Science Focus Area (CSSFA)

2. Carbon Storage. Carbon storage is defined as the placement of CO_2 into a repository in such a way that it will remain stored (or sequestered) permanently. It includes three distinct sub-areas: geologic sequestration, terrestrial sequestration, and ocean sequestration. Each is described below, and Table 5 presents a synopsis of the carbon storage pathways and program goals.

CO_2 storage in geologic formations. The storage of CO_2 in a geologic formation (geosequestration) is the injection of CO_2 into an underground formation that has the capability to contain it securely. There are three categories of formations, each with different challenges and opportunities for CO_2 storage.

> *Oil and gas reservoirs.* An oil or gas reservoir is a formation of porous rock that has held crude oil or natural gas (both of which are buoyant underground like CO_2) over geologic timeframes. It thus has a "demonstrated seal," and is fundamentally an ideal setting for CO_2 storage. The attractiveness of oil and gas reservoirs is often enhanced by the fact that injected CO_2 can enable the production of oil and gas resources left behind by primary recovery and water flood. A challenge is that well-known oil and gas fields have been drilled into extensively. Earlier wells were not sealed to today's high standards when they were abandoned, and most abandoned wells, old and recent, are plugged with Portland cement which is susceptible to corrosion from saline water with dissolved CO_2.
>
> *Saline formations.* A saline formation is a formation of porous rock that is overlain by one or more impermeable rock formations and thus has the potential to trap injected CO_2. It is similar to an oil or gas formation with the exception that it has not actually held oil or gas over geologic time frames. Saline formations lack a demonstrated seal and do not offer the possibility for enhanced oil or gas production, but they have the advantage that they have not been penetrated by as many wells as oil and gas reservoirs.
>
> *Deep coal seams.* CO_2 injected into a coal bed becomes adsorbed onto the coal's surfaces and is sequestered. Most coals contain adsorbed methane, and this methane can be recovered from coals that are too deep or too thin to mine economically. Coals preferentially adsorb CO_2 and, like enhanced oil recovery, CO_2 can be injected into an unmineable coal formation to enable recovery of residual methane not produced by de-pressuring. A challenge is that coals increase in volume when they adsorb CO_2, and coal swelling reduces permeability.

Saline formations are more commonplace than oil and gas formations or coal seams and, on the basis of total pore volume, saline formations offer the potential capacity to store hundreds of years worth of CO_2 emissions. Saline formations are the primary option for geosequestration should substantial storage capacity be needed in the future.

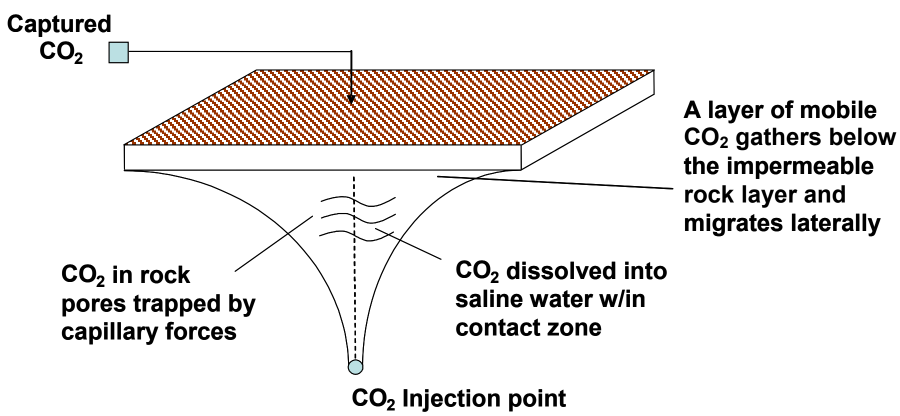
Table 5. Carbon Storage Roadmap

Technology Roadmap			Supporting Program Activities	
Current State of the Art	**Priority Research Pathways**	**Cross Cut Pathways**	**R&D Highlights**	**Program Goals** *Ensure permanence and ecosystem protection*
Geologic Sequestration 32 million tons of CO_2 per year are injected into depleting oil reservoirs in the U.S. as a part of enhanced oil operations, 10% is from anthropogenic sources. Current Commercial-scale geologic sequestration projects include: *Sleipner* (Norway, Statoil, 1996, 1 $MMtCO_2$/yr) *Weyburn* (Canada, ENCANA, 2000, 1.5 $MMtCO_2$/yr) *In Salah* (Algeria, BP, 2004, 1.2 $MMtCO_2$/yr)	Geologic formations Depleting oil reservoirs Unmineable coal seams Saline formations Depleting gas reservoirs Organically-rich shales Trapping mechanisms Structural containment Capillary trapping Dissolution in saline water Mineralization Adsorption on coal	Capability to predict CO_2 storage capacity Injection techniques to enhance CO_2 contact within a reservoir, preserve formation integrity, permeability CO_2-impermeable well bores	Completed an environmental assessment for CO_2 injection near Houston, TX, including a robust model of the injection site. Successfully injected 1,600 tons of CO_2 into a saline formation. A CO_2 ECBM field test at Tiffany, NM, demonstrated recovery of 1 scf of CBM per 3 scf CO_2 sequestered. Initiated a research project in which landfill gas will be injected into an unmineable coal bed to achieve methane/CO_2 separation, enhance CBM recovery, and sequester carbon.	2007 Conduct a CO_2 ECBM field test where CO_2 injectivity is maintained at 90% of its initial value to mitigate the negative effects of coal swelling. 2008 Develop an understanding of trapping mechanisms across oil reservoirs, coal seams, and saline formations. 2009 Initiate at least one large-scale demonstration of CO_2 storage (>1 million tons CO_2/year) in a geologic formation to demonstrate the capability to (1) predict compatibility to CO_2 injection and approximate storage capacity, and (2) achieve enhanced CO_2 trapping. 2012 CO_2 storage capacity prediction precision of ±30%.
Terrestrial Sequestration There are currently over 20,000 acres of forestland in the United States dedicated specifically to sequestering CO_2. The United States has 1.5 million acres of land damaged by past mining practices.	Planting trees instead of grass on mine land Soil reclamation using CCBs or other solid residuals No-till farming, aforestation, and other activities applied to a wide range of geographies to increase carbon uptake	Enhanced carbon transfer from plant to soil	Achieved 80% survival rate for tree plantings in both damaged land amended with flue gas desulfurization sludge (Paradise, KY) and in formerly compacted mineland (Hazard, KY).	2007 Develop optimization strategies and best practice guidelines for maximizing carbon sequestration potential on unproductive mine lands. 2008 Develop to the point of commercial deployment systems for advanced indirect sequestration of greenhouse gases that protect human and ecosystem health and cost no more than $10 per metric ton of carbon sequestered, net of any value-added benefits.
Ocean Sequestration No commercial deployments. Unknown ecosystem impacts. Enormous potential.	Ocean injection Deep injection technology Use of hydrates to increase permanence Ocean fertilization	Enhanced understanding & speculative technologies	An experiment conducted at a natural CO_2 vent in the ocean showed that amphipods can sense and avoid a plume of entrained CO_2. Laboratory tests have shown that premixing CO_2 and water prior to injection creates hydrates that are more dense than ocean water and sink upon injection.	Improved scientific understanding of this option.

CO_2 trapping within a geologic formation. Of emerging importance in the field of geosequestration is the science of maximizing CO_2 trapping mechanisms. At the temperatures and pressures of most underground formations (100 to 150 ^oF, 2,000 to 3,000 psi) CO_2 exists as a supercritical fluid - it has the density near that of a liquid but the viscosity near that of a gas. Supercritical CO_2 is lighter than the saline water in the formation and exhibits a strong tendency to flow upward. The primary method for trapping CO_2 is by a layer or "cap" of impermeable rock that overlies the formation of porous rock into which the CO_2 is injected and prevents upward flow of CO_2. It is called structural trapping and is the mechanism that caused natural deposits of crude oil, natural gas and CO_2. Four other mechanisms for CO_2 trapping described below can enhance the permanence of CO_2 storage within a geologic formation. Figure 4 shows how these advanced trapping mechanisms can apply in a typical CO_2 injection scenario.

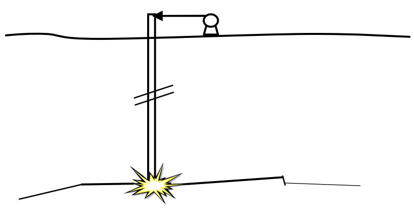
1. Capillary trapping. The surface of sandstone and other rocks preferentially adheres to saline water over CO_2. If there is enough saline water within a pore (75-90% of the pore volume), it will form a capillary plug that traps the residual CO_2 within the pore space.
2. Dissolution in saline water. CO_2 is soluble in saline water. As it comes in contact with the saline water it dissolves into solution.
3. Mineralization. Over longer periods of time (thousands of years), dissolved CO_2 reacts with minerals to form solid carbonates.
4. Adsorption of CO_2. Coal and other organically-rich reservoirs will preferably adsorb CO_2 onto carbon surfaces as a function of reservoir pressure.

Figure 4. CO_2 Storage Mechanisms

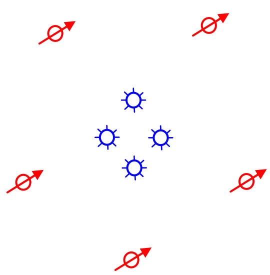


These advanced trapping mechanisms are only effective to the degree CO_2 comes into contact with the rock or coal within a formation. New injection techniques are being developed to maximize CO_2 contact within the reservoir. For example, accurate reservoir characterization can reveal the location of high permeability zones and enable placement of wells that force CO_2 flow through low permeability areas. Also, horizontal wells can enable multiple injection points along the bottom of a porous rock formation greatly increasing the lateral distribution of CO_2. Lateral distribution of CO_2 can also be enhanced through engineered fracturing of the rock. Several advanced drilling and injection techniques are shown in Figure 5.

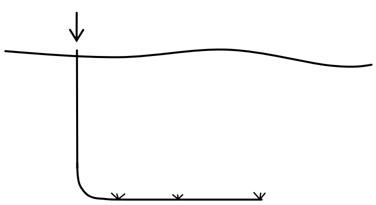
Figure 5. Examples of Advanced Drilling and CO_2 Injection Techniques



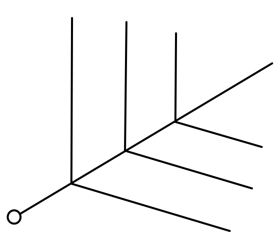
Hydrostatic pressure applied to a conventional vertical well can be used to engineer fractures in the rock that enable greater horizontal distribution of injected CO_2.



In the figure to the left five CO_2 injection wells (red) are positioned around the perimeter of a domed natural gas-bearing formation. CO_2 injected into the formation is drawn laterally toward the middle of the dome by the low pressure zone created by the natural gas recovery wells (blue). As it moves the CO_2 pushes residual natural gas toward the production wells, enhancing recovery. BP is testing this type of injection strategy in its In Salah project in Algeria.



Directional or horizontal drilling enables multiple injection points from one well and broad lateral distribution of injected CO_2. In a cost shared project with NETL, CONSOL will test/demonstrate the injection of CO_2 into an unmineable coal seam using a directional drilling technique.



In the figure to the left a patented pinnate horizontal well network is built from one surface well with multiple lateral diversions. The main stem can be up to 1,500 meters long with the offshoots offering a total of 9,000 meters of well length. A pinnate well network can produce 80% of coal bed methane in place within 3-4 years, and over 500 pinnate wells are currently in use worldwide for primary coal bed methane recovery. There is a possible opportunity to inject CO_2 into a pinnate network for storage after CBM production.

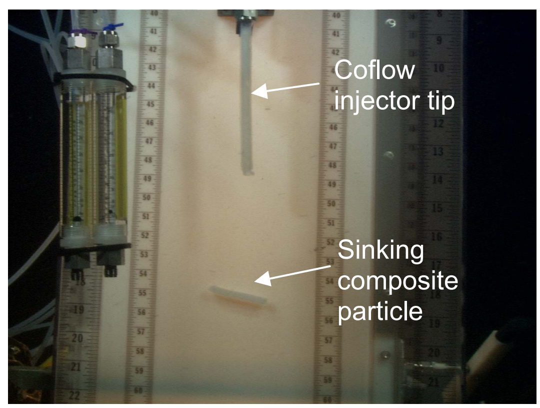
Terrestrial sequestration. Terrestrial sequestration is the enhancement of CO_2 uptake by plants that grow on land and in freshwater, and carbon storage in soils. Tree-plantings, no-till farming, forest preservation and other early activities provide an opportunity for low-cost CO_2 emissions offsets. More advanced research includes the development of fast-growing trees and grasses and deciphering the genomes of carbon-storing soil microbes. Responsibility for terrestrial sequestration research is shared by many Federal agencies, and the program coordinates its activities in this area with the DOE Office of Science, U.S. Department of Agriculture, and Department of Interior Office of Surface Mining.

One area of focus for the DOE's core sequestration R&D Program is in developing field practices for increasing carbon uptake in mined lands. With the passage of the Surface Mining Control and Reclamation Act of 1977 coal mine operators have moved away from reforestation of minelands in favor of compaction and grass planting. Compaction of the soil prevents tree growth because the roots need loose soil to grow in. The program is funding small field experiments with reforesting mineland, both planting trees on new, uncompacted minelands and ripping up compacted land and planting trees. The theory that a forest will provide increased carbon uptake per acre relative to grass lands is being tested in the field experiments and the cost per incremental ton of carbon stored estimated. The core program is also experimenting with the use of coal combustion by-products as soil amendments to repair damaged land.

Ocean sequestration. Ocean sequestration is examining methods that could potentially increase the carbon uptake of the oceans. One way to achieve increased ocean uptake is to enhance the growth of plants in the surface ocean, and a few years ago there was interest in the idea of fertilizing tracts of the oceans to increase algae growth. A field test revealed problems with fertilizer distribution and with the plant material decomposing to CO_2 in the surface ocean and being released back to the atmosphere.

The other option for ocean sequestration is to inject CO_2 into ocean water. The full extent of environmental risks associated with ocean injection are largely unknown at this time and injected CO_2 may not remain permanently sequestered. The core program is funding a limited amount of research in this area with the goal of better understanding the risks of ocean sequestration. As shown in Figure 6, the Program is also exploring methods to increase the storage permanence of injected CO_2 and to minimize its contact with the ocean ecosystems, including the formation of CO_2/water hydrates and mineral carbonates.

Figure 6. Injection of CO_2 Hydrate in Ocean Water 1,200 Meters Below the Surface.



The Monterey Bay Aquarium Research Institute (MBARI) has been conducting small scale experiments where liquid CO_2 is injected into ocean water (50 ml per minute). One of the goals of the experiments is to optimize the formation of dense CO_2/water hydrates. These hydrates sink in deep ocean water and provide a greater residence time for injected CO_2. Another goal is to develop and test instruments to "see" the injected CO_2 in situ and monitor its effects on ocean water, for example Raman spectroscopy.
Source: C. Tsouris, P. Brewer, E. Adams et al.; Jan 2005.

3. Monitoring, Mitigation, and Verification (MM&V). Monitoring and verification are defined as the capability to measure the amount of CO_2 stored at a specific sequestration site, monitor the site for leaks or other deterioration of storage integrity over time, and to verify that the CO_2 is stored in a way that is permanent and not harmful to the host ecosystem. Mitigation is the capability to respond to CO_2 leakage or ecological damage in the unlikely event that it should occur. MM&V is broken into two categories (1) geologic sequestration and (2) terrestrial sequestration. This structure is changed from the 2004 roadmap to reflect the fundamental differences in the suite of technology pathways for MM&V for terrestrial ecosystems versus geologic formations. Research activities in both areas are closely coordinated with the associated work in carbon storage. In addition to ensuring effective and safe storage, MM&V provides information and feedback that is useful in improving and refining storage field practices. Ocean sequestration is in an earlier stage of development and does not yet have an MM&V component. Table 6 shows goals and research pathways for geologic and terrestrial MM&V. Each area is described below.

MM&V technologies for CO_2 storage in geologic formations. Monitoring and verification for geosequestration contains three components:

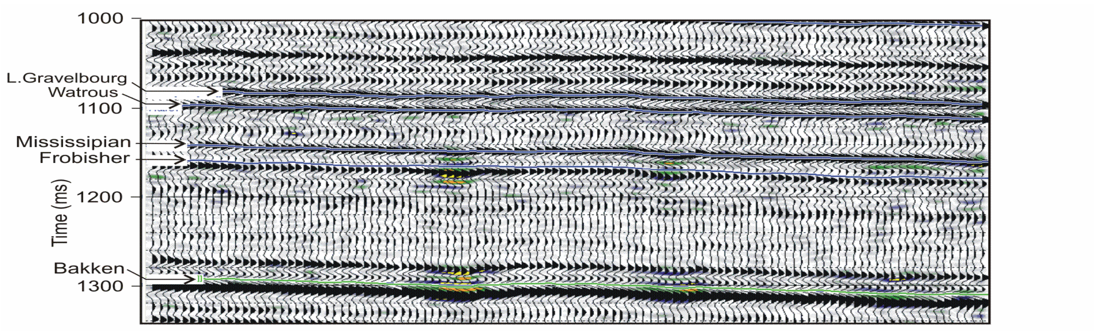
Modeling. Modeling is the understanding of the forces that influence the behavior of CO_2 in a reservoir, and the simulation of that understanding in a computer program that enables one to predict the fate and transport of injected CO_2. Modeling is important due to the very fundamental fact that a geosequestration project operator will need to prove with a high degree of confidence that injected CO_2 will remain securely stored before injection is allowed to commence. Modeling is a complex undertaking that involves the flow of CO_2 through heterogeneous rock; dissolution, capillary trapping, chemical reactions; and the impact of the CO_2 plume and increased pressure on the formation cap rock. The boundary of a robust CO_2 storage model is not limited to the target formation, but also includes fugitive paths that CO_2 may travel up to the surface. The program seeks to acquire the data needed to support the models (e.g., chemical reaction kinetics, and two and three phase vapor/liquid equilibrium data at super critical conditions) and to develop integrated models that support the needs of planned field tests.

Plume tracking. Plume tracking is the ability to "see" the injected CO_2 and its behavior. Seismic has risen up as a key technology in this area. Supercritical CO_2 is more compressible than saline water and sound waves travel through it at a different velocity. Thus free CO_2 in a saline formation leaves a bright seismic signature, as seen at the Weyburn and Frio field tests, Figure 7. Observation wells are another important source of information for plume tracking.

Leak detection. CO_2 leak detection systems will serve as a backstop for modeling and plume tracking. The first challenge for leak detection is the need to cover large areas. The CO_2 plume from an injection of 1 million tons CO_2 per year in a saline formation for twenty years could be spread over a horizontal area of 15 square miles or more. The second challenge is to separate out CO_2 leaks from the varying fluxes of natural CO_2 respiration.

There are important interconnections among the three areas. For example, data from plume tracking enables validation of reservoir models. On the other hand a robust reservoir model enable operators to better interpret data from plume tracking. Models and plume tracking combine to help focus leak detection efforts on high-risk areas.

Figure 7. Time-lapse Seismic CO_2 Monitoring Conducted at the Weyburn Field



The figure above shows the results of a seismic assessment conducted at the Weyburn oil field in Saskatchewan, Canada. The horizontal lines are layers of sedimentary rock that were identified in a pre-injection baseline analysis of the formation. This seismic reading was taken after CO_2 injection had begun, and the splotches of green and yellow show regions within the formation where sound waves travel through the rock at relatively slower speeds - a strong indication of the CO_2 plume location. Source: PRTC, "IEA GHG Weybun CO_2 Monitoring & Storage Project, 2000-2004 Report," Sept., 2004.

Mitigation. If CO_2 leakage occurs, steps can be taken to arrest the flow of CO_2 and mitigate any negative impacts. Examples include lowering the pressure within the CO_2 storage formation to reduce the driving force for CO_2 flow and possibly reverse faulting or fracturing; forming a "pressure plug" by increasing the pressure in the formation into which CO_2 is leaking; intercepting the CO_2 leakage path; or plugging the region where leakage is occurring with low permeability materials using for example "controlled mineral carbonation" or "controlled formation of biofilms."

MM&V for terrestrial ecosystems. The area of MM&V for terrestrial ecosystems contains three components:

Organic Matter Measurement. Conventional technologies for organic matter measurement (i.e., tree trunk diameter measurement and vegetation and soil samples) are too labor intensive for large-scale deployments. Advanced MM&V technologies such as arial videography rely on technology and can provide a significantly more robust site characterization at lower cost. Working with The Nature Conservancy the program is developing a next generation of satellite-based imaging technology.

Soil Carbon Measurement. Soil carbon offers the potential for long-term secure storage. The program is developing automated technologies for measuring soil carbon.

Modeling. Detailed models are used to extrapolate the results from random samples to an entire plot and to estimate the net increase in carbon storage relative to a case without enhanced uptake. Economic models show accumulations of emissions credits and revenues versus an initial investment.

Table 6. MM&V Roadmap

<table>
<tr><th colspan="3">Technology Roadmap</th><th colspan="2">Supporting Program Activities</th></tr>
<tr><th colspan="2">Pathways</th><th>Cross-cut Pathways</th><th>Research Highlights</th><th>Goals</th></tr>
<tr><td>Geologic Formations</td><td>Modeling
Reservoir models (CO_2 flow from target to vadose)
Geochemical models
Geomechanical models
Plume tracking
Surface to borehole seismic
Micro-seismic
Cross well tomography
Reservoir pressure monitoring
Observation wells/fluid sampling
CO_2 leak detection
Vadose zone soil/water sampling
Air sample/gas chromospectrometry
Infrared-based CO_2 in air detectors
Vegetation growth rates
CO_2 tracers, natural and introduced
Well testing
Sub-surface monitoring wells
Mitigation
De-pressure target formation
Pressure, permeability plug
Interception, pump and treat</td><td rowspan="2">Integrated flow, geochemical, and geomechanical models
Ecosystem response models
Model use to focus monitoring on higher-risk leakage areas
Risk analysis protocols
Protocols for using advanced MM&V technologies in commercial systems</td><td>3D seismic tests conducted at the Weyburn field show the ability to detect volumes of CO_2 within the geologic formation as small as 2,500 metric tons.

Completed a rigorous flow model of CO_2 injection into the Frio Saline Formation.

Completed a micro-gravimetric survey of Sleipner Utsira saline formation.</td><td rowspan="2">2006 Apply promising MM&V technologies to at least several sequestration field tests or commercial applications.

2008 An MM&V protocol enables 95% of CO_2 uptake in a terrestrial ecosystem to be credited and represents no more than 10% of the total sequestration cost.

2012 CO_2 material balance greater than 99%.

2012 An MM&V protocol enables 95% of CO_2 injected into a geologic reservoir to be credited.</td></tr>
<tr><td>Terrestrial Ecosystems</td><td>Modeling
Above/below ground correlations
Cash flow models of terrestrial sequestration
Plant matter measurement
Multi-spectral 3-dimensional ariel digital imagery
Satellite imagery
Light Detection and Ranging (LIDAR)
Soil carbon measurement
Laser-induced breakdown spectroscopy (LIBS)
Inelastic Neutron Scattering Soil Carbon Analyzer</td><td>Completed flyovers of the Delta National Forest in Mississippi to measure carbon storage.

Complete construction and testing of person portable LIBS.

Complete calibrations of scanning system.</td></tr>
</table>

4. Non-CO_2 Greenhouse Gas Control.

Because non-CO_2 greenhouse gases (e.g., methane, N_2O, and high global warming potential gases) can have significant economic value, emissions can often be captured or avoided at relatively low net cost. The Sequestration Program is focused on fugitive methane emissions where non-CO_2 greenhouse gas abatement is integrated with energy production, conversion, and use. Landfill gas and coal mine methane are two priority opportunities. Landfill gas is typically half methane, half CO_2, with small amounts of heavier hydrocarbons. Technologies include end-of-pipe separations to concentrate the methane, and landfill engineering to produce a more useful gas stream over a shorter period of time. Coal mine methane is much more dilute (0.3 – 1.5% methane in air) and represents a larger challenge. Methane can be captured for use or oxidized to CO_2 which has a much lower GHG effect per molecule. Table 7 presents a roadmap for non-CO_2 GHG control research and several projects funded by the Program.

Table 7. Non-CO_2 GHG Roadmap

	Technology Pathway	Supporting Research Projects	Program Goals
Landfill Gas	Methane/nitrous oxide generation control Water management Microbe management Methane/CO_2 separation Bacterial oxidation of CH_4 and N_2O Use of landfill gas for ECBM	Methane recovery from landfills [Yolo County Planning and Public Works Department] http://www.netl.doe.gov/publications/factsheets/project/Proj199.pdf Methodologies to minimize microbial production of nitrous oxide and maximize microbial consumption of methane in landfill cover soils [University of Michigan] Maximize biodegradation and minimize the formation of methane by controlled injection of air and liquids [University of Delaware] Design and test a landfill tarp impregnated with immobilized methane oxidizing bacteria [University of North Carolina] Injection of landfill gas into un-mineable coal seams [Kansas Geological Survey] http://www.netl.doe.gov/publications/factsheets/project/Proj324.pdf	2007 Effective deployment of cost-effective methane capture systems 2012 Commercial deployment of at least two technologies from the R&D program
Coal Mine Methane	Separation of methane in air at a concentration of 0.3-1.5 vol% Catalytic oxidation of methane in air at a concentration of 0.3-1.5 vol%	Catalytic combustion of minemouth methane http://www.netl.doe.gov/publications/factsheets/project/Proj248.pdf Nitrogen/methane separation via ultra-fast thermal swing adsorption http://www.netl.doe.gov/publications/factsheets/project/Proj253.pdf	

5. Breakthrough Concepts. Breakthrough Concepts R&D is pursuing revolutionary and transformational sequestration approaches with potential for low cost, permanence, and large global capacity. These concepts are very speculative but have the potential to provide "leap frog" performance and cost improvements compared to existing technologies.

CO_2 conversion is an important part of the portfolio for Breakthrough Concepts. CO_2 can be converted into benign solids to provide permanent storage or back to a hydrocarbon fuel to provide a regenerable energy system using carbon as the energy source. A guiding principal is to mimic and harness processes found in nature, for example, photosynthesis and mollusk shell formation.

Chemical Looping

Chemical looping is a "breakthrough" approach to fossil fuel conversion that has received significant attention. In a chemical looping process, oxygen for combustion is delivered to the fuel via a redox agent rather than by direct air or gaseous oxygen, providing the potential for high-efficiency fuel conversion and venting a high-purity CO_2 exhaust at pressure.

In 2004/2005 the Program explored chemical looping gasification concepts, where the redox agent supplies substoichiometric oxygen for gasification of fuel. These concepts are complex but offer the step change in efficiency associated with combined cycle power plant technology.

6. Field Projects. Field projects are an important part of the program's technology development effort. Conditions in both terrestrial ecosystems and geologic formations are difficult to simulate, and so testing of ideas in the field often enables significant learning and insight. Sequestration field tests provide a test bed for CO_2 detection and measurement technologies and also an opportunity to ground-truth models. Field tests also bring technology developers and communities together to address concerns about the environmental impacts of sequestration deployments and to determine the performance standards that must be met. Figure 8 presents a partial list of program-funded field tests in different stages of planning and execution.

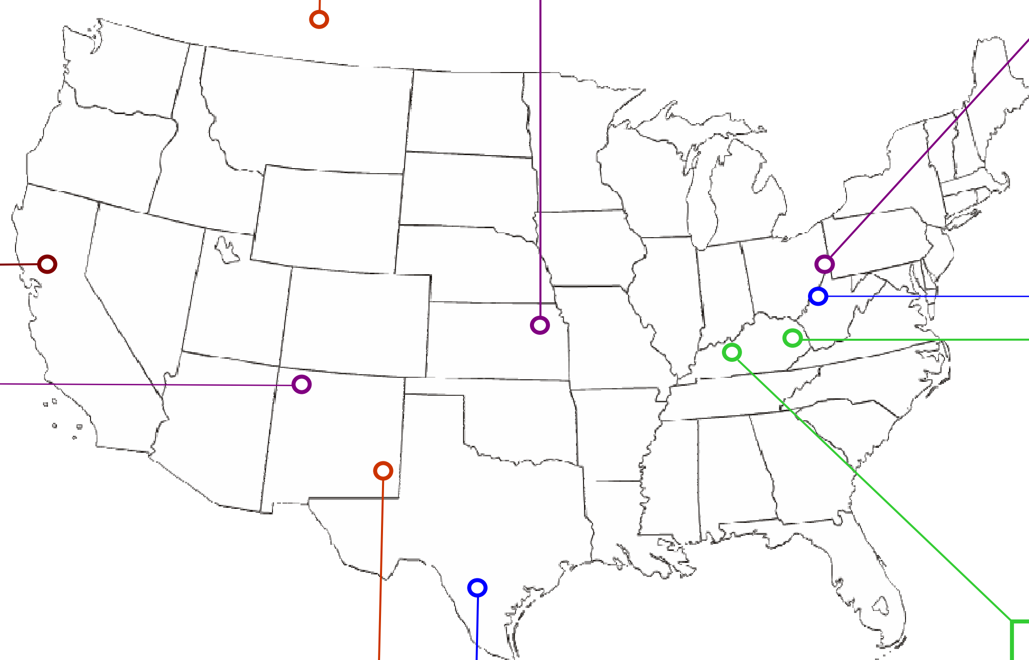
Figure 8. Carbon Sequestration Field Projects

WEYBURN, CANADA
Lead: ENCANA
Type: Geologic, Depleting oil reservoir
Phase: Injection began in 2001
Scale: 20 MM tons CO_2 over 15 yrs
Highlights: Demonstrate use of time lapse (3D) seismic and other technologies to monitor CO_2.
http://www.netl.doe.gov/publications/factsheets/project/Proj282.pdf
http://www.encana.com/operations/upstream/ca_weyburn.html

JOHNSON COUNTY, KS
Lead: Kansas Geologic Survey
Type: Geologic, coal seam
Phase: Pre-injection
Scale: TBD
Highlights: Will explore the possibility of injecting untreated landfill gas (50/50 CO_2/CH_4) into a coal bed for both enhanced CBM recovery and landfill gas purification.
http://www.netl.doe.gov/publications/factsheets/project/Proj324.pdf

MARSHALL COUNTY, WV
Lead: Consol Energy
Type: Geologic, coal seam
Phase: Pre-injection, 2005 injection planned
Scale: 26,000 tons CO_2 over 1 year
Highlights: Plan to demonstrate horizontal CO_2 injection wells with up to 3,000 feet of horizontal length.
http://www.consolenergy.com/content.asp?c=GreenhouseGasManagement_20030613113634

YOLO COUNTY, CA
Lead: Yolo County Planning and Public Works Dept.
Type: Non-CO_2, LFG
Phase: Construction of test cells completed
Scale: 12 acres
Highlights: Seek to demonstrate LFG generation over 5-10 years as opposed to typical 10-30 years for more economical recovery.
http://www.netl.doe.gov/publications/factsheets/project/Proj199.pdf



NEW HAVEN, WV
Lead: American Electric Power
Type: Geologic, Saline formation
Phase: Pre-injection
Scale: TBD
Highlights: Injection well revealed low permeability in target zone; evaluating potential storage capacity in shallower formations.

SAN JUAN BASIN, NM
Lead: Burlington Resources, Advanced Resources International
Type: Geologic, coal seam
Phase: Post-injection
Scale: 280,000 tons CO_2 over 6 years
Highlights: Developed improved understanding of coal swelling and ability to predict CO_2 storage capacity.
http://www.netl.doe.gov/publications/factsheets/project/Proj228.pdf

HAZARD, KY
Lead: University of Kentucky
Type: Terrestrial, tree planting
Phase: Third year of planting
Scale: 500 acres
Highlights: Demonstrated increase site indices and sequestration while increasing water infiltration and reducing sediment runoff with tree planting in uncompacted or ripped mineland.

WEST PEARL QUEEN, NM
Lead: Strata Production
Type: Geologic, Depleting oil reservoir
Phase: Post-injection
Scale: 2,200 tons CO_2 over 42 days
Highlights: Tested tracer and seismic MM&V; examined alternative CO_2 trapping mechanisms.

FRIO, TX
Lead: University of Texas Bureau of Economic Geology
Type: Geologic, Saline formation
Phase: Post-injection
Scale: 1,800 tons CO_2 over 3 weeks
Highlights: Developed a thorough Environmental Assessment under NEPA.
http://www.beg.utexas.edu/environqlty/co2seq/fieldexperiment.htm

PARADISE, KY
Lead: Tennessee Valley Authority
Type: Terrestrial, tree planting
Phase: Post-planting, second growing season
Scale: 100 acres
Highlights: Achieved 80% survival rate for maple poplar, sweet gums, and sycamore using FGD sludge as amendment and irrigating with FGD settling pond water.
http://www.netl.doe.gov/publications/factsheets/project/proj134.pdf

B. Infrastructure Development

Regional Partnerships

> One of the cornerstones of our carbon sequestration program, a national network of regional partnerships, will continue its important work in FY 2006. This Secretarial initiative has brought together the federal government, state agencies, universities, and private industry to determine which options for capturing and storing greenhouse gases are most practical for specific areas of the country.
>
> Mark Maddox
> Principal Deputy Assistant Secretary for Fossil Energy
> March 16, 2005

DOE initiated seven Regional Carbon Sequestration Partnerships (RCSPs) in September of 2003 with the goal of developing an infrastructure to support and enable future carbon sequestration field tests and deployments. The first phase of the RCSPs will end in June of 2005 as a clear success. Together the partnerships have established a national network of companies and professionals working to support sequestration deployments, they have created a carbon sequestration atlas for the United States, and identified and vetted priority opportunities for sequestration field tests. Table 8 presents an overview of the Phase I partnerships. More information about them is accessible via the web links in Table 8 or through the document, "Regional Carbon Sequestration Partnerships: Phase I Accomplishments," which can be downloaded from the NETL website http://www.netl.doe.gov/coal/Carbon%20Sequestration/pubs/PhaseIAccomplishment.pdf

In December 2004, DOE announced an open competitive solicitation for Phase II RCSPs. The Phase II partnerships will be four years in duration with an expected Federal funding per award of $2-4 million per year. Like Phase I, the Phase II awards require a minimum cost share of 20%. Proposals were accepted on March 16, 2005 and awards are expected to be announced before the end of FY 2005.

The primary and overarching objective of the Phase II Regional Partnerships will be to move forward with priority sequestration technology validation tests identified in the Phase I effort. Successful implementation of these tests will support the 2012 assessment under the Administration's Global Climate Change Technology Initiative and will provide direction and focus on viable large-scale sequestration deployments within the regions. Supporting the primary objective will be the refining and implementing of MM&V protocols, developing an improved understanding of environmental and safety regulations, establishing protocols for project implementation, accounting, and contracts, and conducting public outreach and education. Also in Phase II, partnerships will seek to continue the characterization of the regions and to refine a national atlas of carbon sources and sinks.

In FY 2009 DOE will consider an optional Phase III effort for the RCSPs. The third phase, which would run through 2013, is contingent upon continued importance/synergies to the FutureGen initiative, the need for the validation of additional sequestration sites throughout the United States, and budget availability.

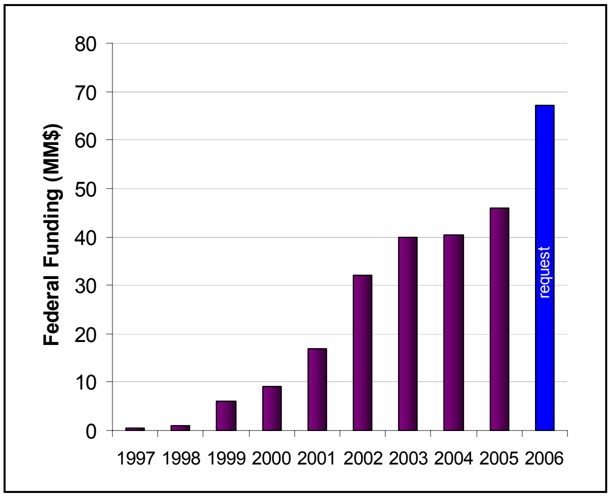
Table 8. Phase I Regional Sequestration Partnerships At-A-Glance

	Lead Organization/ Webpage	Highlights
westcarb.org	California Energy Commission http://www.westcarb.org/	• Identified candidate enhanced coal bed methane and enhanced oil recovery projects • Detailed assessment of forestation as mitigation by storage, fire management, and biofuel opportunities
Southwest Regional Partnership on Carbon Sequestration	New Mexico Institute of Mining and Technology http://www.southwestcarbonpartnership.org/	• Resource-rich region with two CO_2 pipelines • Identified seven candidate sites for field testing • Conducted web-based "town hall" meetings
Big Sky Carbon Sequestration Partnership	Montana State University http://www.bigskyco2.org/	• Large storage potential in basalt formations • Focus on agriculture and forestry project protocols to increase salability of credits • Close interaction with state governments
The Plains CO_2 Reduction Partnership PCOR Partnership	University of North Dakota, Energy & Environmental Research Center http://www.undeerc.org/pcor/	• Region rich in value-added geologic sequestration options • Wetlands a unique regional opportunity • Half-hour sequestration documentary aired on Prairie Public Television
MGSC	University of Illinois, Illinois State Geological Survey http://www.sequestration.org/	• Efforts centered on a CO_2 pipeline "fairway" and a focused region • Transportation plans highly developed • Link to agriculture interests through ethanol
MRCSP Midwest Regional Carbon Sequestration Partnership	Battelle Memorial Institute http://198.87.0.58/default.aspx	• Strong analysis and cost-supply curves for CO_2 sequestration • Region accounts for >20% of GHG emissions in the U.S. • Interactive website as outreach tool
Southeast Regional Carbon Sequestration Partnership	Southern States Energy Board http://www.secarbon.org/	• Electricity supply industry and governor-level participation • Carbon offset program, a web-based portal for advertising sequestration opportunities

C. Program Management

The DOE is dedicated to achieving the Sequestration Program goals and to utilizing the Program funds, shown in Figure 9, as effectively as possible. This is achieved through cooperative and collaborative relationships both domestically and internationally, competitive solicitations, analysis and project evaluation, project merit reviews and proactive public outreach and education. These activities support and enhance the R&D being conducted in the laboratory and the field. Following are management highlights.

Figure 9. DOE Sequestration Program Budget



Public/Private Partnerships Public-private partnerships and cost-shared R&D are a critical part of technology development for carbon sequestration. These relationships draw on pertinent capabilities that the coal, electricity supply, oil and gas, refining, and chemical industries have built up over decades and a technical knowledge base shared with the national laboratories, federal and state geological surveys, and academia. The program engages industry through competitive solicitations, which bring forward the companies and researchers with the best ideas and strongest capabilities and also challenges companies to offer significant cost-share, leveraging Federal dollars. In 2005, the program will award the second phase of the Regional Partnerships through an open competitive solicitation with 20% cost share required. Colleges and universities, private research institutes, national laboratories, and other federal and state agencies also play a significant role in technology development. Separate competitive solicitations are directed towards these institutions to spawn innovative, breakthrough concepts.

In-House R&D at NETL The **C**arbon **S**equestration **S**cience **F**ocus **A**rea (**CSSFA**) at NETL conducts science-based research and analysis in areas related to carbon sequestration using in-house facilities and resources at NETL. The CSSFA has been successful in fostering formal and information collaborative relationships with industry and academia in these high-risk research endeavors. The CSSFA also provides FE/NETL with a scientific understanding of the underlying technologies and, thus, enhances its effectiveness in implementing the carbon sequestration R&D portfolio.

Programmatic Environmental Impact Statement Many pilot and pre-commercial scale research activities are regulated under the National Environmental Policy Act (NEPA), a procedural regulation that requires environmental impact assessments of varying levels of rigor. NETL has conducted a review of the requirements under NEPA, and in October, 2003, Rita Bajura, then Director of NETL, issued a determination stating that "preparation of a programmatic environmental impact statement (PEIS) constitutes the appropriate level of environmental review for implementing the Sequestration Program."

In 2004 and 2005, FE/NETL hosted a series of public meetings where Federal Employees explained the goals and objectives of the Carbon Sequestration Program and the types of research projects the program was conducting and planned to conduct in the future. The PEIS will assess the environmental effects of current and potential future initiatives, including field tests, regional partnerships, and core R&D. Ultimately, it will help define the scope and direction of future Program activities. Later in 2005, FE/NETL will publish a draft Environmental Impact Statement and then conduct a second round of public meetings. More information on the FE/NETL PEIS can be found at: http://www.netl.doe.gov/sequestration

Interagency Coordination In each sequestration area, the DOE program collaborates with other agencies with overlapping responsibilities. For example, during 2003 and 2004 the DOE Carbon Sequestration Program collaborated with the National Academy of Sciences (NAS) in an effort to bolster R&D efforts in Breakthrough Concepts. A workshop hosted by DOE and NRC identified priorities for breakthrough research and a solicitation drawing from the research results produced a pool of over one hundred proposals. Seven awards were made in March 2004 and the work is proceeding.

Charter CSLF Signing Ceremony, June 2003

International Collaboration The Carbon Sequestration Leadership Forum (CSLF) is an international initiative that is focused on development of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage. The purpose of the CSLF is to make these technologies broadly available internationally; and to identify and address wider issues relating to carbon capture and storage. This could include promoting the appropriate technical, political, and regulatory environments for the development of such technology. In 2005 the CSLF welcomed France as a member and endorsed ten carbon sequestration projects around the world. Information on the CSLF and its activities can be found at http://www.cslforum.org

The Carbon Sequestration Program achieves informal international collaborations that complement the CSLF through a variety of mechanisms, including formal bilateral and multilateral agreements, less formal cooperation agreements, and coordination of funding by different governments and the private sector. In 2005 the Sequestration Program provided technical assistance to the Intergovernmental Panel on Climate Change including review of a special report on CO_2 Capture and Geologic Storage and another on Carbon Accounting Protocols.

Systems, Economic, and Benefits Analyses Systems analyses and economic modeling of potential new processes are crucial to providing sound guidance to R&D efforts, which are investigating a wide range of CO_2 capture options. Many of the technologies being developed by the program are investigated at the laboratory or pilot scale. Systems analyses offer the opportunity to visualize how these new technologies might fit in a full-scale power plant and identify potential issues with their integration. Results of the analyses help make decisions on what technologies the Program should continue funding and how the research can be modified to help the technology succeed at full scale. Systems and economic analyses are performed by NETL analysts on the full range of technologies being developed through the Sequestration Program. Results of these studies are posted on the NETL Sequestration Website.

Systems analysis efforts are aided through the use of modeling tools. To enable the modeling of sequestration systems, NETL funds the development of the Integrated Environmental Control Model (IECM) which is a publicly-available model that now includes options for CO_2 capture and storage. http://www.iecm-online.com/

The Program conducts independent studies and participates in cross-cutting studies to model the future national energy situation. These activities include Program-specific analyses to look at how sequestration might help meet future CO_2 emissions reductions goals. They also include broader efforts that use large models like DOE's National Energy Modeling System (NEMs) or ICF's Integrated Planning Model (IPM) to address the benefits and roles of the full suite of advanced fossil energy technologies. The most recent programmatic benefits analysis can be downloaded at:
http://www.netl.doe.gov/coal/Carbon%20Sequestration/pubs/analysis/GHGT-7%20ID%20506%20Atmospheric%20Stabilization.pdf

Education and Outreach The notion of capturing and sequestering carbon dioxide and other greenhouse gases is relatively new, and many people are unaware of its role as a greenhouse gas reduction strategy. Increased education and awareness are needed to achieve acceptance of carbon sequestration by the general public, regulatory agencies, policy makers, and industry and, thus, enable future commercial deployments of advanced technology. The following activities highlight the Program's education and outreach efforts:

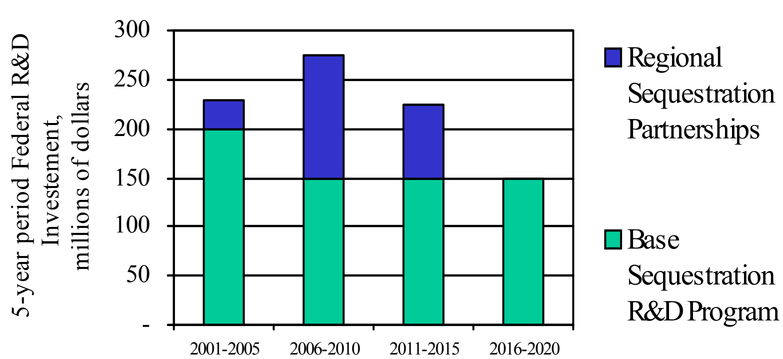
- Carbon Sequestration Webpage at the NETL site
- Monthly sequestration newsletter
- The Sequestration Technology Roadmap and Program Plan, revised annually
- The National Conference on Carbon Sequestration, held annually in the late spring in the Washington, DC, area
- Educational curriculum on global climate change and GHG emissions mitigation options

In addition, the program management team participates in technical conferences through presentations, panel discussions, breakout groups, and other formal and informal venues. These efforts expose professionals working in other fields to the technology challenges of sequestration and also enable examination of some of the more detailed issues underlying the technology.

In concert with R&D, the Program seeks to engage non-governmental organizations (NGO's) and federal, state, and local environmental regulators to raise awareness of the priority the Program places on evaluating the potential environmental impacts of sequestration and ensuring that selected technologies preserve human and ecosystem health. Many of the Program's R&D projects have their own outreach component. For example, field activities at the Mountaineer Power Plant and the Frio Brine Project have resulted in articles that have been run in newspapers across the country. Also, the Regional Partnerships will enhance technology development but also engage regulators, policy makers, and interested citizens at the state and local level through innovative outreach mechanisms. The Program works directly with non-governmental organizations and the environmental community through a variety of activities. Successful outreach entails two-way communications, and the Program will consider concerns voiced at outreach venues and continually assess the adequacy and focus of the current R&D portfolio.

Resource Requirements Figure 10 shows the estimated resources needed to pursue the opportunities identified in the Program plan and to achieve the Program's goals. The base Program funding is estimated at roughly $55 million per year. The Regional Partnerships require an initial investment but are structured to become self-sustaining by 2013.

Figure 10. Funding Requirements of the Carbon Sequestration Program



If you have any questions, comments, or would like more information about DOE's Carbon Sequestration Program, please contact the following persons:

Program-level Personnel:

National Energy Technology Laboratory Strategic Center for Coal Office of Fossil Energy	U.S. Department of Energy Office of Coal and Power Systems Office of Fossil Energy
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You can also find information about carbon sequestration at our web sites:

http://www.netl.doe.gov/sequestration
http://www.fe.doe.gov/coal_power/sequestration/

APPENDIX D

NDIC PCOR PARTNERSHIP PHASE II LETTER OF SUPPORT

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Agriculture Commissioner,
Roger Johnson

February 16, 2005

Mr. Edward Steadman
Associate Director for Research
Energy & Environmental Research Center
PO Box 9018
Grand Forks, ND 58202-9018

Subject: Letter of Interest and Financial Commitment Supporting "The Plains CO_2 Reduction Partnership (PCORP) Phase II"

Dear Mr. Steadman:

This letter is in response to your request for participation in the proposed University of North Dakota (UND) Energy & Environmental Research Center (EERC) project entitled "The Plains CO_2 Reduction Partnership (PCORP) Phase II" submitted to the U.S. Department of Energy, Solicitation DE-PS26-05NT42255, Regional Carbon Sequestration Partnerships – Phase II

The North Dakota Lignite Research, Development and Marketing Program (Program) is committed to the development and commercialization of advanced technologies for the North Dakota energy industry. As federal regulations continue to become more stringent, it is important to identify regional resources and options to address anticipated environmental issues such as carbon management and sequestration.

This letter of support and potential funding of up to $180,000 per year for the proposed 4-year program from the Program is subject to DOE selection of your proposal for award, submission of a proposal that meets Program guidelines, peer review by experts in the field, a funding recommendation by the Lignite Research Council and approval by the North Dakota Industrial Commission. Program funding guidelines require matching industrial funds.

Sincerely,

Harvey M. Ness
Director and Technical Advisor, Lignite Research, Development and Marketing Program

cc: Karlene Fine, Executive Director and Secretary, North Dakota Industrial Commission
John W. Dwyer, Chairman, Lignite Research Council

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INDUSTRIAL COMMISSION OF NORTH DAKOTA
Karlene Fine
Executive Director & Secretary
kfine@state.nd.us
600 E. Blvd., State Capitol
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APPENDIX E

BUDGET AND BUDGET NOTES

SUMMARY BUDGET - ALL YEARS

PLAINS CO2 REDUCTION PARTNERSHIP - PHASE II
DOE
PROPOSED START DATE: OCT 1, 2005
EERC PROPOSAL #2006-0054

	TOTAL		NDIC - LIGNITE SHARE		OTHER COST SHARE		DOE SHARE	
CATEGORY	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**
TOTAL DIRECT LABOR	104,787	$ 3,778,183	4,790	$ 158,231	5,910	$ 195,205	94,087	$ 3,424,747
TOTAL FRINGE BENEFITS		$ 1,867,578		$ 79,117		$ 96,405		$ 1,692,056
TOTAL LABOR		$ 5,645,761		$ 237,348		$ 291,610		$ 5,116,803
OTHER DIRECT COSTS								
TRAVEL		$ 464,050		$ -		$ -		$ 464,050
COMMUNICATION - PHONES & POSTAGE		$ 22,929		$ 852		$ 1,020		$ 21,057
OFFICE (PROJECT SPECIFIC SUPPLIES)		$ 35,065		$ 1,049		$ 1,545		$ 32,471
SUPPLIES		$ 157,930		$ 15,920		$ 21,080		$ 120,930
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)		$ 11,569		$ 224		$ 276		$ 11,069
FEES		$ 5,869,825		$ 206,145		$ 258,187		$ 5,405,493
TOTAL OTHER DIRECT COST		$ 6,561,368		$ 224,190		$ 282,108		$ 6,055,070
TOTAL DIRECT COST		$ 12,207,129		$ 461,538		$ 573,718		$ 11,171,873
FACILITIES & ADMIN. RATE - % OF MTDC	VAR	$ 3,707,871	56%	$ 258,462	56%	$ 321,282	46.5%	$ 3,128,127
TOTAL CASH		$ 15,915,000		$ 720,000		$ 895,000		$ 14,300,000
IN-KIND SUPPORT - SEE COST SHARE SUMMARY		$ 5,572,892		$ -		$5,572,892		$ -
TOTAL PROJECT		$ 21,487,892		$ 720,000		$6,467,892		$ 14,300,000

NOTE: Due to limitations within the University's accounting system, the system does not provide for accumulating and reporting expenses at the Detailed Budget level. The Summary Budget is presented for the purpose of how we propose, account, and report expenses. The Detailed Budget is presented to assist in the evaluation of the proposal.

DETAILED BUDGET - YEAR ONE

PLAINS CO_2 REDUCTION PARTNERSHIP - PHASE II
DOE
PROPOSED START DATE: OCT 1, 2005
EERC PROPOSAL #2006-0054

LABOR	LABOR CATEGORY	TOTAL YEAR ONE HRS	TOTAL YEAR ONE $COST	NDIC - LIGNITE SHARE HRS	NDIC - LIGNITE SHARE $COST	OTHER COST SHARE HRS	OTHER COST SHARE $COST	DOE SHARE HRS	DOE SHARE $COST
TOTAL DIRECT LABOR			$ 768,282		$ 52,411		$ 62,622		$ 653,249
TOTAL FRINGE BENEFITS			$ 380,356		$ 26,206		$ 31,310		$ 322,840
TOTAL LABOR			$ 1,148,638		$ 78,617		$ 93,932		$ 976,089
OTHER DIRECT COSTS									
TRAVEL			$ 107,135		$ -		$ -		$ 107,135
COMMUNICATION - PHONES & POSTAGE			$ 4,322		$ 264		$ 286		$ 3,772
OFFICE (PROJECT SPECIFIC SUPPLIES)			$ 5,826		$ 298		$ 356		$ 5,172
SUPPLIES			$ 21,650		$ -		$ -		$ 21,650
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)			$ 4,050		$ -		$ -		$ 4,050
NATURAL MATERIALS ANALYTICAL RES. LAB.			$ -		$ -		$ -		$ -
GC/MS LABORATORY			$ 77,770		$ 35,439		$ 42,331		$ -
OUTSIDE LABS			$ -		$ -		$ -		$ -
GRAPHICS SUPPORT			$ 23,283		$ 766		$ 916		$ 21,601
SUBCONTRACT - NEXANT			$ 10,000		$ -		$ -		$ 10,000
SUBCONTRACT - USGS			$ 79,989		$ -		$ -		$ 79,989
SUBCONTRACT - DUCKS UNLIMITED			$ 50,719		$ -		$ -		$ 50,719
SUBCONTRACT - PRAIRIE PUBLIC TV			$ 74,031		$ -		$ -		$ 74,031
SUBCONTRACT - ALBERTA EUB			$ 100,000		$ -		$ -		$ 100,000
SUBCONTRACT - NDSU			$ 49,913		$ -		$ -		$ 49,913
SUBCONTRACT - FISCHER OIL & GAS			$ 100,000		$ -		$ -		$ 100,000
SUBCONTRACT - UNSPECIFIED (MMV work)			$ 80,000		$ -		$ -		$ 80,000
TOTAL OTHER DIRECT COST			$ 788,688		$ 36,767		$ 43,889		$ 708,032
TOTAL DIRECT COST			$ 1,937,326		$ 115,384		$ 137,821		$ 1,684,121
FACILITIES & ADMIN. RATE - % OF MTDC		VAR	$ 757,674	56%	$ 64,616		$ 77,179	46.5%	$ 615,879
TOTAL CASH			$ 2,695,000		$ 180,000		$ 215,000		$ 2,300,000
IN-KIND SUPPORT - SEE COST SHARE SUMMARY			$ 771,227		$ -		$ 771,227		$ -
TOTAL PROJECT			$ 3,466,227		$ 180,000		$ 986,227		$ 2,300,000

DETAILED BUDGET - YEAR TWO

PLAINS CO2 REDUCTION PARTNERSHIP - PHASE II
DOE
PROPOSED START DATE: OCT 1, 2005
EERC PROPOSAL #2006-0054

		TOTAL YEAR TWO		NDIC - LIGNITE SHARE		OTHER COST SHARE		DOE SHARE	
LABOR	**LABOR CATEGORY**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**
TOTAL DIRECT LABOR			$ 892,540		$ 30,677		$ 42,430		$ 819,433
TOTAL FRINGE BENEFITS			$ 440,805		$ 15,339		$ 21,215		$ 404,251
TOTAL LABOR			$ 1,333,345		$ 46,016		$ 63,645		$ 1,223,684
OTHER DIRECT COSTS									
TRAVEL			$ 120,370		$ -		$ -		$ 120,370
COMMUNICATION - PHONES & POSTAGE			$ 5,986		$ 165		$ 229		$ 5,592
OFFICE (PROJECT SPECIFIC SUPPLIES)			$ 9,223		$ 140		$ 460		$ 8,623
SUPPLIES			$ 85,070		$ 12,558		$ 17,442		$ 55,070
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)			$ 2,633		$ 42		$ 58		$ 2,533
NATURAL MATERIALS ANALYTICAL RES. LAB.			$ 38,160		$ 5,342		$ 7,420		$ 25,398
GC/MS LABORATORY			$ 83,104		$ 17,394		$ 24,158		$ 41,552
OUTSIDE LABS			$ 225,000		$ 33,488		$ 46,512		$ 145,000
GRAPHICS SUPPORT			$ 24,645		$ 239		$ 333		$ 24,073
SUBCONTRACT - NEXANT			$ 50,000		$ -		$ -		$ 50,000
SUBCONTRACT - USGS			$ 151,487		$ -		$ -		$ 151,487
SUBCONTRACT - DUCKS UNLIMITED			$ 830,677		$ -		$ -		$ 830,677
SUBCONTRACT - PRAIRIE PUBLIC TV			$ 105,992		$ -		$ -		$ 105,992
SUBCONTRACT - ALBERTA EUB			$ 100,000		$ -		$ -		$ 100,000
SUBCONTRACT - NDSU			$ 74,842		$ -		$ -		$ 74,842
SUBCONTRACT - FISCHER OIL & GAS			$ 100,000		$ -		$ -		$ 100,000
SUBCONTRACT - UNSPECIFIED			$ 160,000		$ -		$ -		$ 160,000
TOTAL OTHER DIRECT COST			$ 2,167,189		$ 69,368		$ 96,612		$ 2,001,209
TOTAL DIRECT COST			$ 3,500,534		$ 115,384		$ 160,257		$ 3,224,893
FACILITIES & ADMIN. RATE - % OF MTDC		VAR	$ 929,466	56%	$ 64,616		$ 89,743	46.5%	$ 775,107
TOTAL CASH			$ 4,430,000		$ 180,000		$ 250,000		$ 4,000,000
IN-KIND SUPPORT - SEE COST SHARE SUMMARY			$ 1,817,298		$ -		$ 1,817,298		$ -
TOTAL PROJECT			$ 6,247,298		$ 180,000		$ 2,067,298		$ 4,000,000

DETAILED BUDGET - YEAR THREE

PLAINS CO2 REDUCTION PARTNERSHIP - PHASE II
DOE
PROPOSED START DATE: OCT 1, 2005
EERC PROPOSAL #2006-0054

LABOR	LABOR CATEGORY	TOTAL YEAR THREE HRS	TOTAL YEAR THREE $COST	NDIC - LIGNITE SHARE HRS	NDIC - LIGNITE SHARE $COST	OTHER COST SHARE HRS	OTHER COST SHARE $COST	DOE SHARE HRS	DOE SHARE $COST
TOTAL DIRECT LABOR			$ 958,800		$ 34,369		$ 41,377		$ 883,054
TOTAL FRINGE BENEFITS			$ 474,201		$ 17,185		$ 20,579		$ 436,437
TOTAL LABOR			$ 1,433,001		$ 51,554		$ 61,956		$ 1,319,491
OTHER DIRECT COSTS									
TRAVEL			$ 120,370		$ -		$ -		$ 120,370
COMMUNICATION - PHONES & POSTAGE			$ 5,320		$ 137		$ 163		$ 5,020
OFFICE (PROJECT SPECIFIC SUPPLIES)			$ 8,836		$ 324		$ 386		$ 8,126
SUPPLIES			$ 39,200		$ 3,134		$ 3,366		$ 32,700
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)			$ 2,353		$ 91		$ 109		$ 2,153
NATURAL MATERIALS ANALYTICAL RES. LAB.			$ 38,295		$ 5,786		$ 6,910		$ 25,599
GC/MS LABORATORY			$ 88,578		$ 20,182		$ 24,107		$ 44,289
OUTSIDE LABS			$ 225,000		$ 34,177		$ 40,823		$ 150,000
GRAPHICS SUPPORT			$ 33,247		$ -		$ -		$ 33,247
SUBCONTRACT - NEXANT			$ 50,000		$ -		$ -		$ 50,000
SUBCONTRACT - USGS			$ 154,653		$ -		$ -		$ 154,653
SUBCONTRACT - DUCKS UNLIMITED			$ 735,915		$ -		$ -		$ 735,915
SUBCONTRACT - PRAIRIE PUBLIC TV			$ 74,031		$ -		$ -		$ 74,031
SUBCONTRACT - ALBERTA EUB			$ 100,000		$ -		$ -		$ 100,000
SUBCONTRACT - NDSU			$ 74,842		$ -		$ -		$ 74,842
SUBCONTRACT - FISCHER OIL & GAS			$ 100,000		$ -		$ -		$ 100,000
SUBCONTRACT - UNSPECIFIED			$ 160,000		$ -		$ -		$ 160,000
TOTAL OTHER DIRECT COST			$ 2,010,640		$ 63,831		$ 75,864		$ 1,870,945
TOTAL DIRECT COST			$ 3,443,641		$ 115,385		$ 137,820		$ 3,190,436
FACILITIES & ADMIN. RATE - % OF MTDC		VAR	$ 951,359	56%	$ 64,615		$ 77,180	46.5%	$ 809,564
TOTAL CASH			$ 4,395,000		$ 180,000		$ 215,000		$ 4,000,000
IN-KIND SUPPORT - SEE COST SHARE TABLE			$ 1,803,986		$ -		$ 1,803,986		$ -
TOTAL PROJECT			$ 6,198,986		$ 180,000		$ 2,018,986		$ 4,000,000

DETAILED BUDGET - YEAR FOUR

PLAINS CO2 REDUCTION PARTNERSHIP - PHASE II
DOE
PROPOSED START DATE: OCT 1, 2005
EERC PROPOSAL #2006-0054

		TOTAL YEAR FOUR		NDIC - LIGNITE SHARE		OTHER COST SHARE		DOE SHARE	
LABOR	**LABOR CATEGORY**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**
TOTAL DIRECT LABOR			$ 1,158,561		$ 40,774		$ 48,776		$ 1,069,011
TOTAL FRINGE BENEFITS			$ 572,216		$ 20,387		$ 23,301		$ 528,528
TOTAL LABOR			$ 1,730,777		$ 61,161		$ 72,077		$ 1,597,539
OTHER DIRECT COSTS									
TRAVEL			$ 116,175		$ -		$ -		$ 116,175
COMMUNICATION - PHONES & POSTAGE			$ 7,301		$ 286		$ 342		$ 6,673
OFFICE (PROJECT SPECIFIC SUPPLIES)			$ 11,180		$ 287		$ 343		$ 10,550
SUPPLIES			$ 12,010		$ 228		$ 272		$ 11,510
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)			$ 2,533		$ 91		$ 109		$ 2,333
NATURAL MATERIALS ANALYTICAL RES. LAB.			$ 38,976		$ 5,466		$ 7,503		$ 26,007
GC/MS LABORATORY			$ 95,816		$ 21,831		$ 26,077		$ 47,908
OUTSIDE LABS			$ 162,000		$ 24,608		$ 29,392		$ 108,000
GRAPHICS SUPPORT			$ 46,226		$ 1,427		$ 1,705		$ 43,094
SUBCONTRACT - NEXANT			$ 50,000		$ -		$ -		$ 50,000
SUBCONTRACT - USGS			$ 125,107		$ -		$ -		$ 125,107
SUBCONTRACT - DUCKS UNLIMITED			$ 332,530		$ -		$ -		$ 332,530
SUBCONTRACT - PRAIRIE PUBLIC TV			$ 60,155		$ -		$ -		$ 60,155
SUBCONTRACT - ALBERTA EUB			$ 100,000		$ -		$ -		$ 100,000
SUBCONTRACT - NDSU			$ 74,842		$ -		$ -		$ 74,842
SUBCONTRACT - FISCHER OIL & GAS			$ 100,000		$ -		$ -		$ 100,000
SUBCONTRACT - UNSPECIFIED			$ 260,000		$ -		$ -		$ 260,000
TOTAL OTHER DIRECT COST			$ 1,594,851		$ 54,224		$ 65,743		$ 1,474,884
TOTAL DIRECT COST			$ 3,325,628		$ 115,385		$ 137,820		$ 3,072,423
FACILITIES & ADMIN. RATE - % OF MTDC		VAR	$ 1,069,372	56%	$ 64,615	56%	$ 77,180	46.5%	$ 927,577
TOTAL CASH			$ 4,395,000		$ 180,000		$ 215,000		$ 4,000,000
IN-KIND SUPPORT - SEE COST SHARE SUPPORT			$ 1,180,381		$ -		$ 1,180,381		$ -
TOTAL PROJECT			$ 5,575,381		$ 180,000		$ 1,395,381		$ 4,000,000

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

Background

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC receives no appropriated funding from the state of North Dakota and is funded through federal and nonfederal grants, contracts, or other agreements. Although the EERC is not affiliated with any one academic department, university academic faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, subcontracts) is for planning purposes only. The principal investigator may, as dictated by the needs of the work, reallocate the budget among approved items or use the funds for other items directly related to the project, subject only to staying within the total dollars authorized for the overall program. Escalation of labor and EERC fee rates is incorporated in the budget when a project's duration extends beyond the current fiscal year. Escalation is calculated by prorating an average annual increase over the anticipated life of the project. The current escalation rate of 5% is based on historical averages. The budget prepared for this proposal is based on a specific start date; this start date is indicated at the top of the EERC budget or identified in the body of the proposal. Please be aware that any delay in the start of this project may result in an increase in the budget.

Salaries and Fringe Benefits

As an interdisciplinary, multiprogram, and multiproject research center, the EERC employs an administrative staff to provide required services for various direct and indirect support functions. Direct project salary estimates are based on the scope of work and prior experience on projects of similar scope. Technical and administrative salary charges are based on direct hourly effort on the project. The labor rate used for specifically identified personnel is the current hourly rate for that individual. The labor category rate is the current average rate of a personnel group with a similar job description. For faculty, if the effort occurs during the academic year and crosses departmental lines, the salary will be in addition to the normal base salary. University policy allows faculty who perform work in addition to their academic contract to receive no more than 20% over the base salary. Costs for general support services such as grants and contracts administration, accounting, personnel, and purchasing and receiving, as well as clerical support of these functions, are included in the EERC facilities and administrative cost rate.

Fringe benefits are estimated on the basis of historical data. The fringe benefits actually charged consist of two components. The first component covers average vacation, holiday, and sick leave (VSL) for the EERC. This component is approved by the UND cognizant audit agency and charged as a percentage of direct labor for permanent staff employees eligible for VSL benefits. The second component covers actual expenses for items such as health, life, and unemployment insurance; social security matching; worker's compensation; and UND retirement contributions.

Travel

Travel is estimated on the basis of UND travel policies which can be found at: http://www.und.edu/dept/accounts/employeetravel.html. Estimates include General Services Administration (GSA) daily meal rates. Travel includes scheduled meetings and conference participation as indicated in the scope of work.

Communications (phones and postage)

Monthly telephone services and fax telephone lines are generally included in the facilities and administrative cost. Direct project cost includes line charges at remote locations, long-distance telephone, including fax-related long-distance calls; postage for regular, air, and express mail; and other data or document transportation costs.

Office (project-specific supplies)

General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are provided through a central storeroom at no cost to individual projects. Budgeted project office supplies include items specifically related to the project; this includes duplicating and printing.

Data Processing

Data processing includes items such as site licenses and computer software.

Supplies

Supplies in this category include scientific supply items such as chemicals, gases, glassware, and/or other project items such as nuts, bolts, and piping necessary for pilot plant operations. Other items also included are supplies such as computer disks, computer paper, memory chips, toner cartridges, maps, and other organizational materials required to complete the project.

Instructional/Research

This category includes subscriptions, books, and reference materials necessary to the project.

Fees

Laboratory, analytical, graphics, and shop/operation fees are established and approved at the beginning of the university's fiscal year.

Laboratory and analytical fees are charged on a per sample, hourly, or daily rate, depending on the analytical services performed. Additionally, laboratory analyses may be performed outside the University when necessary.

Graphics fees are based on an established per hour rate for overall graphics production such as report figures, posters for poster sessions, standard word or table slides, simple maps, schematic slides, desktop publishing, photographs, and printing or copying.

Shop and operation fees are for expenses directly associated with the operation of the pilot plant facility. These fees cover such items as training, safety (protective eye glasses, boots, gloves), and physicals for pilot plant and shop personnel.

General

Freight expenditures generally occur for outgoing items and field sample shipments.

Membership fees (if included) are for memberships in technical areas directly related to work on this project. Technical journals and newsletters received as a result of a membership are used throughout development and execution of the project as well as by the research team directly involved in project activity.

General expenditures for project meetings, workshops, and conferences where the primary purpose is dissemination of technical information may include costs of food (some of which may exceed the institutional limit), transportation, rental of facilities, and other items incidental to such meetings or conferences.

Facilities and Administrative Cost

The facilities and administrative rate (indirect cost rate) included in this proposal is the rate that became effective July 1, 2005. Facilities and administrative cost is calculated on modified total direct costs (MTDC). MTDC is defined as total direct costs less individual items of equipment in excess of $5000 and subcontracts/subgrants in excess of the first $25,000 for each award.