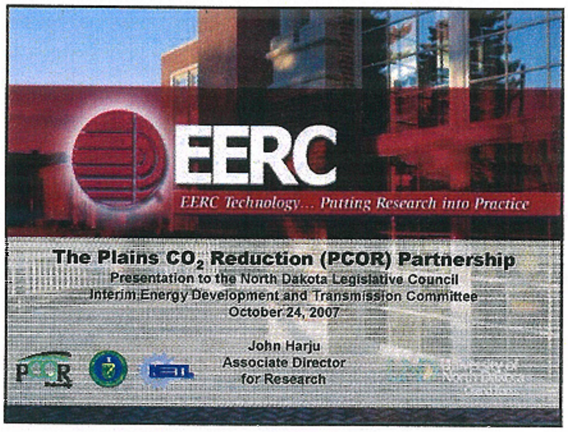
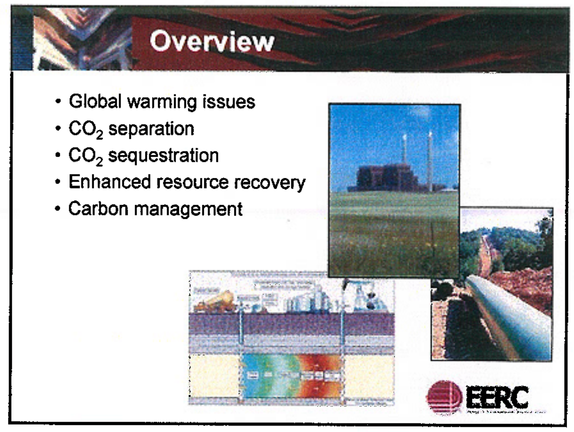
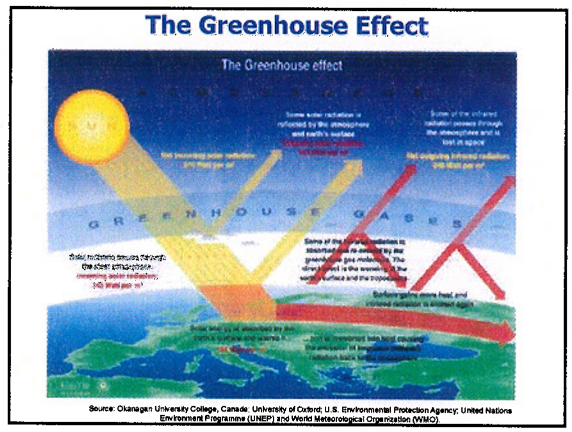
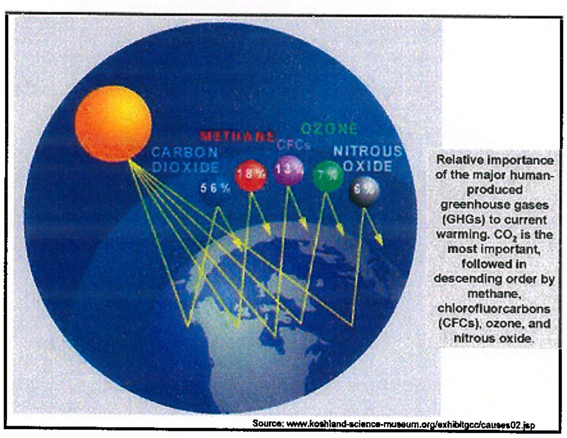
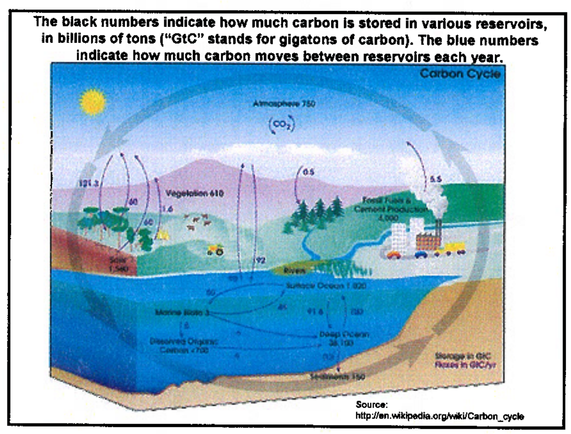

EERC
EERC Technology... Putting Research into Practice
The Plains CO_2 Reduction (PCOR) Partnership
Presentation to the North Dakota Legislative Council
Interim Energy Development and Transmission Committee
October 24, 2007
John Harju
Associate Director
for Research


Overview
• Global warming issues
• CO_2 separation
• CO_2 sequestration
• Enhanced resource recovery
• Carbon management
EERC


SPECIAL REPORT GLOBAL WARMING
TIME
BE WORRIED. BE VERY WORRIED.
an inconvenient truth
NATIONAL GEOGRAPHIC
GLOBAL WARNING
EERC


The Greenhouse Effect
The Greenhouse effect
GREENHOUSE GASES
Source: Okanagan University College, Canada; University of Oxford; U.S. Environmental Protection Agency; United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO).


METHANE
OZONE
CFCs
CARBON DIOXIDE
NITROUS OXIDE
56 %
18 %
13 %
7 %
6 %
Relative importance of the major human-produced greenhouse gases (GHGs) to current warming. CO_2 is the most important, followed in descending order by methane, chlorofluorocarbons (CFCs), ozone, and nitrous oxide.
Source: www.koshland-science-museum.org/exhibitgcc/causes02.jsp


The black numbers indicate how much carbon is stored in various reservoirs, in billions of tons ("GtC" stands for gigatons of carbon). The blue numbers indicate how much carbon moves between reservoirs each year.
Carbon Cycle
Atmosphere 750
CO_2
Vegetation 610
Fossil Fuels & Cement Production 4,000
Soils 1,580
Rivers
Surface Ocean 1,020
Marine Biota 3
Dissolved Organic Carbon <700
Deep Ocean 38,100
Sediments 150
Storage in GtC
Fluxes in GtC/yr
Source:
http://en.wikipedia.org/wiki/Carbon_cycle

Industry-Related Activities Play a Huge Role in CO_2 Levels – The Industrial Revolution Made a Huge Impact

The current concentration of CO_2 in the atmosphere is around 380 ppm; whereas it was 250 ppm in preindustrialized days.

Current projections, assuming a business-as-usual scenario, indicate that children born today will see levels reach 1000 ppm before they die.

Source: http://tacitus.org/story/2006/7/5/103516/0286 (July 5, 2006)

Global CO_2 Levels

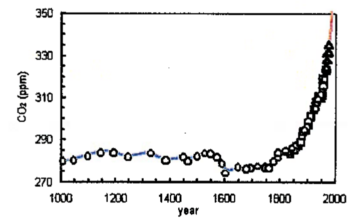
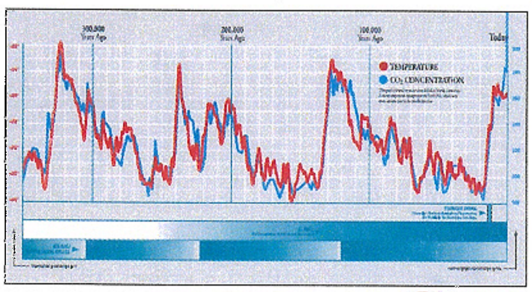


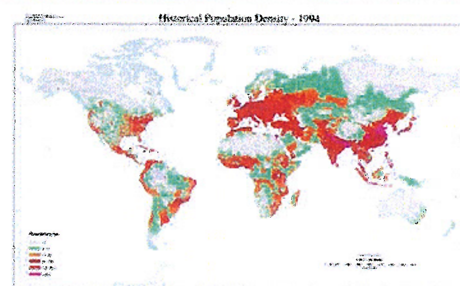
Figure 1: Changing levels of carbon dioxide in the atmosphere as determined from air recovered from Antarctic ice and from direct atmospheric measurements. DE08, DE08-2 and DSS refer to different ice cores from which samples were taken. After Etheridge (1999).

Atmospheric CO_2 and Temperature



Source: Marian Koshland Science Museum of the National Academy of Sciences

Human Population Has *Quadrupled* and Energy Consumption Has *Increased Sixteenfold* in the 20th Century



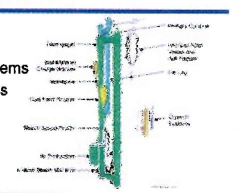
Source: Science, Vol. 798, 1 November, 2002. Map from NRCDS USDA

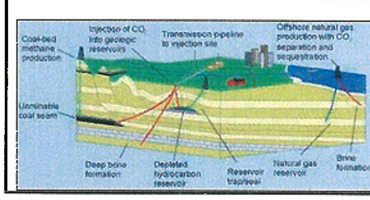
Primary Power Consumption Today Is Approximately *85% Fossil Fuel Derived*

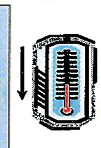
Source: Science, Vol. 798, 1 November, 2002 Photo from NASA

Methods for Reducing GHG Emissions

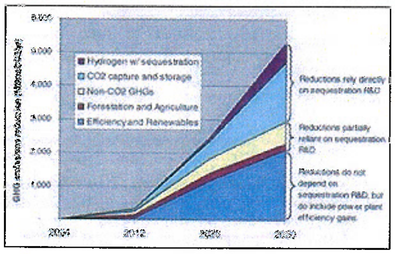
- Renewable energy technologies
- Advanced high-efficiency energy systems
- Improve efficiency on existing systems
- Reduce consumption of energy
- **Sequester GHG emissions**





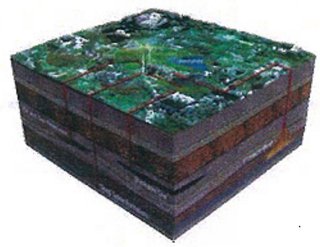


U.S. GHG Emission Scenarios – Technologies to Fill the Gap



Source: Carbon Sequestration Technology Roadmap and Program Plan – 2004; U.S. Department of Energy National Energy Technology Laboratory Office of Fossil Energy, 2004.

Source to Sink



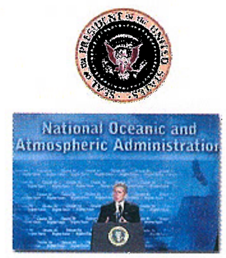
Anthropogenic CO_2 can be captured and sent to storage before it enters the atmosphere (geologic sequestration), or land management practices can be used to enhance carbon uptake after it enters the atmosphere (terrestrial sequestration).

International Attention

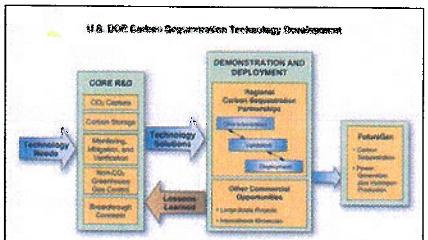
- 1992 Framework Convention on Climate Change.
- 1997 Kyoto Protocol calls for a 7% reduction of carbon-equivalent emissions from 1990 levels.

U.S. Activities

- The United States did not ratify the Kyoto Protocol.
- President Bush's Global Climate Change-Initiative calls for an 18% reduction in CO_2 intensity by 2012.



U.S. Department of Energy (DOE) Climate Change Technology Program



Source: www.netl.doe.gov/technologies/carbon_seq/index.html

Regional Carbon Sequestration Partnerships

What Is Our Region Doing?

PCOR Partnership Region

Nine states and four provinces

1,382,089 square miles

The PCOR Partnership has brought together the key stakeholders to make geologic CO_2 sequestration a near-term reality.

EERC

The PCOR Partnership currently has over 70 partners representing public agencies, utilities, oil and gas companies, engineering firms, associations and nonprofit organizations, and universities.

Phase II Partners

PCOR Partnership

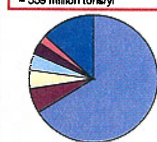
Phase I

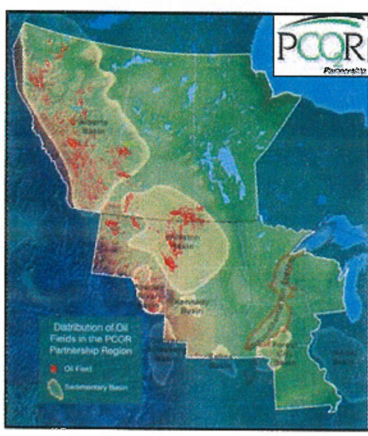
- Gauge public understanding
- Develop database for:
  - Sources
  - Sinks
  - Separation and transportation options
  - Regulatory and permitting requirements
  - Environmental benefits and risks
- Identify sequestration opportunities
- Conduct public outreach campaign
- Develop action plan for Phase II (field validation tests)

Sources

1225 stationary sources

Total CO_2 emissions: ≈ 559 million tons/yr





Oil Fields

6000+ fields evaluated

Fields in the Williston, Powder River, Denver–Julesberg, and Alberta Basins were evaluated.

Used two methods: enhanced oil recovery (EOR) and volumetric

- **EOR approach:**

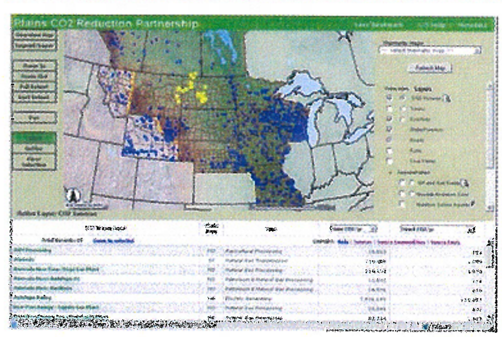
Evaluated ~ 160 fields.

Sequestration capacity ≈ 1 billion tons

Incremental oil >3 billion bbls

- **Volumetric approach:** Thousands of fields, total capacity >10 billion tons.

PCOR Partnership Decision Support System (DSS)



PCOR Partnership Deliverables

Deliverables in Phases I and II have included the following:

- Regional atlas
- Road map documents
- Fact sheets
- Topical reports
- Design packages
- Sampling protocols
- Outreach action plans
- Progress reports
- Site health and safety plans
- Video Documentaries
- Public and Private Web sites
- Regional characterization gap assessment
- National Environmental Policy Act (NEPA) compliance forms
- Regional permitting implementation outlines
- Project management plans
- Regulatory permitting action plans

EERC

PCOR Partnership

Phase II Goals

- Increase public understanding of CO_2 sequestration
- Perform field validation tests that develop:
  - Monitoring, mitigation, and verification (MMV) protocols.
  - Regional sequestration strategies.
  - Best separation/source matches.
  - Regulatory and permitting strategies.
  - Environmental benefits and risks.
  - Information needed to monetize C credits.
- Continued regional characterization.
- Creating a vision for practical environmentally sound carbon management strategies.

Williston Basin CO_2 Sequestration and EOR Test

PCOR EERC

Williston Basin Test Goals and Objectives

Goal

- To validate the sequestration of CO_2 in deep (>10,000 ft) carbonate oil reservoirs using cost-effective monitoring, mitigation, and verification (MMV) approaches.

Objectives

- Inject pure CO_2 into a deep carbonate oil reservoir for simultaneous sequestration and EOR.
- Determine the effects of high pressure and temperature on sequestration, EOR, and MMV.
- Implement a cost-effective approach for MMV in a deep oil field.

PCOR EERC

Zama Acid Gas EOR, CO_2 Sequestration, and Monitoring Project

PCOR EERC

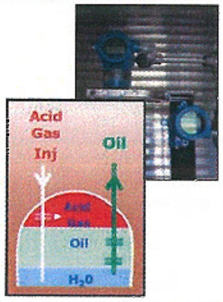
Zama Project Goals and Objectives

Goal

- To validate the sequestration of CO_2-rich acid gas in a depleted oil reservoir.

Objectives

- Inject a stream of acid gas (70% CO_2 – 30% H_2S) for simultaneous acid gas disposal, CO_2 sequestration, and EOR.
- Determine the effects of acid gas injection on target reservoir and caprock formations.
- Implement a cost-effective approach for MMV for sequestration of a CO_2-rich acid gas stream.



PCOR EERC

Lignite for CO_2 Sequestration and Enhanced Coalbed Methane

PCOR EERC

Lignite Goal and Objectives

Goal

- Determine the feasibility of simultaneous CO_2 sequestration and natural gas production from a lignite coal seam.

Objectives

- Inject CO_2 into lignite coal seam and monitor CO_2 fate in the reservoir.
- Determine the potential for coalbed methane production from the lignite seam.
- Determine the potential for production enhancement by CO_2 injection.
- Develop Regional Technology Implementation Plan for CO_2 sequestration in lignite coal.

PCOR EERC

Prairie Pothole Wetlands/Grasslands Field Validation Test

PCOR EERC

Prairie Pothole Wetlands/Grasslands Goal and Objectives

Goal

- Validate and quantify carbon sequestration potential in the PPR wetlands and grasslands.

Objectives

- Develop the technical capacity to systematically identify, develop, and apply alternate land use management practices to the prairie pothole ecosystem that will result in greenhouse gas (GHG) reductions.
- Quantify the amount of carbon sequestered in restored wetland and surrounding grassland systems.
- Define best management practices for sequestering carbon and reducing GHGs in wetlands and grasslands.

PCOR EERC

Key Results of Phases I and II

- Tertiary-phase enhanced oil recovery (EOR) is the primary near-term opportunity for managing CO_2 in the PCOR Partnership region.
- Demand for CO_2 exceeds near-term supply.
- When CO_2 supply surpasses EOR demand, saline formations are available throughout the region to meet sequestration demand.
- Significant accumulations of unminable coal also represent potential opportunities for sequestration.
- Terrestrial opportunities represent a key near-term strategy to offset emissions, and the Prairie Pothole Region (PPR) represents a unique opportunity therein.

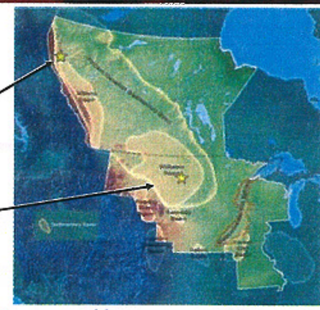
PCOR EERC

Energy & Environmental Research Center PCOR Partnership Phase III Goals

- Meet or exceed our partners' expectations – develop a project that leads to commercial success.
- Develop infrastructure and expertise that propagate our region's competitive advantage into the future.
- Develop public support through outreach and education.
- Develop industry standards for MMV.
- Develop user-friendly standards for:
  - Site selection/permitting.
  - Risk assessment.
  - MMV.
- Develop markets and standards for the monetization of carbon credits.

PCOR EERC

We Are Planning Two Phase III Efforts



PCOR EERC

Why the Williston Basin?

- We have great Partners!
- The Williston Basin is perfect (both geologically and socioeconomically) for this demonstration.
- One of the first commercial-scale projects to capture CO_2 from a retrofitted coal-fired power plant (CFPP).
- Develop supporting evidence for the hypothesis that effective MMV need not be intrusive to field operations nor expensive to implement.

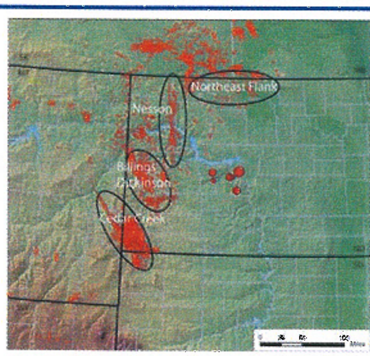
PCOR EERC

Williston Basin Phase III – Concept

- Capture at least 1 Mt/yr of CO_2 at existing CFPP in central North Dakota.
- Transport via pipeline to Williston Basin oil field.
- Meet or exceed all of the U.S. Department of Energy (DOE) Phase III objectives.
- Conduct MMV activities to document integrity of storage.
- Ultimately monetize credits.

PCOR EERC

Williston Basin Oil Field EOR



Monitoring CO_2 Sequestration – Partner Relationships

- Need to coordinate and integrate our activities with ongoing and planned power plant and oil field operations.
- Data deemed by operating partner to provide competitive advantage may not be available.

PCOR EERC

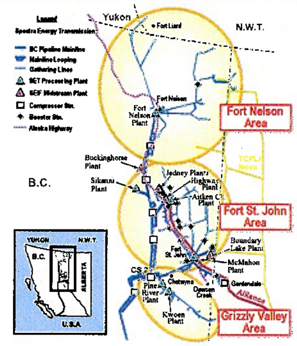
Fort Nelson Carbon Capture and Sequestration in a Deep Saline Formation

Fort Nelson Gas Plant
British Columbia, Canada

Spectra Energy Transmission

EERC

A Critical Component of North America's Energy Future



EERC

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