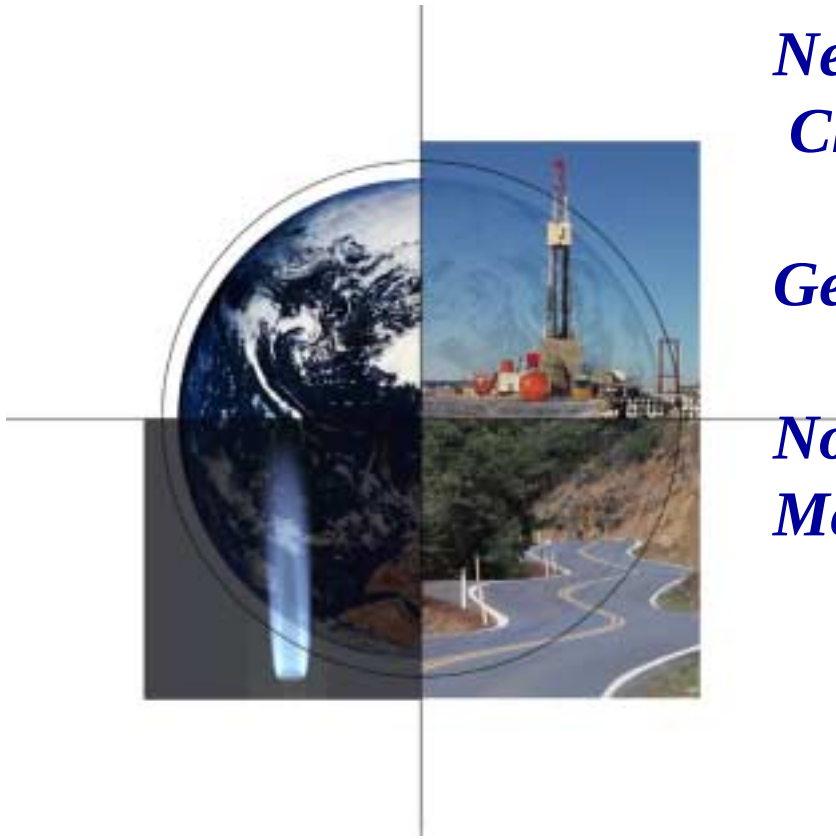
US DOE's Carbon Sequestration Program



New Initiatives for U.S. Climate Change

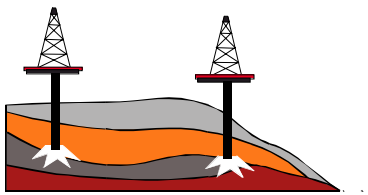
Geological Sequestration

North American Coalbed Methne Forum

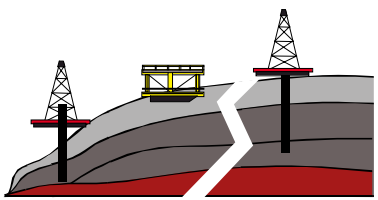
Charles W. Byrer
National Energy Technology Laboratory

Sequestration Sinks for CO_2 Emissions

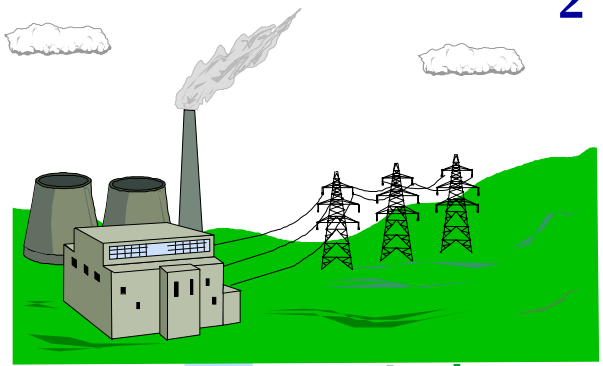
Geological Sinks



Unminable Coal Seams

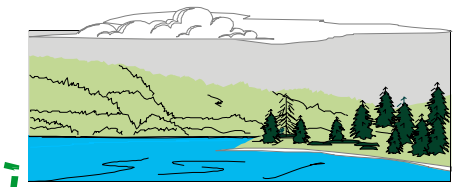


Depleted Oil / Gas Wells;
Saline Reservoirs

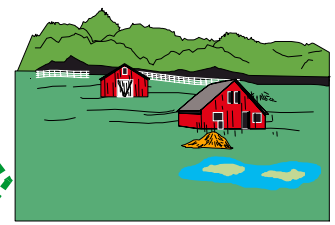


CO_2 Emissions Separation and Capture

Enhanced Natural Sinks



Forestation



Enhanced Photosynthesis;
Biomimetics

Ocean Storage

? Novel Concept ?

NETL

CO_2 Sequestration in Geologic Formations

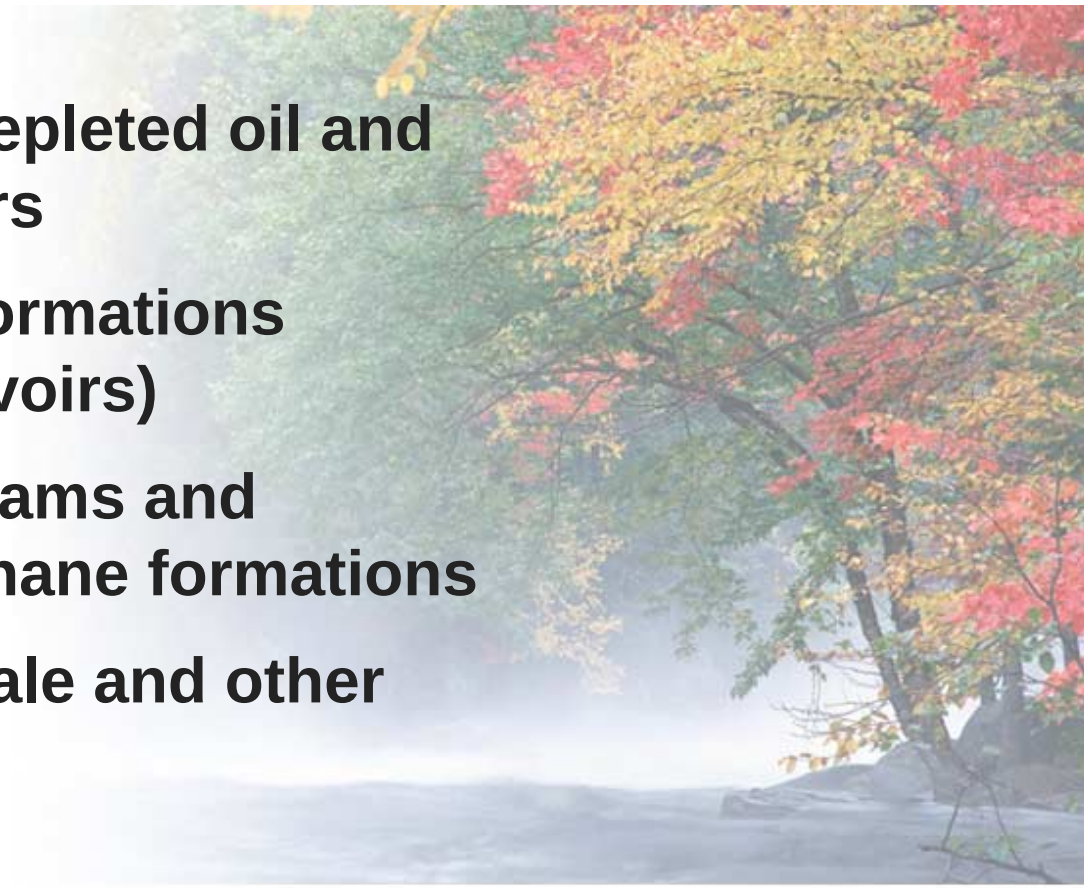
- Related industrial experience
- Potential capacity ?
- Beneficial use of CO_2
- Natural analogues for sequestration
- Safety and cost analysis
- Performance assessment and prediction
- Monitoring

Range of Estimates for CO_2 Sequestration in U.S. Geologic Formations

Geologic Formation	Capacity Estimate (GtC)	Source
Deep saline reservoirs	1-130	Bergman and Winter 1995
Natural gas reservoirs in the United States	25[a] 10[b]	R.C. Burruss 1977
Active gas fields in the United States	0.3 / year[c]	Baes et al. 1980
Enhanced coal-bed methane production in the United States	10	Stevens, Kuuskraa, and Spector 1998

a. Assuming all gas capacity in the United States is used for sequestration
b. Assuming cumulative production of natural gas is replaced by CO_2
c. Assuming that produced natural gas is replaced by CO_2 at the original reservoir pressure

Sequestration in Geologic Formations Builds on a Strong Industry Experience Base



- Active and depleted oil and gas reservoirs
- Deep brine formations (saline reservoirs)
- Deep coal seams and coalbed methane formations
- Devonian shale and other formations

What the Gas Industry Knows Now

- Dynamic flow properties of oil, gas, and coal formations
- Storage capacity of oil and gas formations
- Monitoring technologies for pressure, volume, water saturation
- Fairly complete geologic characterization of formations

Drivers for Geologic Sequestration R&D

- **Monitoring - developing reliable and cost-effective systems for monitoring / tracking CO_2 in subsurface**
- **Stability - assessing and ensuring long-term stability of sequestered CO_2 (>100 years)**
- **Cost- reducing the cost and energy requirements of CO_2 sequestration in geologic formations**
- **Public perception - gaining public acceptance for geologic sequestration of CO_2**

Ongoing Natural Gas Storage and Natural CO_2 Analogs in Geologic Formations

- **Provides experience and demonstrates the feasibility of the geologic trapping mechanisms for use in sequestering CO_2 emissions**

- **Reservoir *Examples:***
  - ***Mt. Simon Sandstone reservoir***
  - ***Natural CO_2 reservoirs in the western and gulf coast regions of U.S.***

CO_2 Sequestration in Geological Formations Can Have Auxiliary Benefits

- **Injection of CO_2 into oil reservoirs can recover residual oil by two primary mechanisms:**
  - CO_2 displaces oil and brine
  - CO_2 dissolves in oil and reduces viscosity and swelling of oil
- **Injection of CO_2 into coalbeds could enhance coalbed methane (CBM) production:**
  - Pilot program of CO_2-assisted CBM in San Juan Basin has been underway since 1996:
    - Injects 4 million cubic feet / day of CO_2 in nine injection wells
    - Preliminary results: CBM recovery could be boosted to 75-90%
    - Over 2.5 Bcf of CO_2 injected - CO_2 breakthrough very slight

Geologic Sequestration
Coordination of Efforts with a Strategy

- **DOE facilitated a 9-month roadmapping exercise focused on Carbon Sequestration R&D**
- **Collaborating on-going R & D strategy and priority efforts with stakeholders (industry , government agencies, academia, and environmental organizations (NGOs)**
- **DOE-NETL is the lead National Laboratory for geologic CO_2 sequestration**

Geological Sequestration
FY 2002 Participants and Activities

• Oklahoma State - Penn State	– Adsorption assessments of CO_2, N_2, and CH_4 on targeted coal samples
• Univ. Texas -Bureau of Economic Geology	– Coal characterization of coal samples
• Battelle Columbus	– Assessment of characteristics of saline reservoirs in U.S.
• Lawrence Berkeley National Lab – Lawrence Livermore N.L. – Oak Ridge N.L. – ARC, academia partners – Industry partners	– Geochemical Assessment of Mt. Simon Reservoir: Lab, modeling & economic effort – Multiple R&D areas with industry: EOR, ECBM, and saline reservoirs (Reservoir modeling and monitoring)
• ORNL -	– Measuring kinetics, equilibrium densities, and sorption relations for CO_2 -CH modeling validation

Geological Sequestration:
FY 2002 Participants and Activities (Cont'd)

• Texas Tech	– CO_2 injectivity and capacity studies / modeling
• Ala. Geological Survey	– Geologic screening for coalbeds in Alabama
• ARI	– Natural CO_2 Analogs for Geologic CO_2 Sequestration
• Sandia National Lab	– Field demo for EOR-CO_2 monitoring/storage; Los Alamos and Industry partner
• ARI / BP	– Field Demonstration: Enhanced coalbed methane recovery - CO_2 sequestration
• CONSOL	– CO_2-CBM field demo associated with mining operations
• Battelle - AEP	– Pilot field demonstration in Mt. Simon saline reservoir
• UT - BEG	– Pilot field demonstration of CO_2 into Frio Formation

CO_2 Sequestration in R&D Priorities

2000-2005	2005-2010	2010-2015
Understand Adsorption/ Desorption Processes	Develop Modeling Tools	Obtain Full-Scale Demo Cost & Performance Data
Assess Porposity/ Permeability & Expansion/ Contraction Effects	Assess Flue Gas-Coal Interactions	Develop Low-Permeability & Deep Formation Injection Technologies
Increased Gas Production Pilot Test	Flue Gas Injection Pilot Tests	Evaluate Water-Saturated versus Dewatered CO_2 Injections
Develop Reservoir Screening Criteria	Test Drilling Technologies versus Injection/Production Dynamics	Test/Monitor Long-Term CO_2 Sequestration on Various Coal Seams
Develop Injection Engineering & Design Techniques	Develop Methods for Monitoring CO_2 Migration	
Understand Seismic Wave Propagation Responses	Understand Microorganism-CO_2-Matrix Interactions	

Summary

- Storage / disposal of fluids in deep formations is a widely accepted industry practice
- There is enormous potential capacity on a regional basis for CO_2 storage in coal deposits
- The key issues are local capacity, long-term fate, engineering, cost, safety, public acceptance, and industry's level of interest in concept
- These issues are presently being explored using computer simulations and laboratory experiments - then validate with pilot-scale demonstrations