



U.S. DEPARTMENT OF
ENERGY

Fossil Energy Sequestration Program

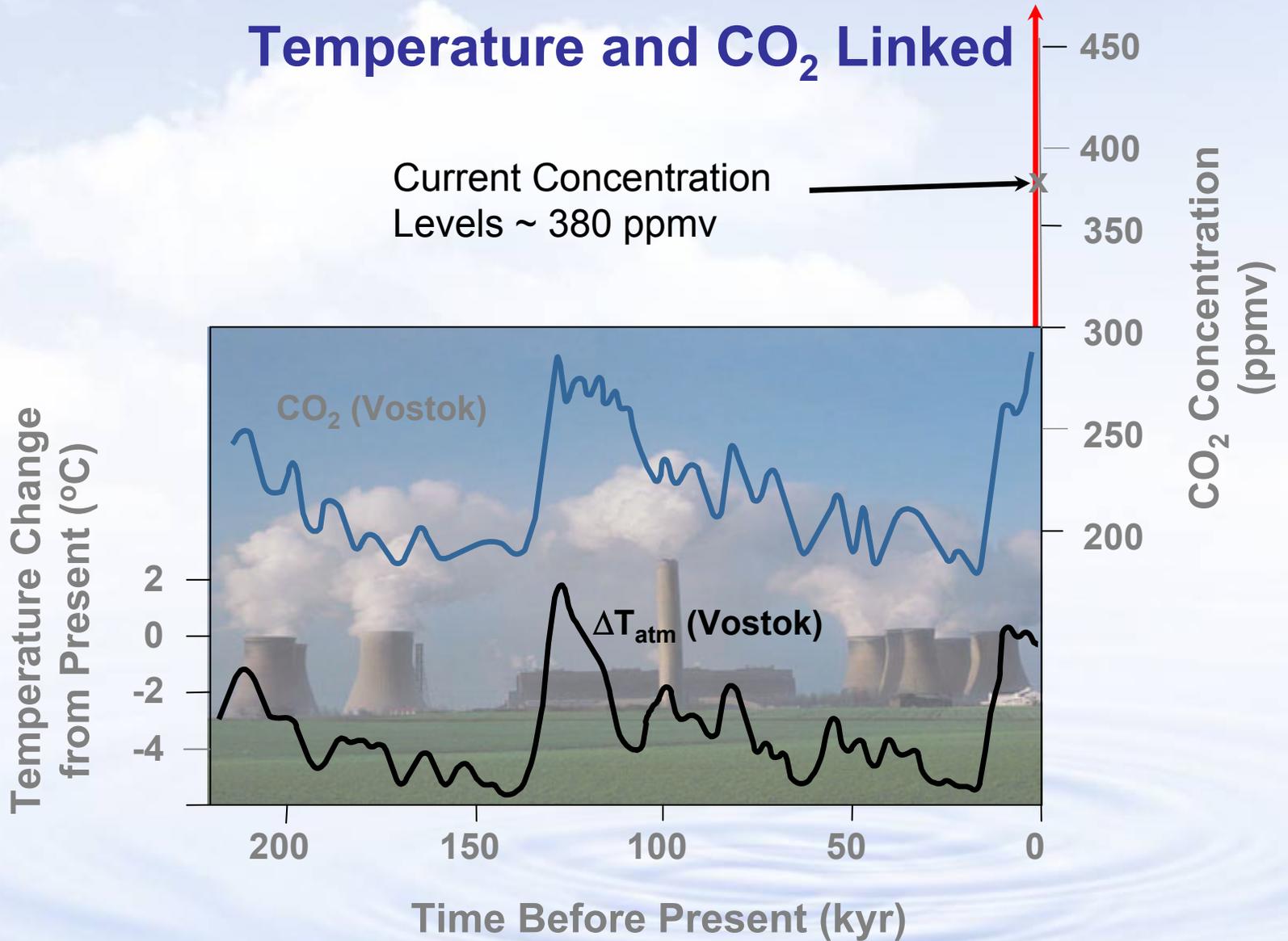
Sean I. Plasynski, PhD

**2006 DOE Hydrogen Program
Merit Review and Peer Evaluation Meeting**

May 16, 2006

Temperature and CO₂ Linked

Current Concentration
Levels ~ 380 ppmv



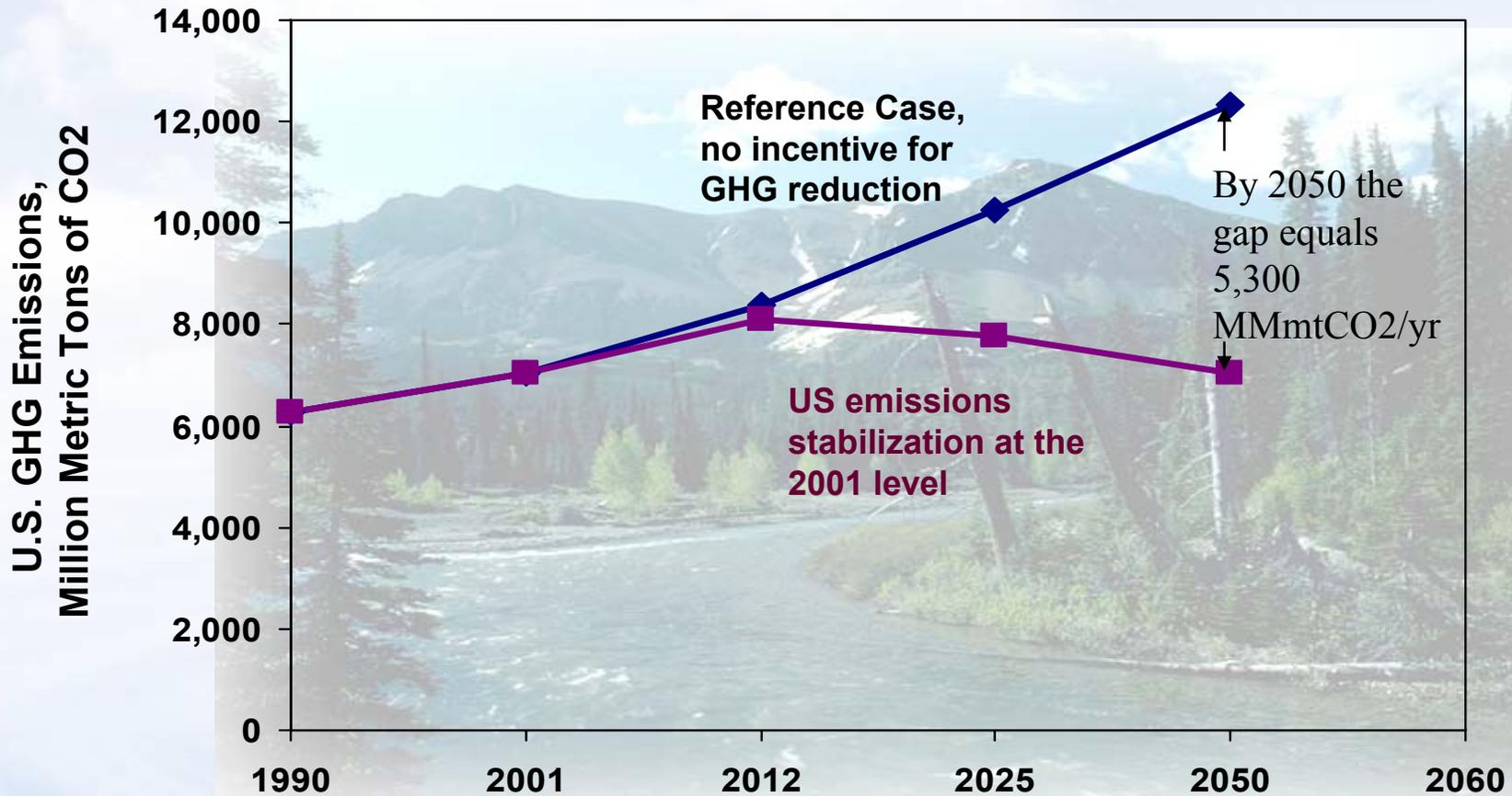
"Historical CO₂ Record From the Vostok Ice Core" J.M. Barnolo et al, August 1999

www.cdiac.esd.ornl.gov/ftp/trends/co2/vostok_icecore_co2

Oak Ridge National Laboratory Current Greenhouse Gas Concentrations

http://cdiac.ornl.gov/pns/current_ghg.html

U.S. Emissions of GHG Under the Reference and Stabilization Scenarios



Technological Carbon Management Options

Reduce Carbon Intensity

- Renewables
- Nuclear
- Fuel Switching

Improve Efficiency

- Demand Side
- Supply Side

Sequester Carbon

- Capture & Store
- Enhance Natural Sinks

All options needed to:

- Affordably meet energy demand
- Address environmental objectives

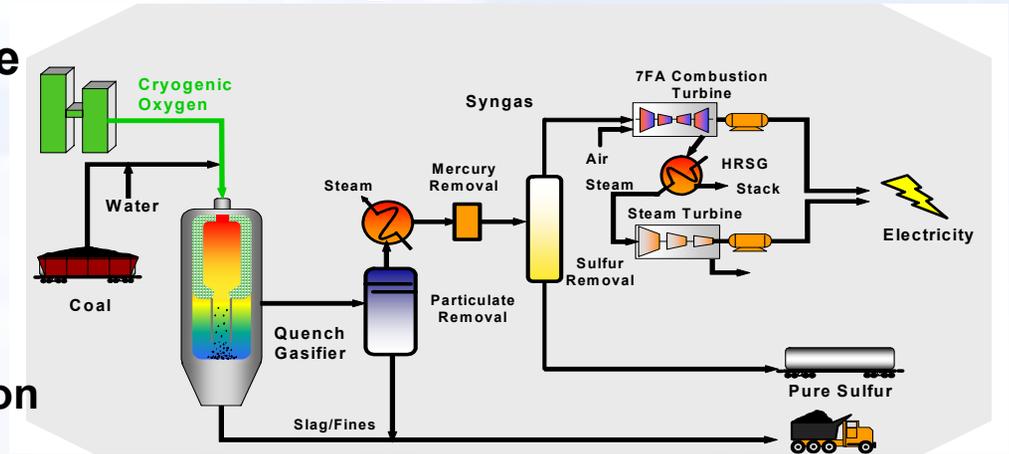


What is Carbon Capture

Separation and concentration of CO₂ from flue streams:

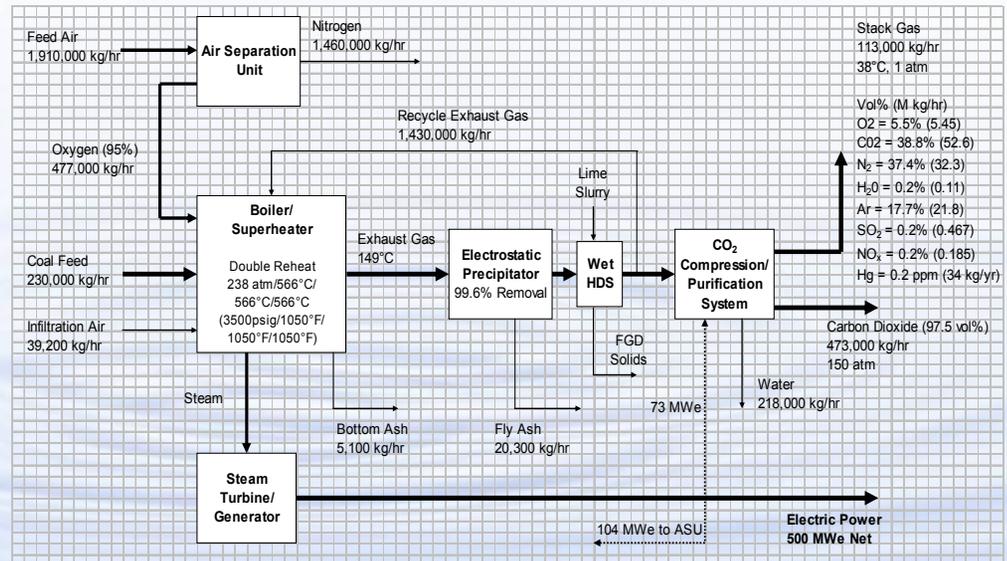
Three general classes of capture technology:

- Post-combustion (e.g., amine scrubbing; adv. membranes)
- Pre-combustion (e.g., H₂O-gas shift; hydrate separation)
- Oxy-firing combustion (recirculation of the flue stream)



Very expensive (40-80% in C.O.E.)

Primary research goal – cost reduction



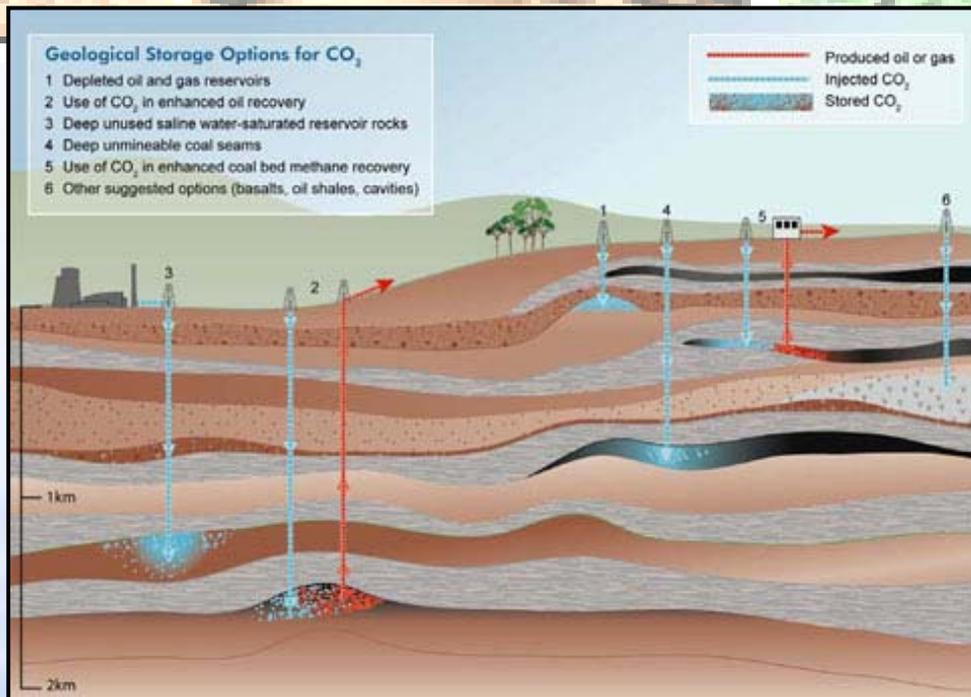
What is Sequestration

Geologic

Placement of CO₂ into an underground formation where it will remain isolated from interactions with the Earth's atmosphere for hundreds to thousands of years

Terrestrial

Enhancement of the uptake of CO₂ by plants that grow on land and in freshwater as well as enhancement of carbon storage in soils



Carbon Storage – How does it work?

Storage mechanisms vary by target class; generally multiple processes which improve over time

Physical trapping

- Impermeable cap rock
- Either geometric or hydrodynamic stability

Residual phase trapping

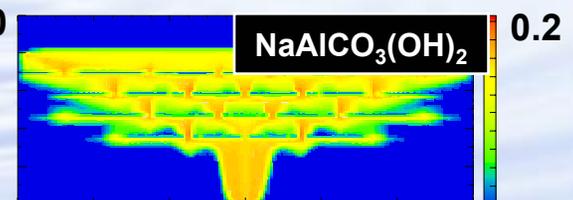
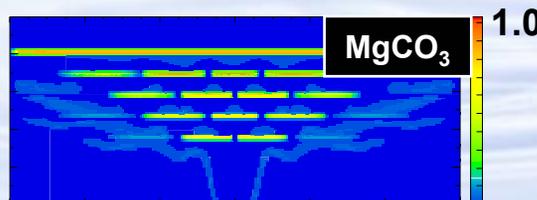
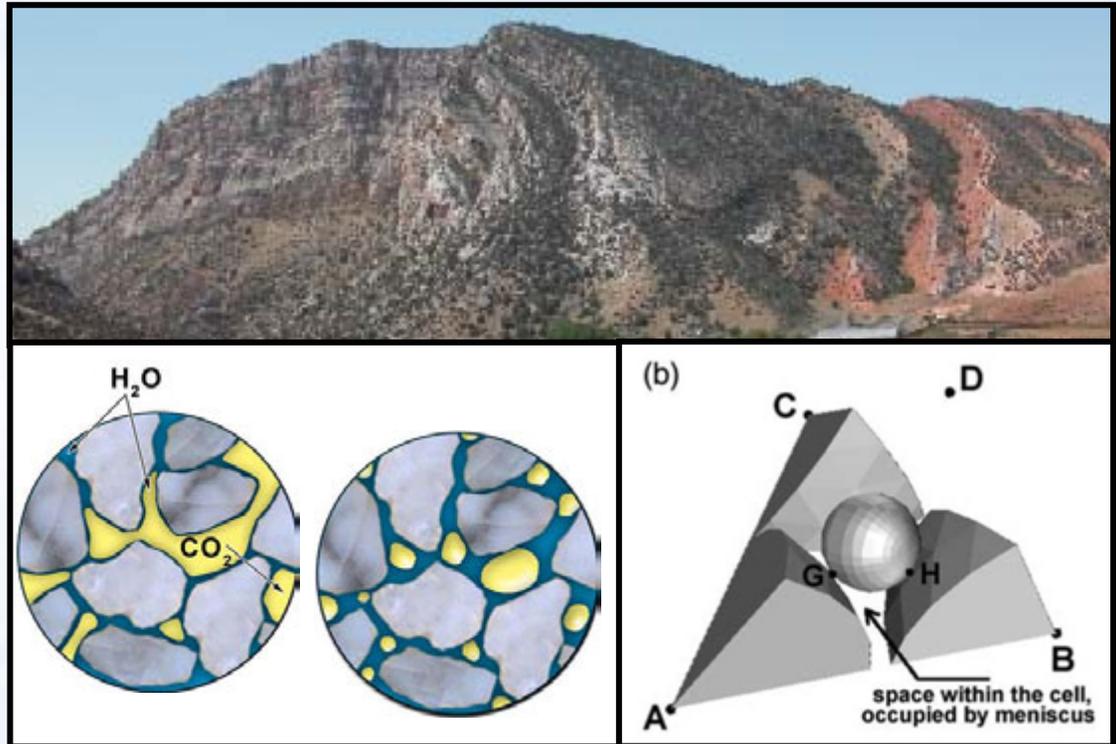
- Capillary forces immobilized fluids
- Sensitive to pore geometry (<25% pore vol.)

Solution/Mineral Trapping

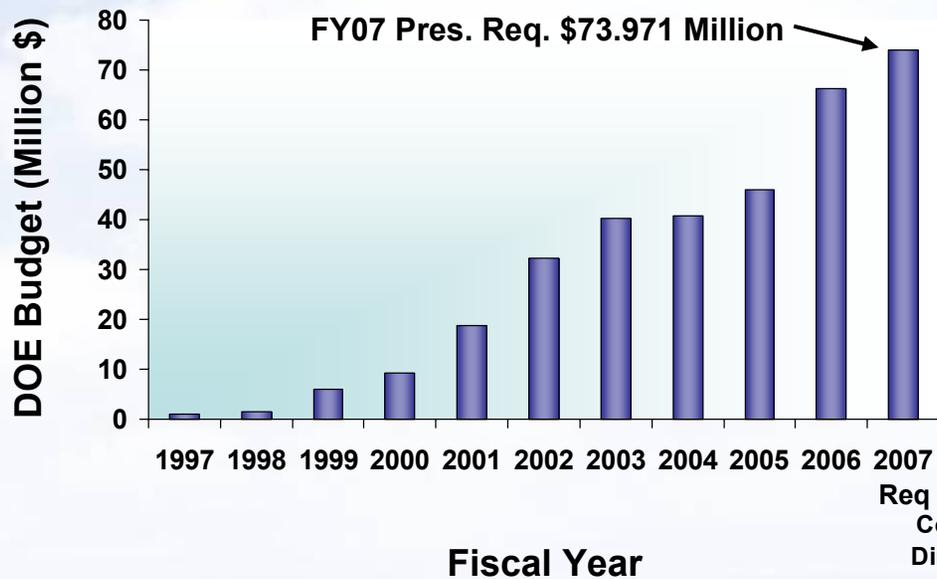
- Slow kinetics
- High permanence

Gas adsorption

- For organic minerals only (coals, oil shales)



Sequestration Program Statistics FY2006

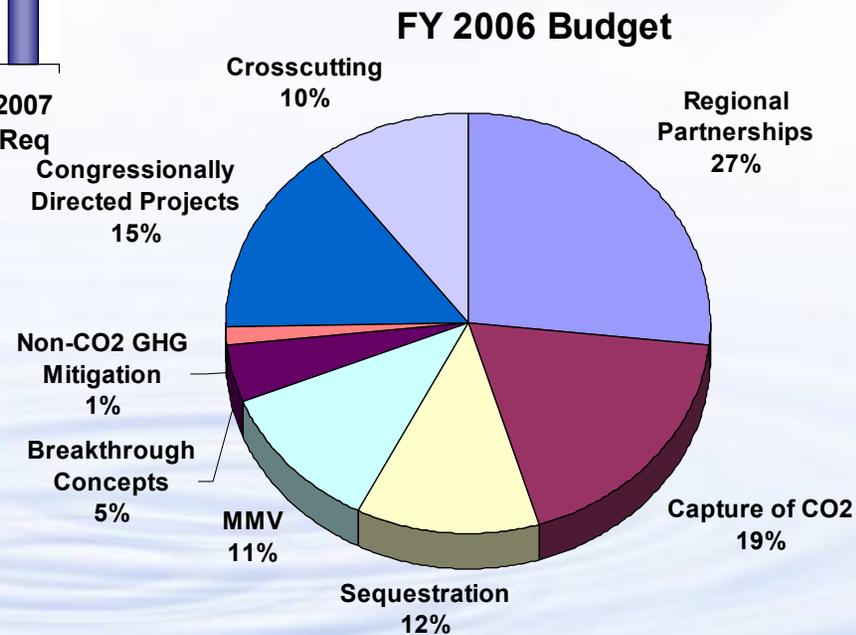


Strong industry support
 ~ 39% cost share on projects

Federal Investment to Date
 ~ \$260 Million

Diverse research portfolio

~ 70 R&D Projects



Sequestration Program Goals

Develop Technology Options for GHG Management That...

- **Are safe and environmentally acceptable**
- **Separation and Capture R&D Goals**
 - 2007 have two technologies < 20% increase in Cost of Energy ***
 - 2012 developed two technologies < 10% increase Cost of Energy
- **Sequestration/Storage R&D Goals**
 - 2012 predict CO₂ storage capacity with +/- 30% accuracy
 - Develop best practice reservoir management strategies that maximize CO₂ trapping
- **Monitoring, Mitigation & Verification**
 - 2012 ability to verify 95% of stored CO₂ for credits (1605b)
 - CO₂ material balance to >99%

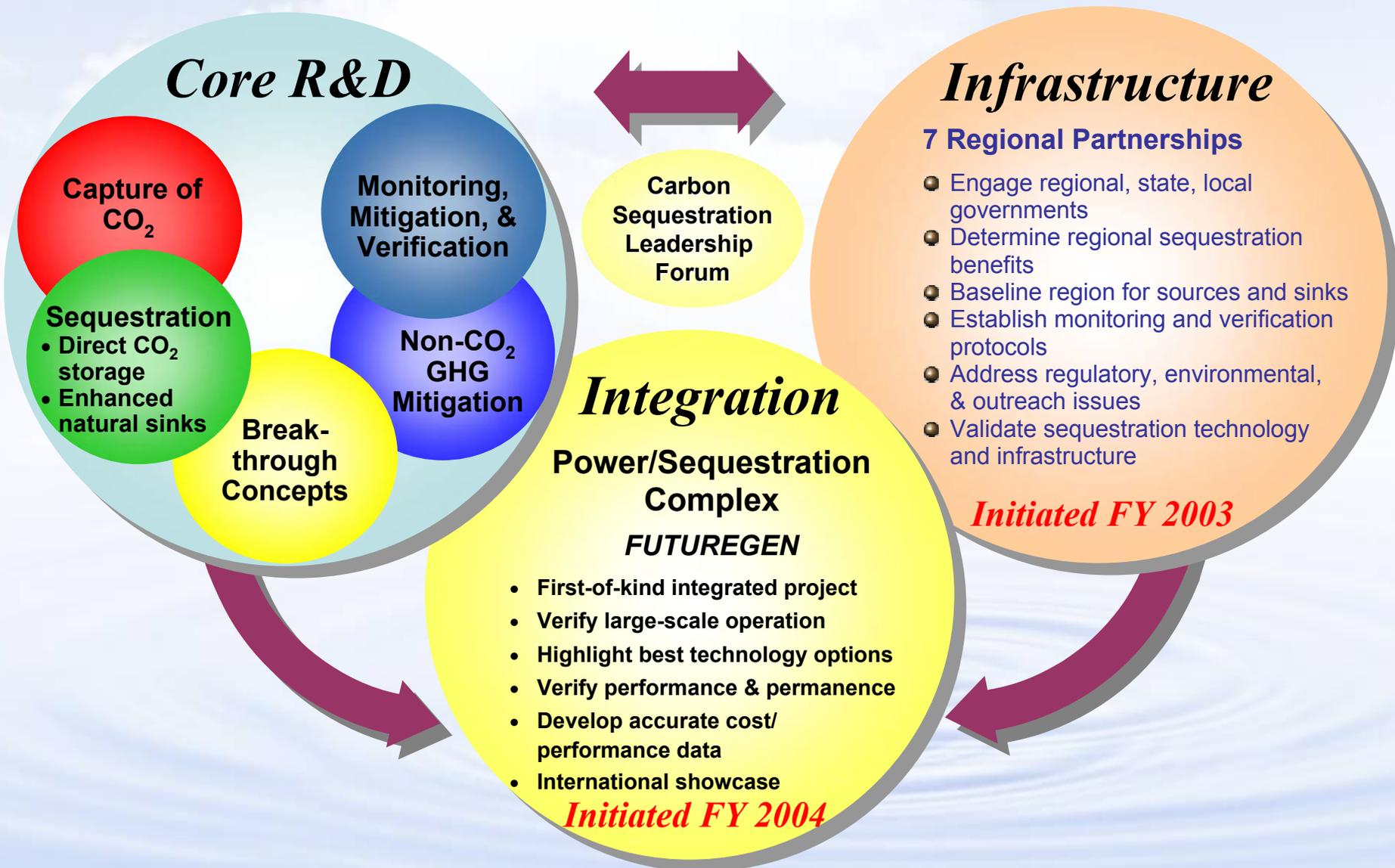
Cost Performance Goals

| Year | COE Penalty IGCC Plants (% Increase) | COE Penalty PC Plants (% Increase) |
|-------|--|--|
| 2002 | 30 | 80 |
| 2007 | 20 | 45 |
| 2012 | 10 | 20 |
| 2015 | <10 | 10 |
| 2018* | 0 | 0 |

*Cost/Energy offset from sequestering CO₂ with criteria pollutants NOX, SOx, H2S (gasification)

*** technologies identified and ready to move to demonstration (~ 4yrs) and then deployment (~4 yrs) – IGCC 20% and PC 45%

Carbon Sequestration Program Structure



Regional Partnership Update

“Developing the Infrastructure for Wide Scale Deployment”

Phase I (Characterization)

- 7 Partnerships (40 states)
- 24 months (2003-2005)



Phase II (Field Validation)

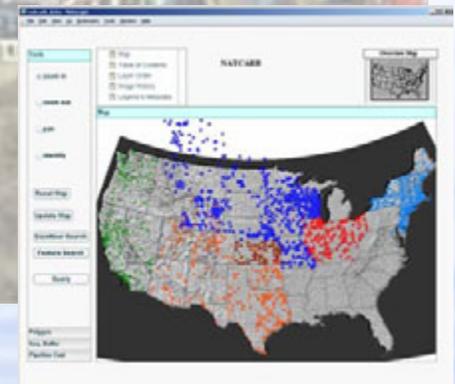
- 4 years (2005 - 2009)
- All seven Phase I partnerships continued
- \$100 million federal funds
- \$45 million in cost share

Phase III (Deployment)

- 8 years (2009-2017)
- Large Scale Injection Tests

Phase I Highlights/Accomplishments

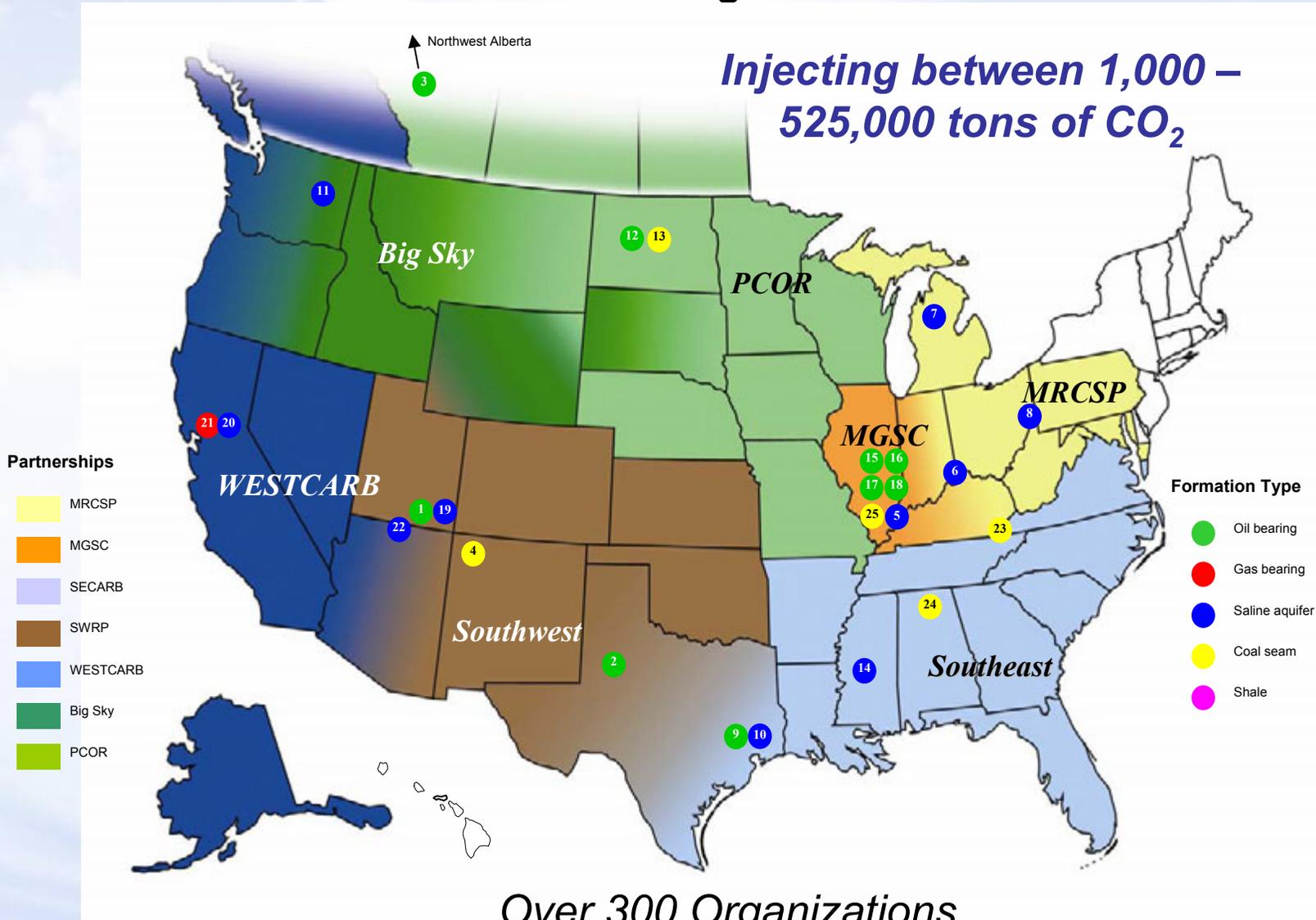
- **Identified Thousands of Years of Storage Capacity during Characterization Phase**
 - Coal Seams and Shales- ~ 18 GT
 - Oil and Gas Reservoirs - ~27 GT
 - Saline Formations - >5,000 GT
- **Identified Value Added Products in Potential Sinks**
 - Oil – 16 billion barrels of oil during sequestration in favorable fields
 - Coal Seams – 126 TCF CBM during sequestration in unmineable coal seams
- **Created a Carbon Sequestration Atlas for the U.S.**
 - NATCARB and Regional Atlases Available Online
 - www.natcarb.org



Regional Carbon Sequestration Partnerships

Phase II Geologic Field Tests

Injecting between 1,000 – 525,000 tons of CO₂



Over 300 Organizations

In Addition to Geologic - 10 Terrestrial Test

Example Phase II Project

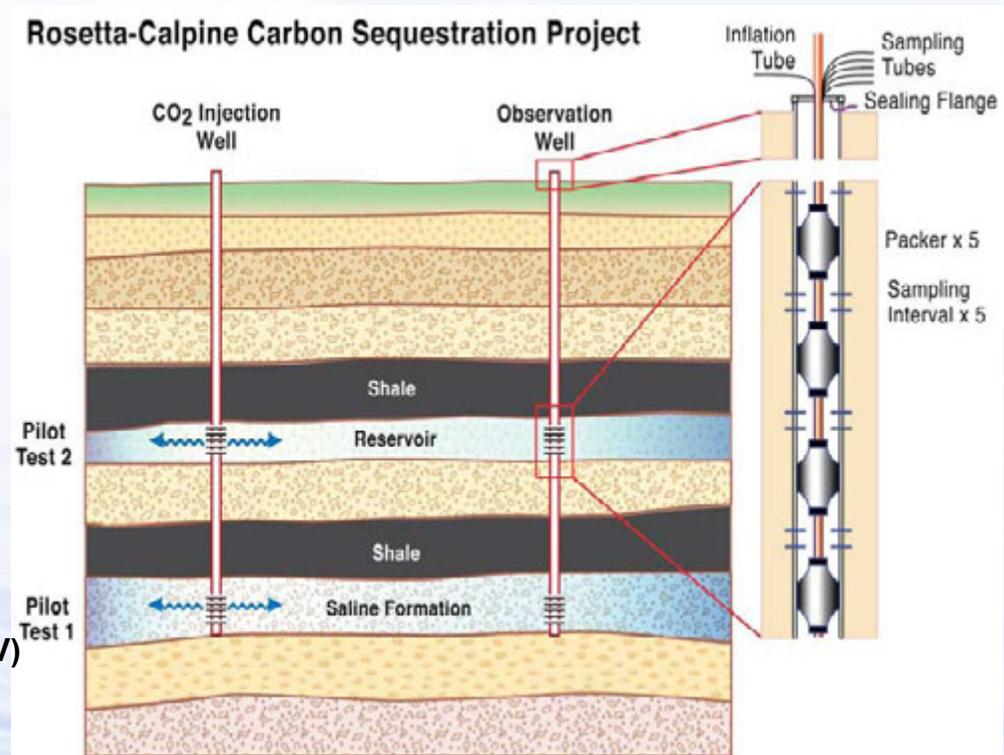
WESTCARB

Rossetta-Calpine, Sacramento Valley, CA:

- Stacked sequestration EOR/Saline Aquifer test
- 2,000 tons CO₂ in a saline formation (end of 2006)
- 2,000 tons CO₂ in enhanced gas recovery scenario (end of 2007)
- 1.8 Gt CO₂ storage capacity in depleted gas fields in Sacramento Valley (128 fields)
- Estimated 140-840 Gt CO₂ storage capacity in saline formations in California, based on ten largest basins

Regional Partnerships Addressing Key Issues

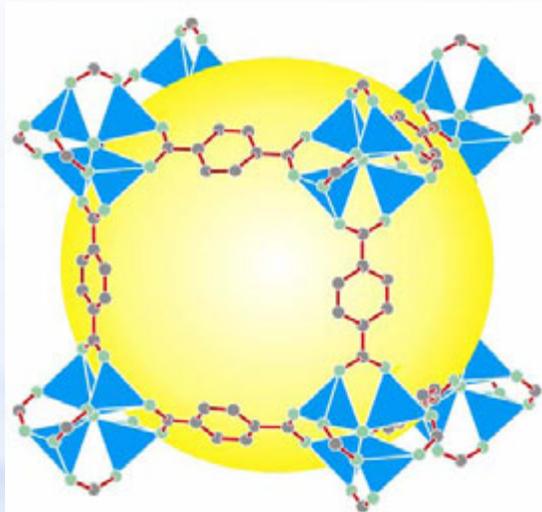
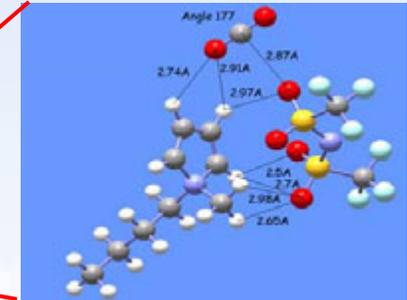
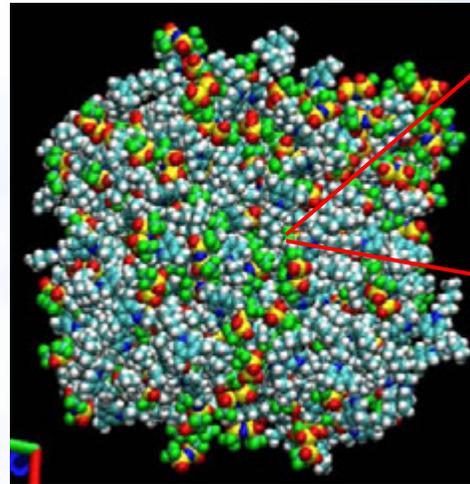
- Geologic Capacity estimates
- Site selection criteria
- Reservoir modeling and validation
- Monitoring, Mitigation, and Verification (MMV)
- Operational considerations
- Economics of sequestration



Core R&D - Separation and Capture *Advanced Capture Technologies*

Ionic Liquids⁽¹⁾

- Been discovered that CO₂ is *highly soluble* in some ionic liquids
- Non-volatile liquid and high thermal stability
- Ability to capture SO₂ with one solvent



Metal Organic Frameworks⁽²⁾

- Highly porous materials
- Thermally stable
- High loading capacities
- Low manufacturing costs

Participants: UOP LLC⁽¹⁾ and University of Notre Dame⁽²⁾

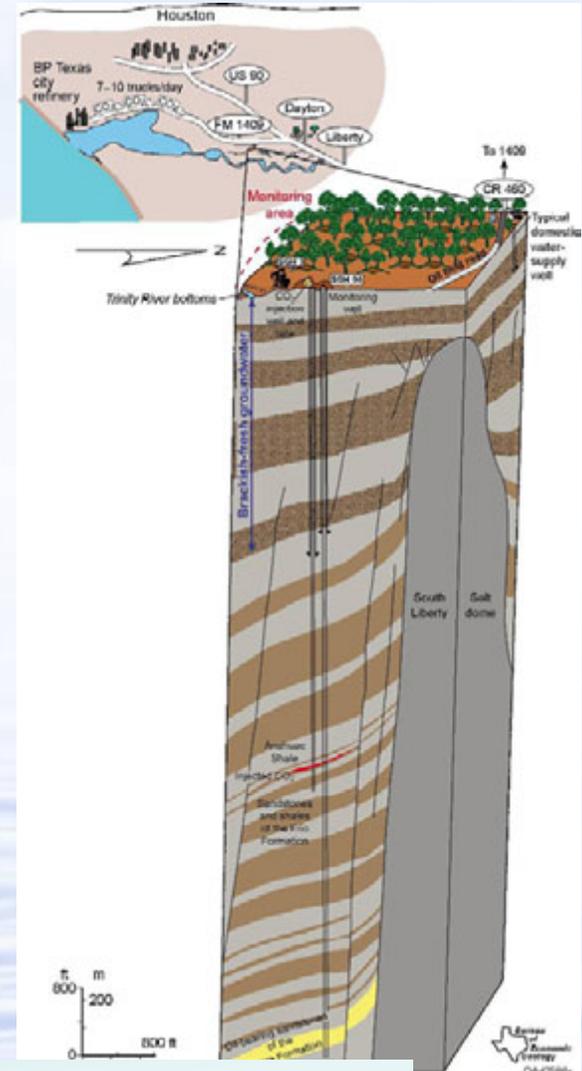
Funding Opportunity Announcement in CO₂ Capture DE-PS26-06NT42829

- 'Novel Technology and Commercially Focused Approaches to CO₂ Capture and Separation for Existing and Future Carbon Based Electric Generation Power Plants'
- Released: 4/19/2006
- Closes: 6/16/2006 at 8:00 PM Eastern Time
- Three (3) Areas of Interest
 - **Breakthrough Approaches to Carbon Dioxide and Separation**
 - Novel and innovative methods (Post- and Oxy-combustion)
 - **Continued Development of Direct CO₂ Capture and Separation Technologies**
 - Technologies continuing the development of post-, pre-, and oxy-combustion based CO₂ capture
 - **Field-Testing of CO₂ Capture and Separation Technologies**
 - Conduct field-testing of oxygen-based combustion and post combustion CO₂ capture technologies
- \$39 Million DOE over 3-yrs, Cost-Sharing required of 20% of project costs
- <http://www.netl.doe.gov/business/solicitations/index.html#42829>

Sequestration Core R&D Frio Brine Reservoir Pilot Test

Univ. of Texas Bureau of Economic Geology

- Investigated injectivity, safety, capacity and permanence of CO₂ for Gulf Coast saline reservoir
- Phase I (Oct 2004 injection):
 - demonstrated 1600 tons CO₂ injection at 5100 ft in a brine reservoir without adverse health, safety, or environmental effects;
 - determined the distribution of injected CO₂ using diverse monitoring technologies;
 - demonstrated validity of models; and
 - developed expertise necessary for success of large-scale CO₂ injection
- Phase II will follow these successes and inject ~700 tons CO₂ into unperturbed lower Frio sandstone unit using existing injection and observations wells; based on experience, study will:
 - develop effective monitoring strategy with geophysics, geochemistry, logging, and reservoir properties
 - refine reservoir modeling
 - develop best practices

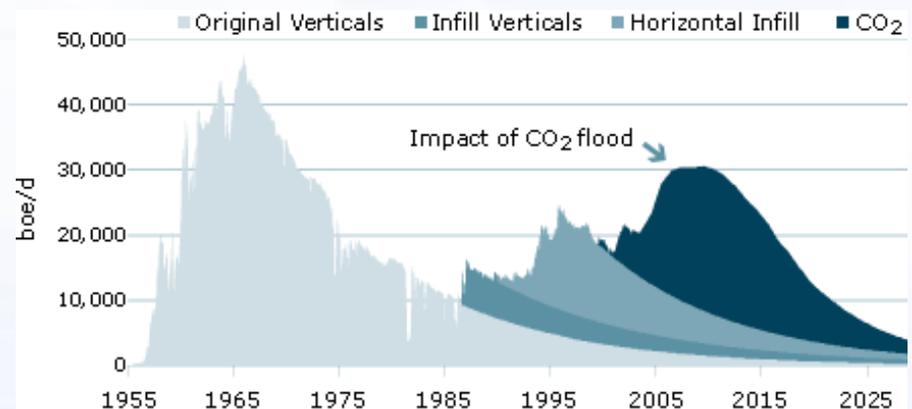


Participants: Texas BEG, BP, Schlumberger, Texas American Resources, Praxair, Core Labs, Sandia Technologies, LBNL, LLNL, ORNL, NETL

MMV Core R&D

IEA GHG Weyburn CO₂ Monitoring and Storage Project

- Weyburn field EOR flood operations inject CO₂ into carbonate oil reservoir at 5000 ft depth; integrated with CO₂ storage study
- CO₂ (with H₂S) is piped 204 miles from Dakota Gasification Plant
- Results for CO₂ reduction:
 - 5000 tons/day of CO₂ stored in ground
 - more than 5 million tons already injected
 - storage potential of 30 million tons of CO₂
- Results for oil increase:
 - additional 10,000 barrels/day
 - oil production potential of additional 130 million barrels
- Phase II:
 - expand to the Midale Unit operated by Apache Canada Ltd. who will implement a field-wide CO₂ EOR project in 2005
 - expand studies of characterization, monitoring and verification, reservoir performance, modeling, environmental impacts, and risk assessment
 - develop a “Best Practices Manual” for geological storage, monitoring, and verification



Additional Information

National Energy Technology Laboratory Site Map GO>



THE ONLY U.S. NATIONAL LABORATORY DEVOTED TO FOSSIL ENERGY TECHNOLOGY

ABOUT NETL

KEY ISSUES & MANDATES

ONSITE RESEARCH

TECHNOLOGIES

- Oil & Natural Gas Supply
- Coal & Power Systems
- Carbon Sequestration
 - CO₂ Capture
 - CO₂ Storage
 - Monitoring, Mitigation, Verification
 - Non-CO₂ Greenhouse Gases
 - Breakthrough Concepts
 - Regional Partnerships
 - FAQs
 - Contacts
- Hydrogen & Clean Fuels
- Technology Transfer

SOLICITATIONS & BUSINESS

CAREERS & FELLOWSHIPS

Home > Technologies > Carbon Sequestration

Technologies

Carbon Sequestration

NETL manages a portfolio of laboratory and field R&D focused on technologies with great potential for reducing greenhouse gas emissions and controlling global [climate change](#). Most efforts focus on capturing carbon dioxide from large stationary sources such as power plants, and sequestering it using geologic, terrestrial ecosystem, or oceanic approaches. Control of fugitive methane emissions is also addressed.



Carbon sequestration work directly implements the President's Global Climate Change Initiative, 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.

The programmatic timeline is to demonstrate a portfolio of safe, cost effective greenhouse gas capture, storage, and mitigation technologies at the commercial scale by 2012, leading to substantial deployment and market penetration beyond 2012. These greenhouse gas mitigation technologies will help slow greenhouse

NEWS & FEATURES // All >

- Carbon Sequestration Technology Roadmap [PDF-4542KB]
- Carbon Sequestration Program Outreach Plan [PDF-1438MB]
- DOE Advances Commercialization of Climate Change Technology
- Regional Carbon Sequestration Partnerships Program Adds Canadian Provinces

EVENTS CALENDAR // All >

- The 2006 EIC Climate Change Technology Conference - Engineering Challenges and Solutions in the 21st Century

PUBLICATIONS & PROJECTS // All >

- Carbon Sequestration Reference Shelf
- Carbon Sequestration Project Portfolio [PDF-4200KB]

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