

Carbon Sequestration R&D Overview



Carbon Sequestration

Briefing

October 2007

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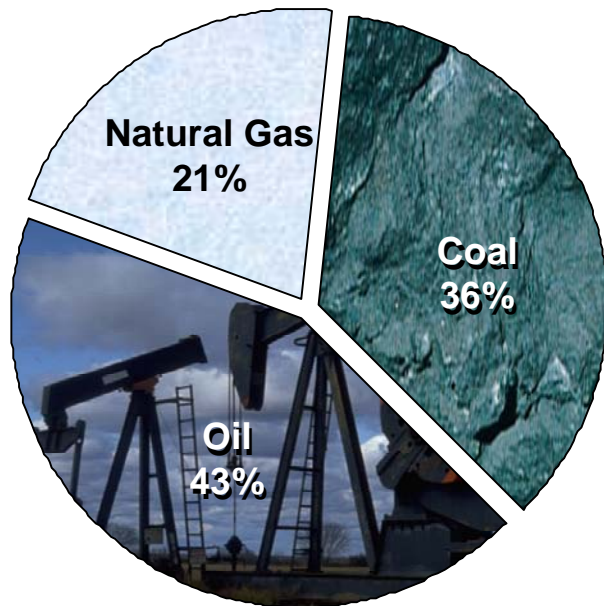
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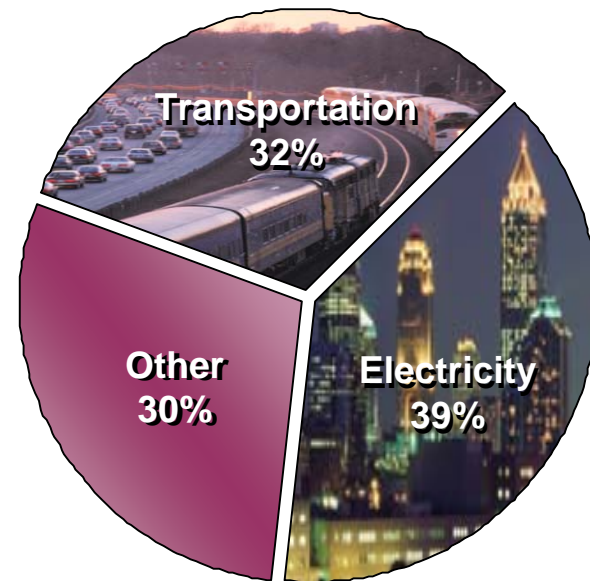
R&D Focus is on Coal & Electricity

United States CO2 Emissions

36% Emissions From Coal



39% Emissions From Electricity

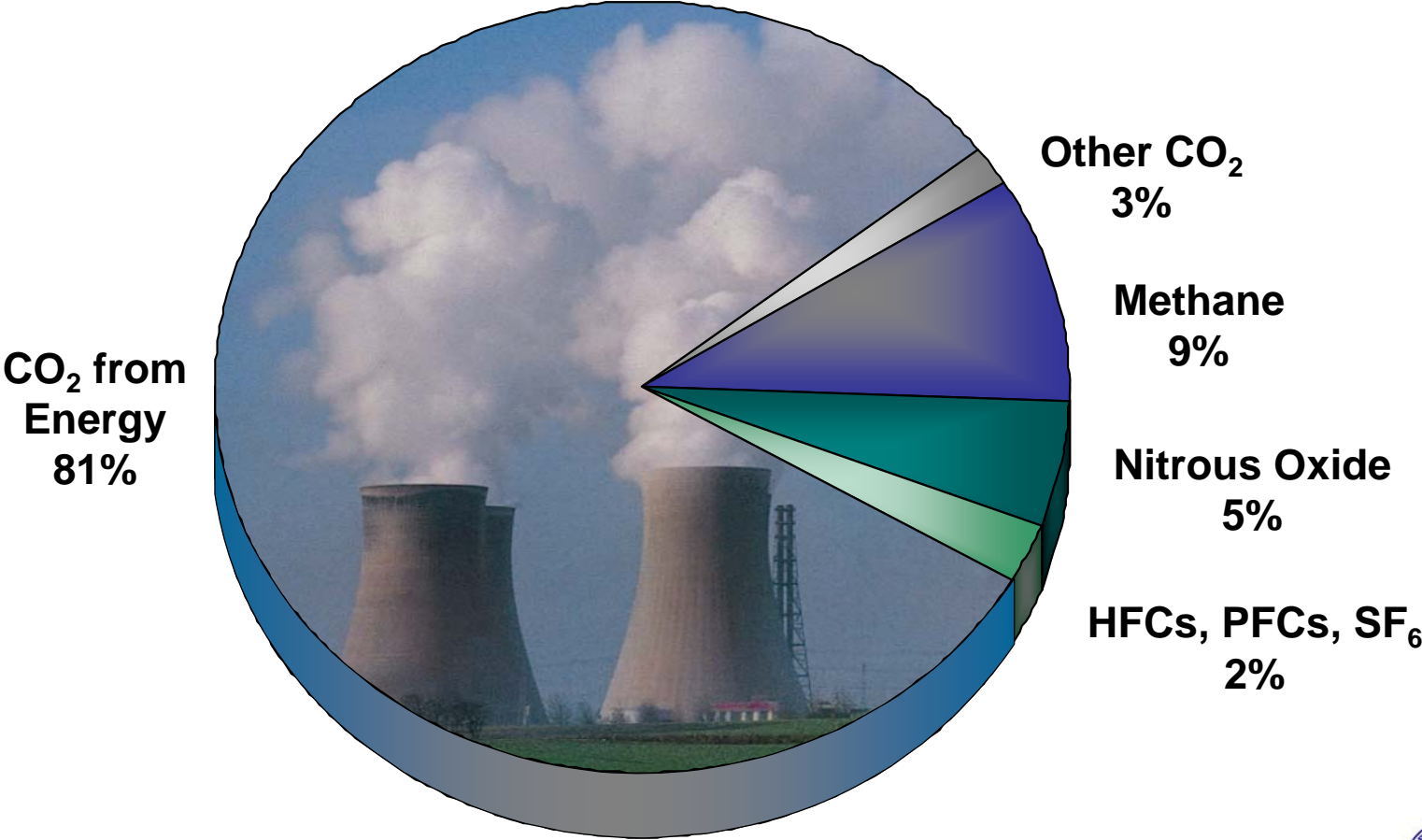


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R&D Focus is on CO₂

United States Greenhouse Gas Emissions
(Equivalent Global Warming Basis)



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"EIA Emissions of Greenhouse Gases in the U.S.



Annual CO₂ Emissions Extremely Large

Emissions	Total Release in the U.S., short tons per year
Mercury	120
Sulfur Dioxide (SO ₂)	15,000
Municipal solid waste	230,000,000
Carbon Dioxide (CO ₂)	6,300,000,000

Data sources: Mercury - EPA National Emissions Inventory (1999 data); SO₂ - EPA air trends (2002 data); MSW - EPA OSWER fact sheet (2001 data); CO₂ - EIA AEO 2004 (2002 data)



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How Much CO₂ is Produced?

- **1 million metric tons of CO₂:**
 - Every year would fill a volume of 32 million cubic feet
 - *Close to the volume of the Empire State Building*
- **U.S. emits roughly 6 billion tons (gigatons) of CO₂ per year**
 - Under an EIA reference case scenario cumulative CO₂ emissions 2004-2100 are expected to be 1 trillion tons
 - *Enough to fill Lake Erie with liquid CO₂ almost twice*



Technological Carbon Management Options

Reduce Carbon Intensity

- Renewables
- Nuclear
- Fuel Switching

Improve Efficiency

- Demand Side
- Supply Side

Sequester Carbon

- Capture & Store
- Enhance Natural Sinks

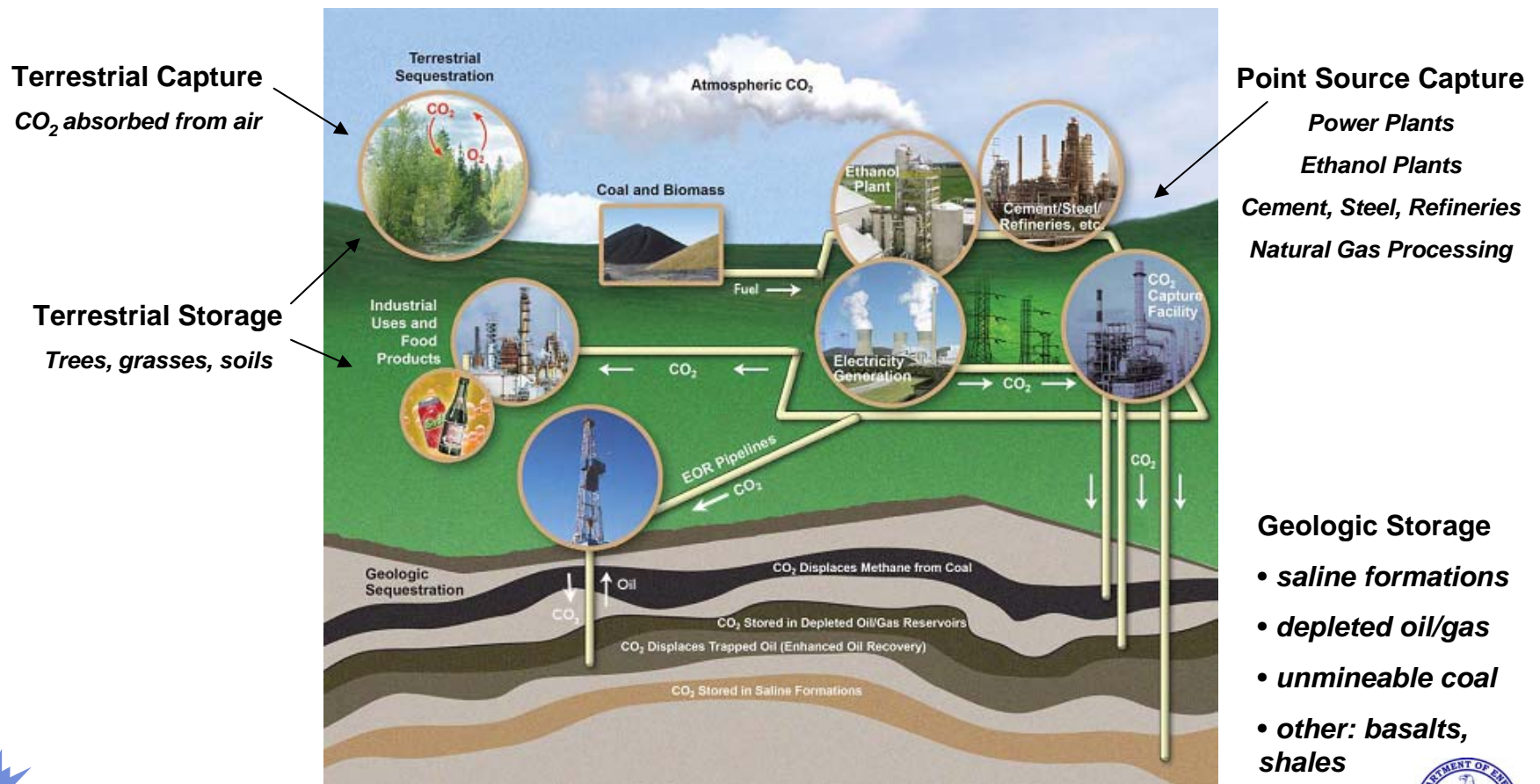
All options needed to:

- Affordably meet energy demand
- Address environmental objectives



What is Carbon Sequestration?

Capture and storage of CO₂ and other Greenhouse Gases that would otherwise be emitted to the atmosphere



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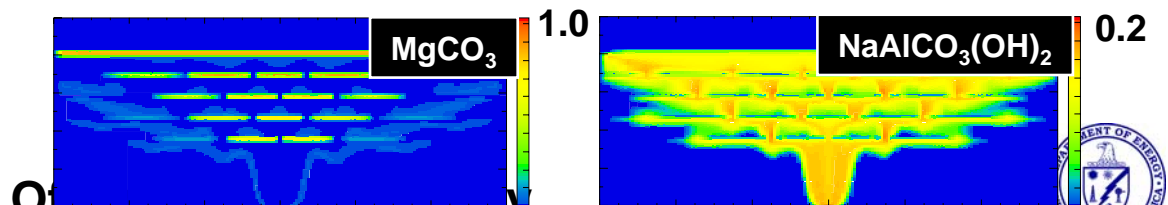
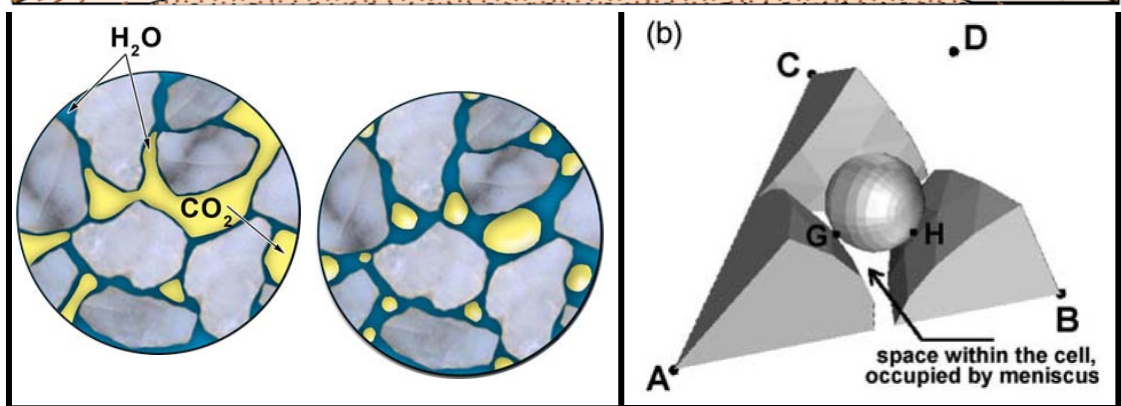
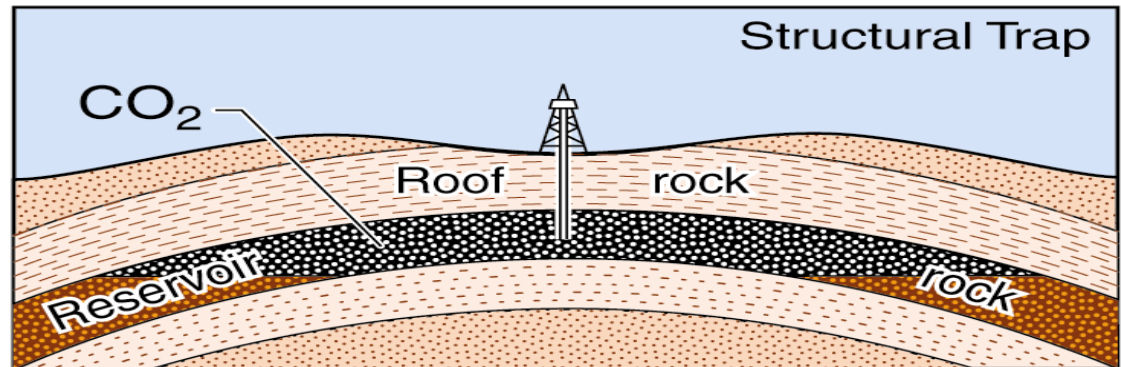
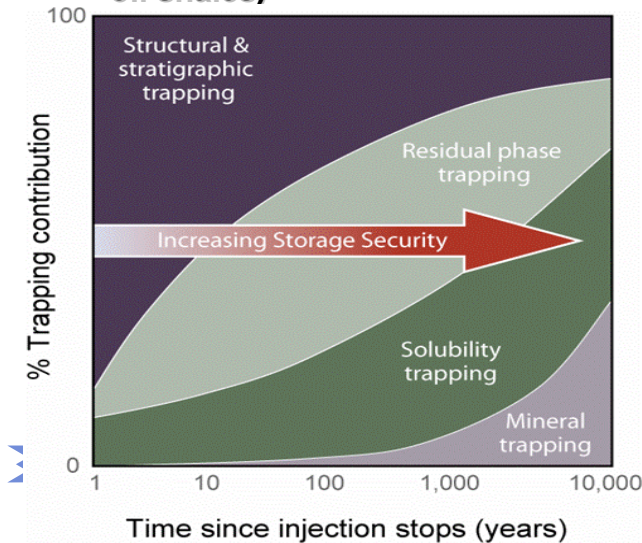


Carbon Storage – How does it work?

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

- Physical trapping
- Residual phase trapping
- Solution/Mineral Trapping
- Gas adsorption

•For organic minerals only (coals, oil shales)

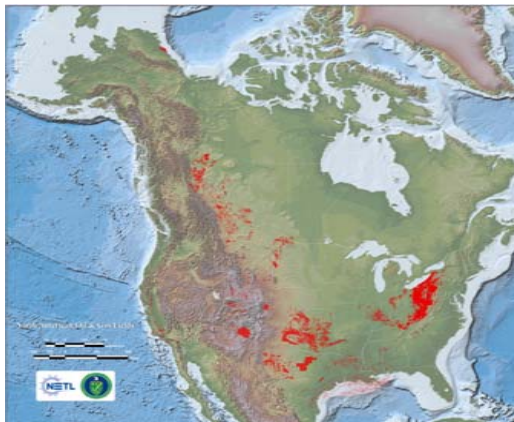


Office of Fusion Energy
Source: S Benson, LBNL

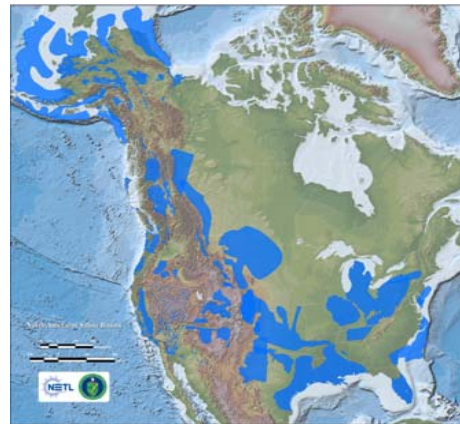


National Atlas Highlights *Adequate Storage Projected*

U.S. ~ 6 GT CO₂/yr all sources

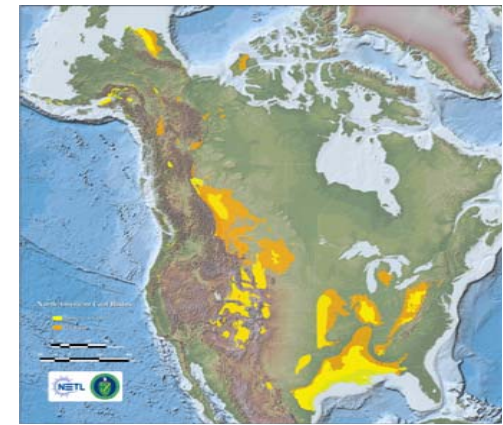


Oil and Gas Fields



Saline Formations

North American CO₂ Storage Potential
(Giga Tons)



Unmineable Coal Seams

Sink Type	Low	High
Saline Formations	969	3,223
Unmineable Coal Seams	70	97
Oil and Gas Fields	82	83

**Hundreds of
Years of
Storage
Potential**



Available for download at http://www.netl.doe.gov/publications/carbon_seq/refshelf.html

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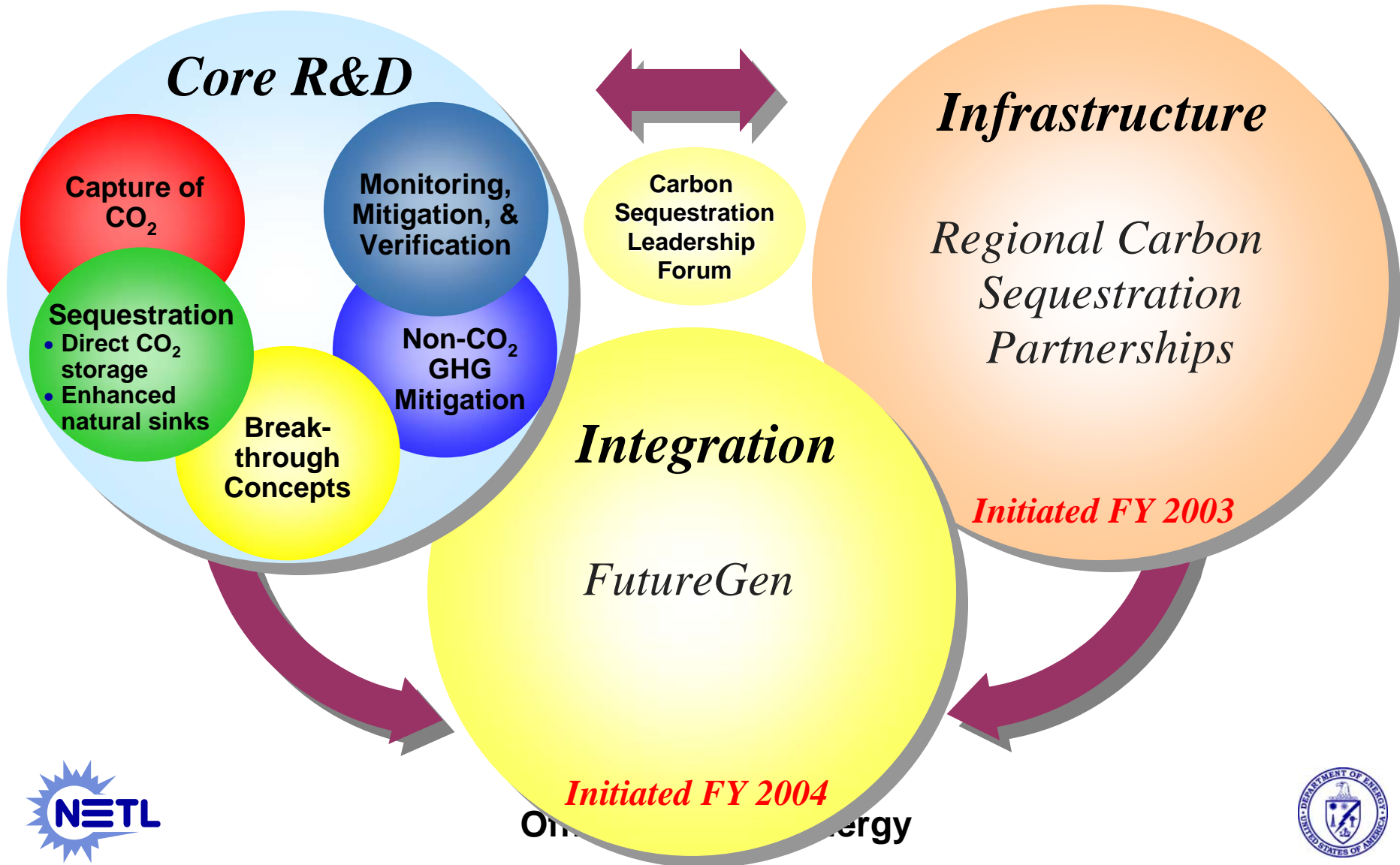


Requirements for Sequestration

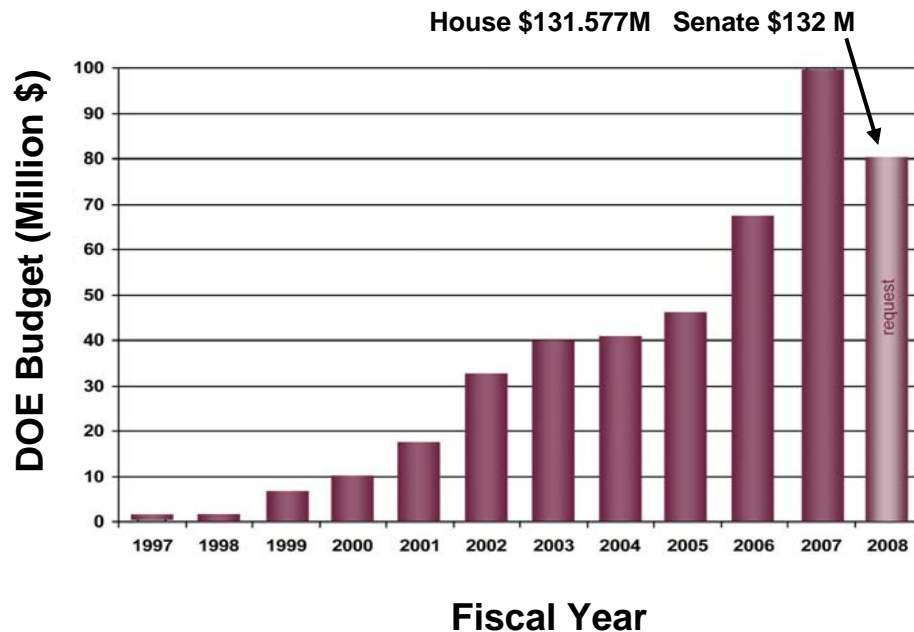
- **Environmentally acceptable**
 - No legacy for future generations
 - Respect existing ecosystems
- **Safe**
 - No sudden large-scale CO₂ discharges
- **Verifiable**
 - Ability to verify amount of CO₂ sequestered
- **Economically viable**



Carbon Sequestration Program Structure



Sequestration Program Statistics FY2007



Strong industry support

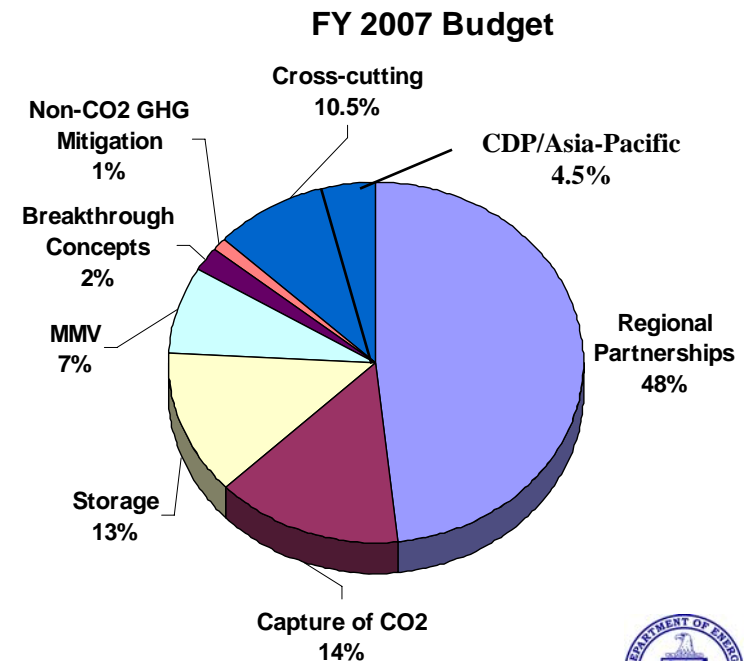
~ 39% cost share on projects

Federal Investment to Date

~ \$360 Million

Diverse research portfolio

~ 70 Active R&D Projects



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Overcoming Barriers to Carbon Capture and Storage (CCS)

- **Capture Costs**
 - Capital Investments
 - Increases in COE
- **Lack of Infrastructure**
- **Regulatory Requirements**
- **Public Acceptance**
- **Human Capital Resources**

- **DOE/FE—NETL Sequestration Program is overcoming these barriers through:**
 - Core R&D
 - Technology/Infrastructure Development
 - Government/Industry Partnerships
 - International Collaborations



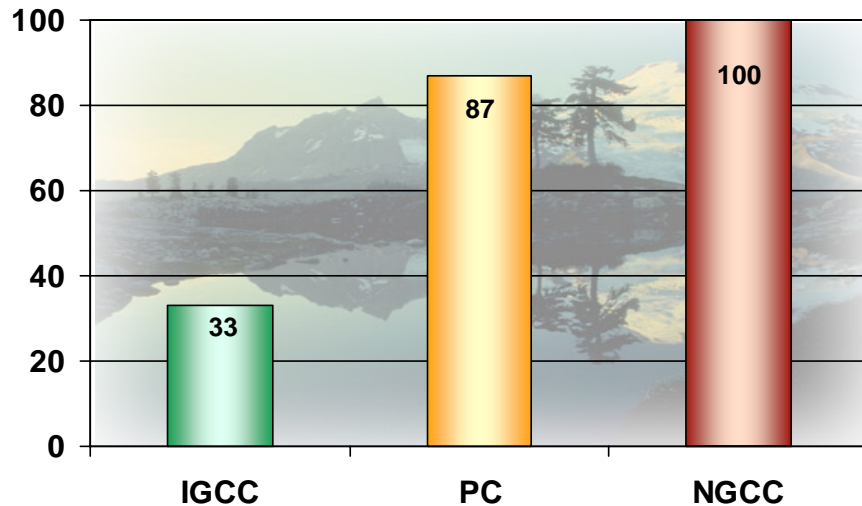
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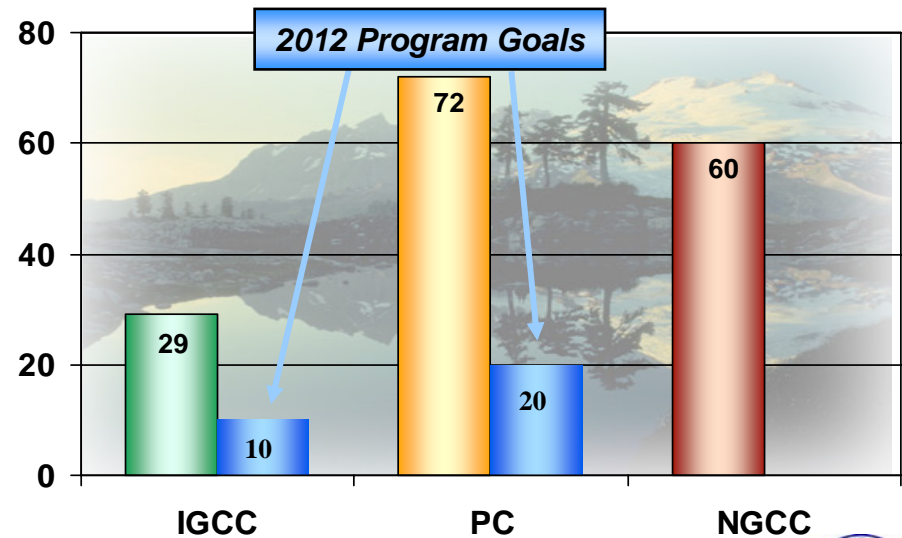
Capture Cost Reduction Needed !!

- 5–30% parasitic energy loss
- 30–100% increase in capital cost
- 25–75% increase in cost of electricity

Effect of CO₂ Capture on Capital Cost
(% Increase Resulting From CO₂ Capture)

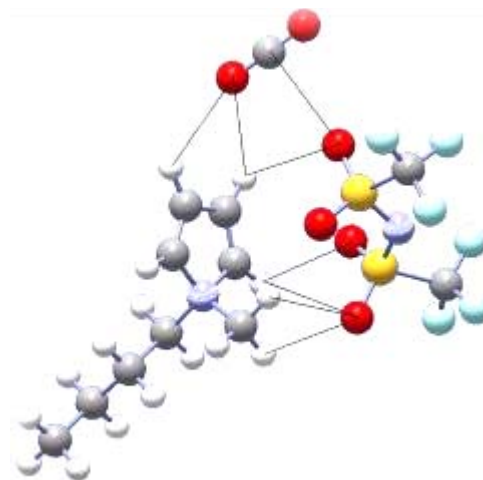
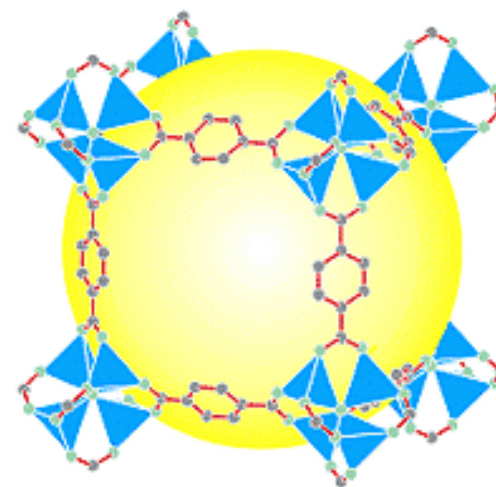


Effect of CO₂ Capture on Cost of Electricity
(% Increase Resulting From CO₂ Capture)



Capture Innovations – Driving Down Costs !!

- Ionic liquids
- Metal organic frameworks (MOF)
- Ceramic Autothermal Recovery (CAR)
- Polymer-based high-temperature membrane
- Carbonic anhydrase enzymatic membrane
- Ammonia-based scrubbing
- Amine-enriched absorbents



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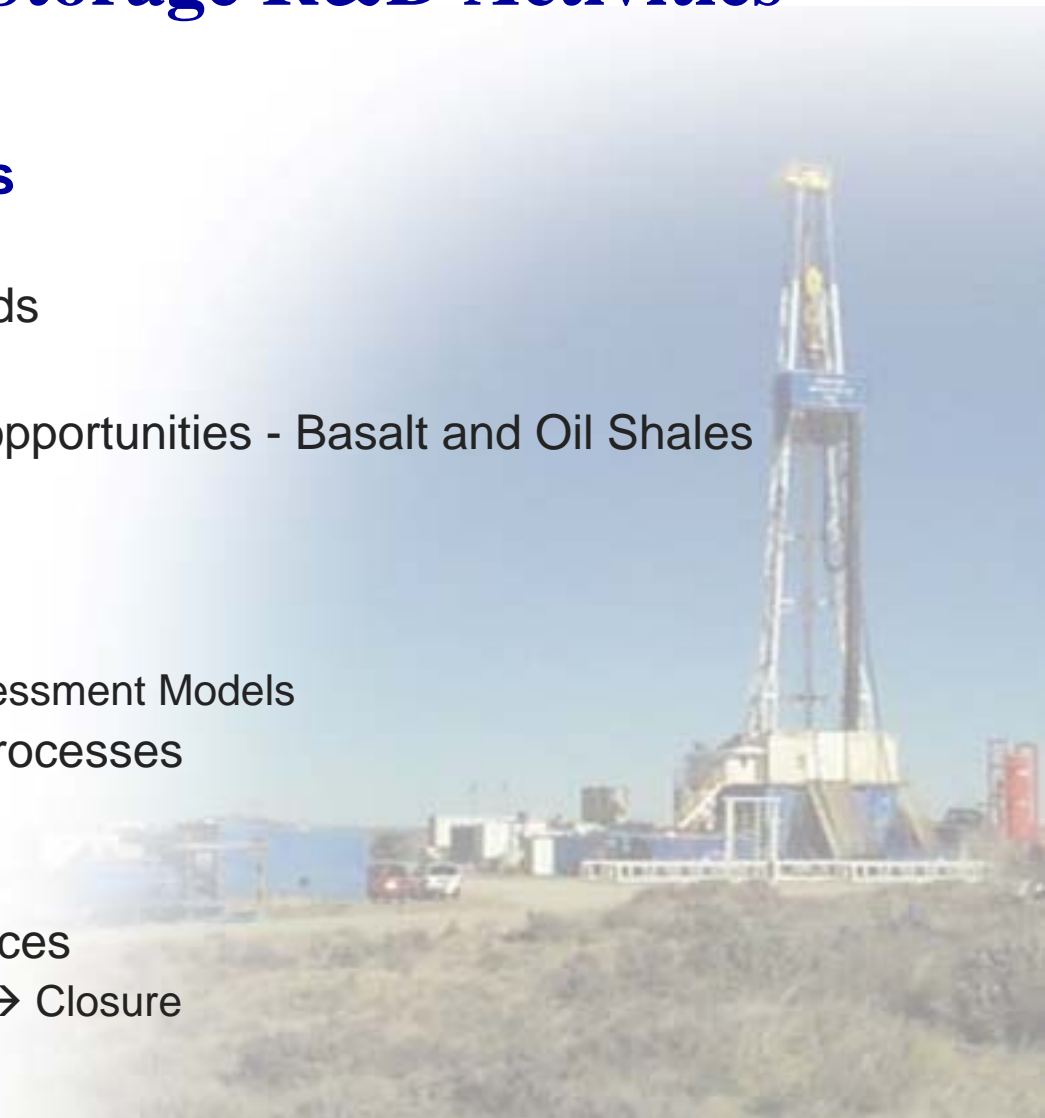
Summary of Storage R&D Activities

Geologic Storage Sinks

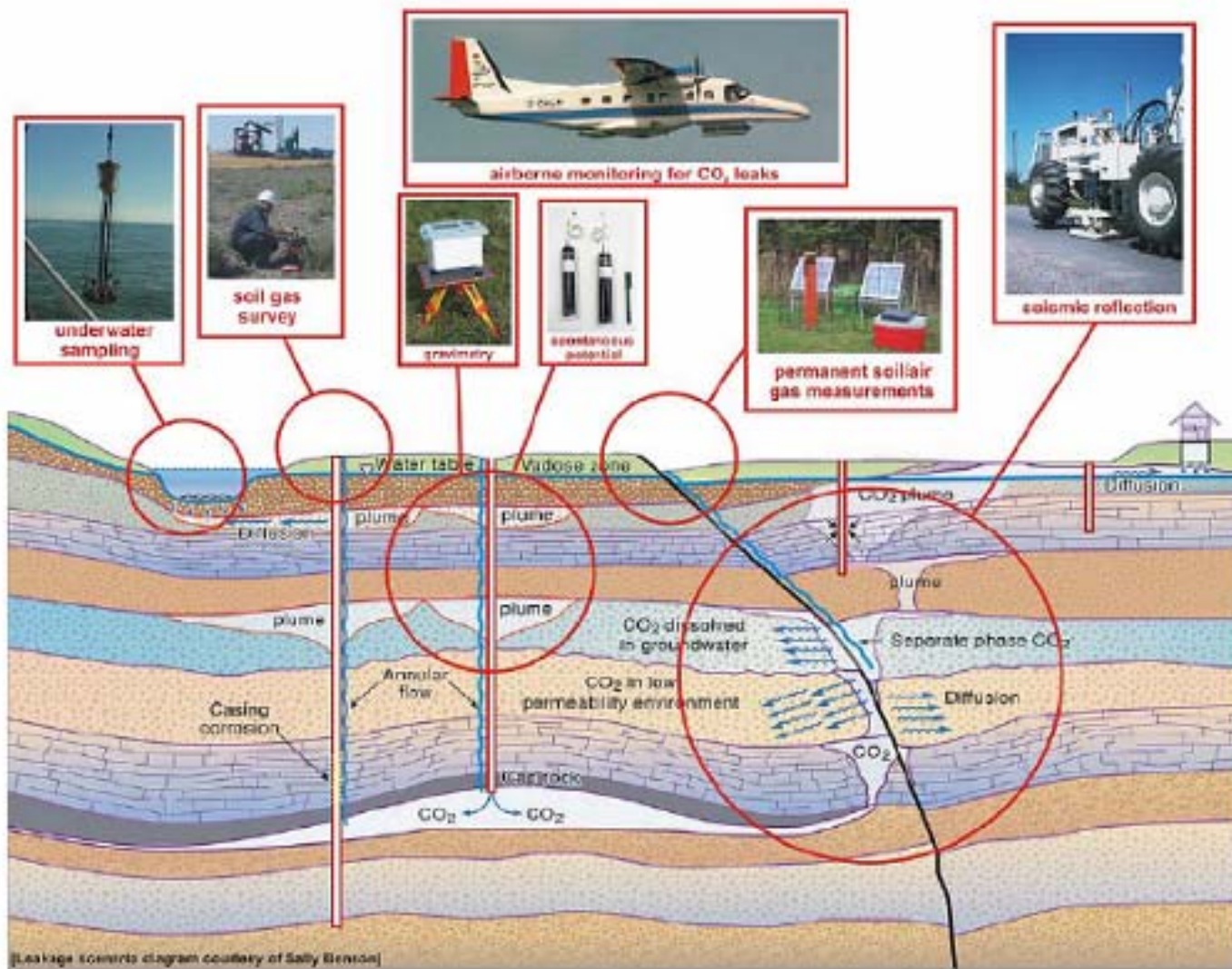
- Unmineable coal seams
- Depleted oil and gas fields
- Saline formations
- Other potential storage opportunities - Basalt and Oil Shales

Research Pathways

- Model development
 - Reservoir and Risk Assessment Models
- Physical and chemical processes
- Monitoring technologies
- Well bore management
- Best management practices
 - Selection → Operation → Closure



Monitoring, Mitigation, and Verification Ensuring Permanent Storage !!



Regional Carbon Sequestration Partnerships

Characterization Phase

- 24 months (2003-2005)
- \$16M DOE funds

Validation Phase

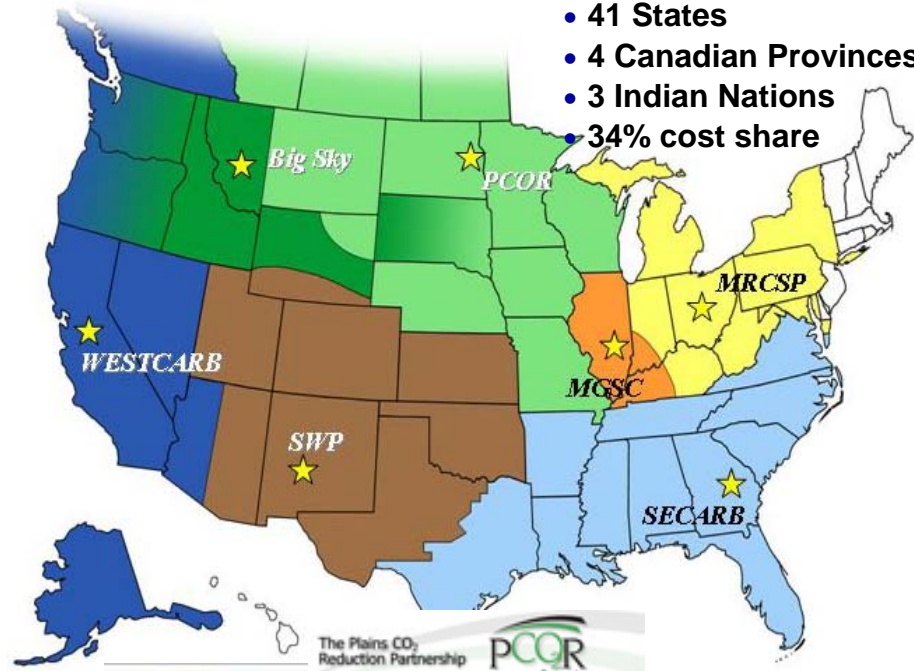
- 4 years (2005 - 2009)
- 7 Partnerships (41 states)
- 25 Geologic field validation tests
- \$112M DOE funds

Deployment Phase

- 10 years (2008-2017)
 - FY07 Initiated
- Several large injection tests in different geology

Representing:

- >340 Organizations
- 41 States
- 4 Canadian Provinces
- 3 Indian Nations
- 34% cost share



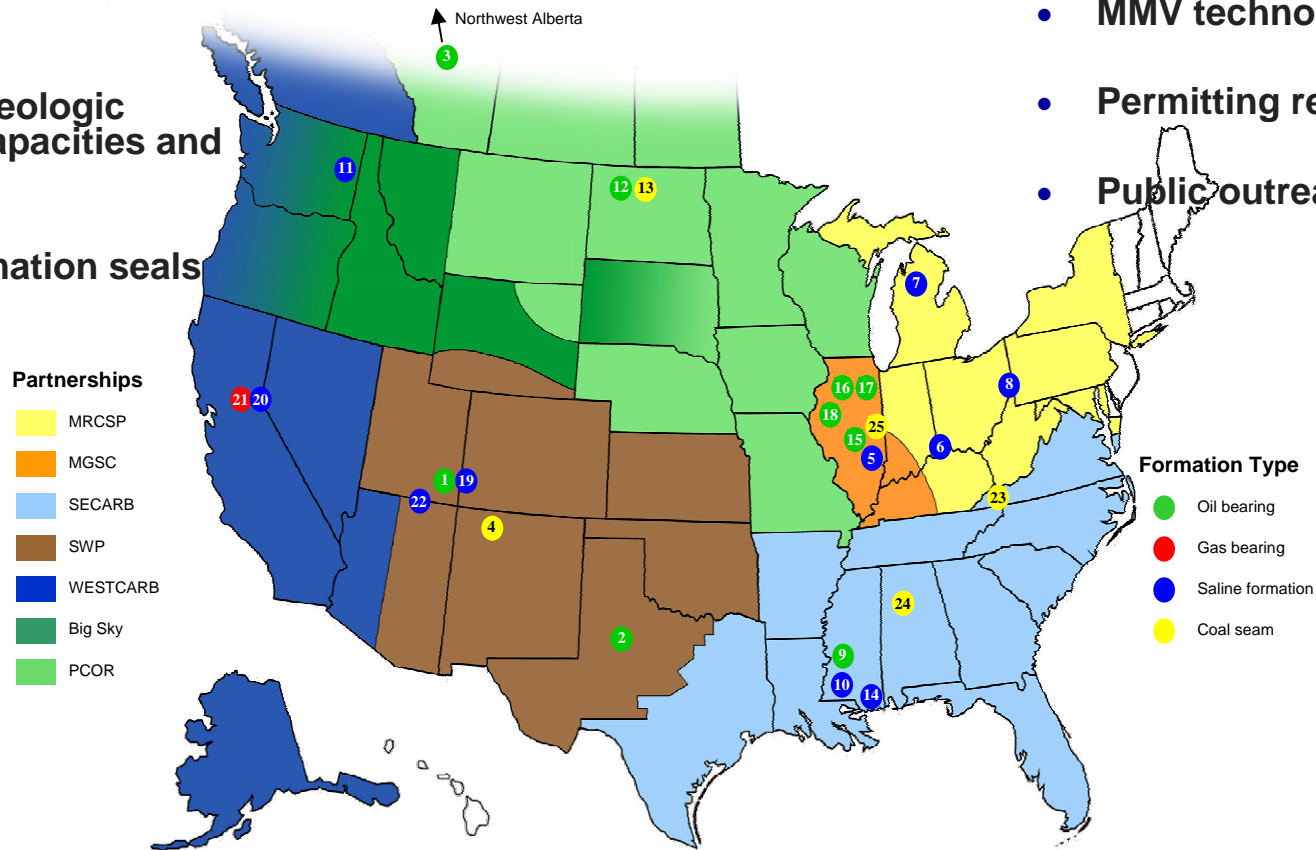
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Phase II Field Validation 25 Geologic Tests

- Injections 750-525,000 Tons CO₂
- Validating geologic formation capacities and injectivity
- Testing formation seals

- MMV technologies
- Permitting requirements
- Public outreach



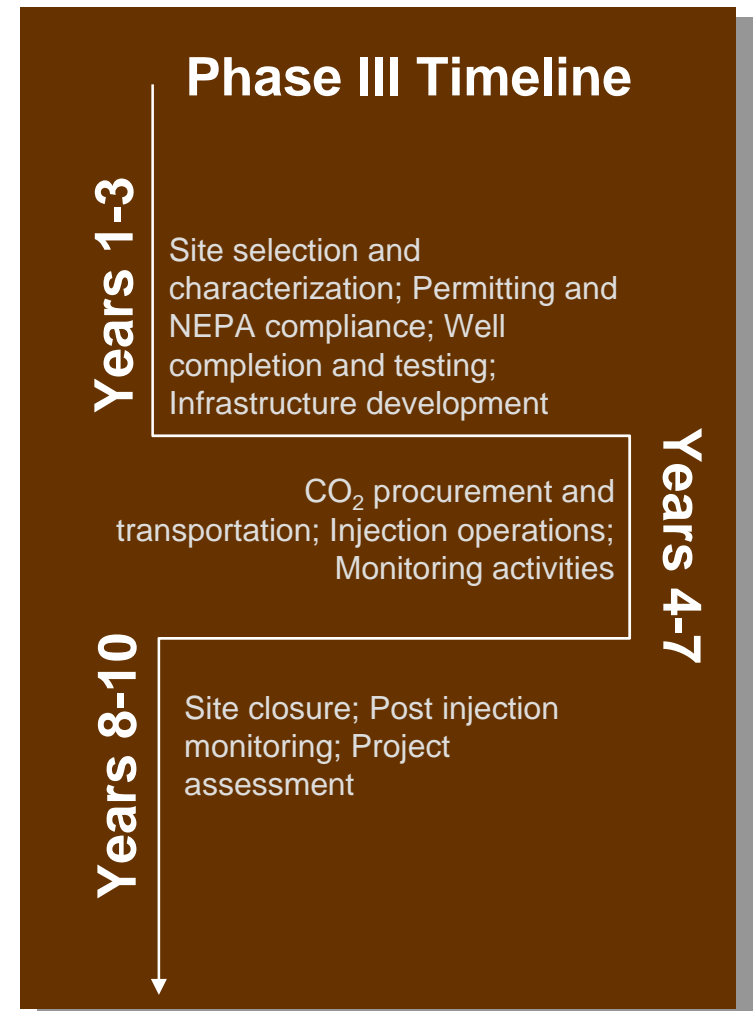
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Deployment Phase

Scaling Up Towards Commercialization

- **FY 2008-2017 (10 years)**
- **Several Large Volume Sequestration tests in North America**
- **Injection rates up to 1,000,000 tons per year for several years**
- **Scale up is required to provide insight into several operational and technical issues in different formations**

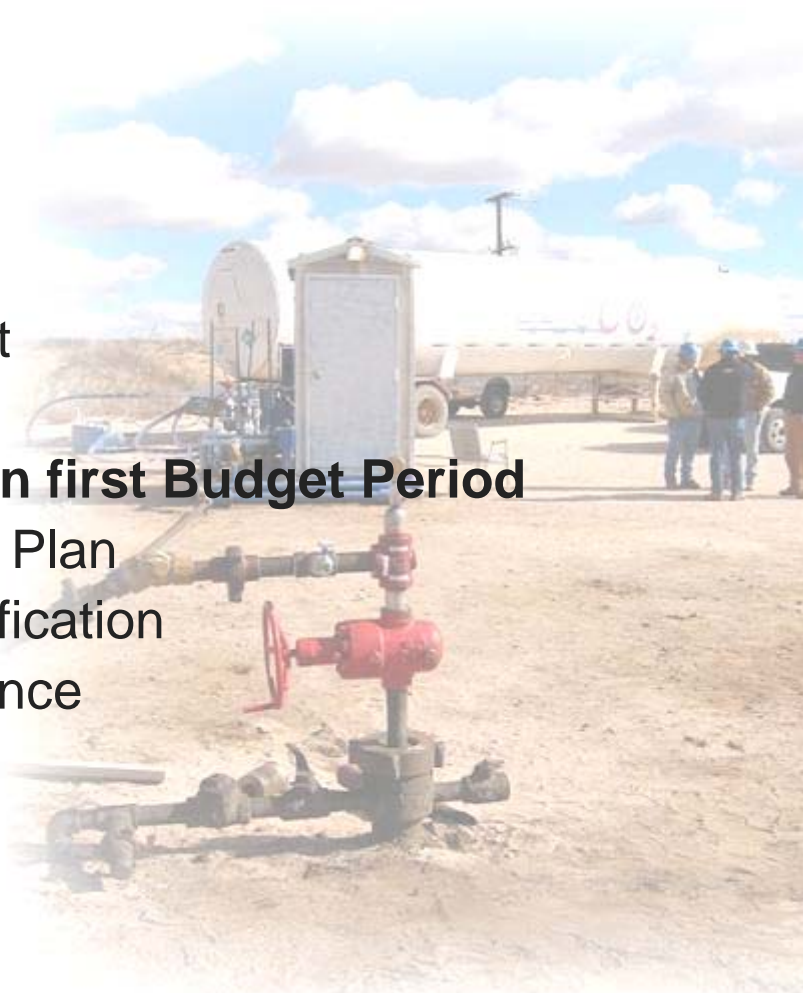


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Phase III: Deployment *Activities*

- **Awarded in 3 budget periods**
 - 1 - Site characterization
 - 2 - Injection and monitoring
 - 3 - Site closure and assessment
- **Necessary Accomplishments in first Budget Period**
 - Detailed Project Management Plan
 - Site characterization and certification
 - Permitting and NEPA compliance
 - Well completion and testing
 - Infrastructure development



Initial 3 Phase III Projects Announced

- **First set of projects awarded Sept 2007**
 - Plains CO2 Reduction Partnership
 - Southeast Regional Carbon Sequestration Partnership
 - Southwest Regional Partnership for Carbon Sequestration

- **Several more projects to follow**



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Plains CO₂ Reduction Partnership (PCOR)

- **Lead by University of North Dakota- EERC**
- **Alberta Basin**
 - deep saline formation
 - co-sequestration of CO₂ and hydrogen sulfide from a large gas-processing plant
 - 1.8 million tons/year (3-6 years)
- **Williston Basin**
 - enhanced oil recovery and CO₂ storage in a deep carbonate formation that is also a major saline formation
 - CO₂ from post-combustion capture facility at a coal-fired power plant in the region
- **Total Project Cost: \$135,586,059**
 DOE Share: \$ 67,000,000
 Partner Share: \$ 68,586,059



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Southeast Regional Carbon Sequestration Partnership

- **Lead by Southern States Energy Board (SSEB)**
- **Lower Tuscaloosa Formation Massive Sand Unit**
 - Deep saline formation
 - Two injection sites within same formation with CO₂ from two different sources
 - assess different CO₂ streams and how the heterogeneity of the formation affects the injection and containment.
- **Injection of several million tons of CO₂ from a natural deposit**
- **Conduct a second injection into the formation using CO₂ captured from a coal-fired power plant in the region**
 - 100,000 Tons per year
- **Total Project Cost: \$93,689,242**
DOE Share: \$64,949,079
Partner Share: \$28,740,163



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Southwest Regional Partnership (SWRP)

- **Coordinated by the New Mexico Institute of Mining and Technology**
 - Jurassic-age Entrada Sandstone Formation in the southwestern United States
 - Several million tons of CO₂ from natural sources
- **Extensive baseline characterization and simulation modeling.**
- **Information gained from the project will be used to evaluate locations throughout the region where future power plants are being considered.**
- **Total Project Cost: \$88,845,571**
 - DOE Share: \$65,437,395**
 - Partner Share: \$23,408,176**



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Deployment Phase

Outcomes

- **Site characterization requirements**
- **Storage capacity assessment**
- **Design criteria**
 - Injection wells
 - Regional monitoring, mitigation, and verification program
 - Site Closure
- **Permitting requirements**
- **Validate reservoir and risk assessment models**
- **Accelerate public outreach**
- **Best practice manuals**

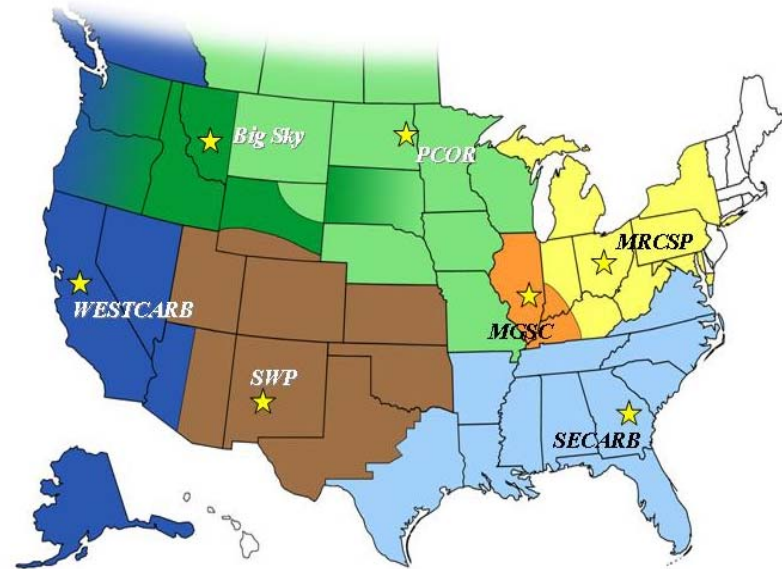
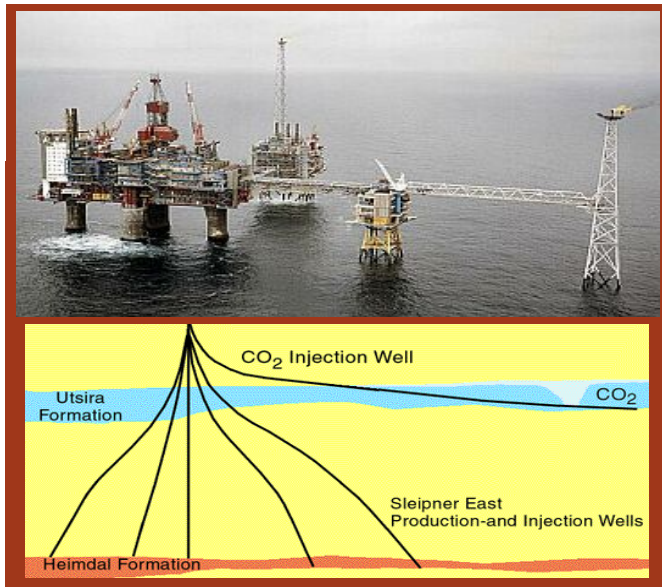


Geologic Sequestration

Undertaking needed Science and Engineering

Million Tonnes per year injections

- Statoil at Sleipner since '96
- BP at In Salah
- EnCana EOR project with CO₂ storage in the Weyburn field
- US EOR since 1970's



Proving Technical Feasibility

- Proper characterization and siting
- Low Risk: Oil and Gas in formations for thousands of years
- DOE undertaking testing in US to develop and prove technology
 - Monitoring tools, models, public outreach, best management practices
- Regulatory & Legal Frameworks are being developed for future large-scale deployment



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Additional Information

The screenshot shows the National Energy Technology Laboratory (NETL) website. The header includes the NETL logo and the tagline "THE ONLY U.S. NATIONAL LABORATORY DEVOTED TO FOSSIL ENERGY TECHNOLOGY". The main navigation menu on the left lists categories such as "ABOUT NETL", "KEY ISSUES & MANDATES", "ONSITE RESEARCH", "TECHNOLOGIES", "SOLICITATIONS & BUSINESS", and "CAREERS & FELLOWSHIPS". The "TECHNOLOGIES" section is expanded, showing sub-categories like "Oil & Natural Gas Supply", "Coal & Power Systems", and "Carbon Sequestration". The "Carbon Sequestration" sub-category is further expanded, listing topics such as "CO₂ Capture", "CO₂ Storage", "Monitoring, Mitigation, Verification", "Non-CO₂ Greenhouse Gases", "Breakthrough Concepts", "Regional Partnerships", "FAQs", and "Contacts". The main content area displays the breadcrumb "Home > Technologies > Carbon Sequestration" and the title "Technologies Carbon Sequestration". Below the title, there is a paragraph of text and a photograph of a forest. The right sidebar contains sections for "NEWS & FEATURES", "EVENTS CALENDAR", and "PUBLICATIONS & PROJECTS".


National Energy Technology Laboratory Site Map GO>

NETL
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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-1201KB]



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