

# Carbon Sequestration Program



***Regional Engagement and  
Overcoming Barriers to Carbon  
Capture and Storage in the U.S.***

***Carbon Sequestration  
Leadership Forum  
Paris, France  
27 March 2007***

**George Guthrie—Los Alamos National Laboratory  
John Litynski—National Energy Technology Laboratory**



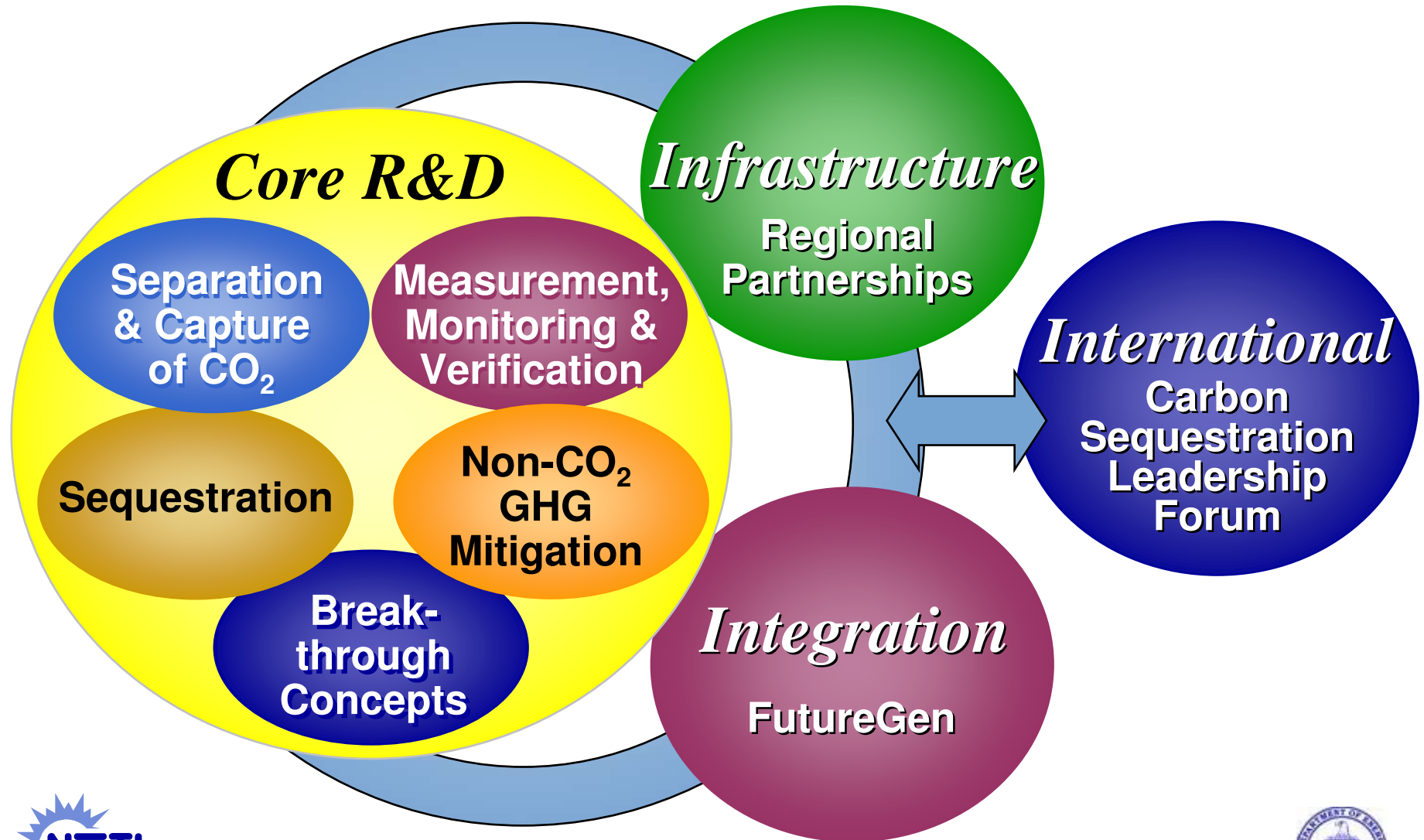
# Overcoming Barriers to Carbon Capture and Storage (CCS)

- **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*



# US DOE (Office of Fossil Energy) Program Organization

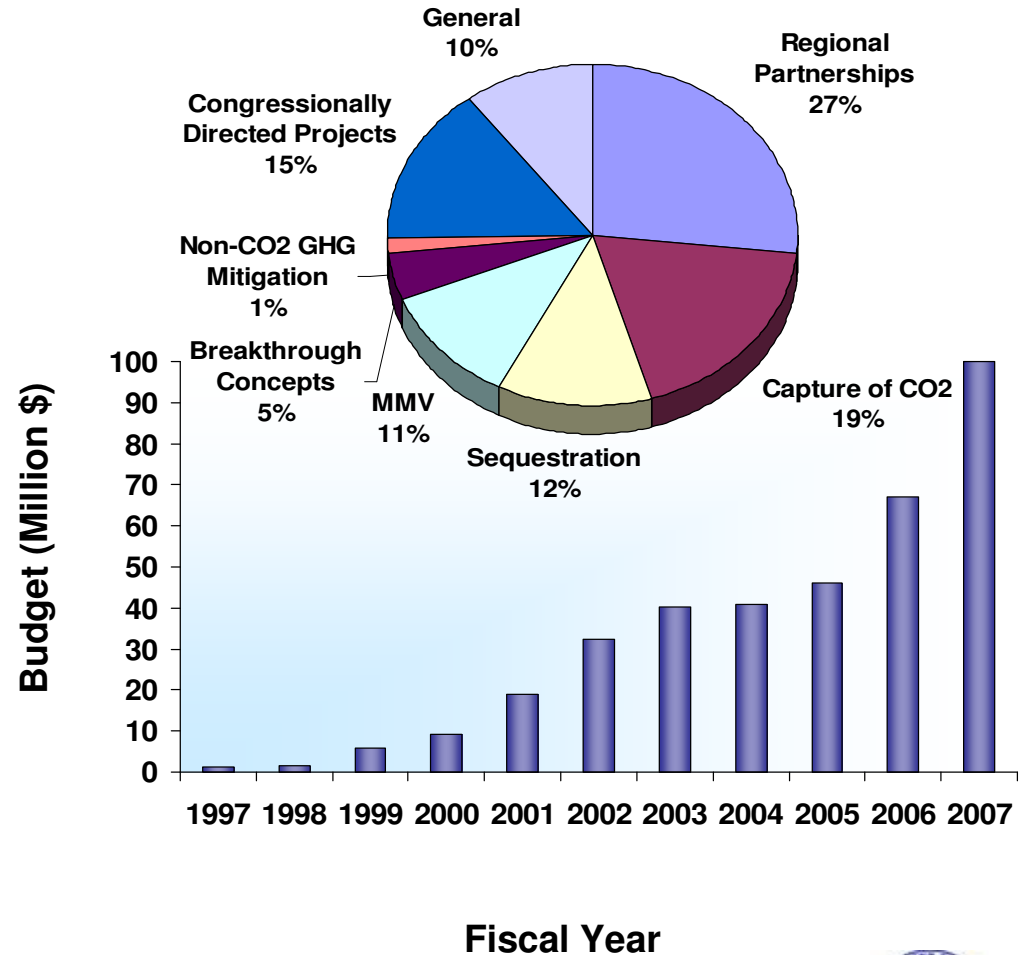
*Breaking Down Barriers To Sequestration*



# US DOE-FE Sequestration Program Portfolio Overview (FY2006)

FY 2006 Budget

- **Diverse research portfolio**
  - ~ 70 R&D Projects
- **Strong industry support**
  - ~ 39% cost share
- **Federal Investment to Date**
  - ~ \$260 Mil
- **Administration Priority**



# Core R&D 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 CO<sub>2</sub> storage capacity with +/- 30% accuracy
  - Develop best practice reservoir management strategies that maximize CO<sub>2</sub> trapping
- Monitoring, Mitigation & Verification
  - 2012 ability to verify 95% of stored CO<sub>2</sub> for credits (1605b)
  - CO<sub>2</sub> material balance to >99%

### Cost Performance Goals

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

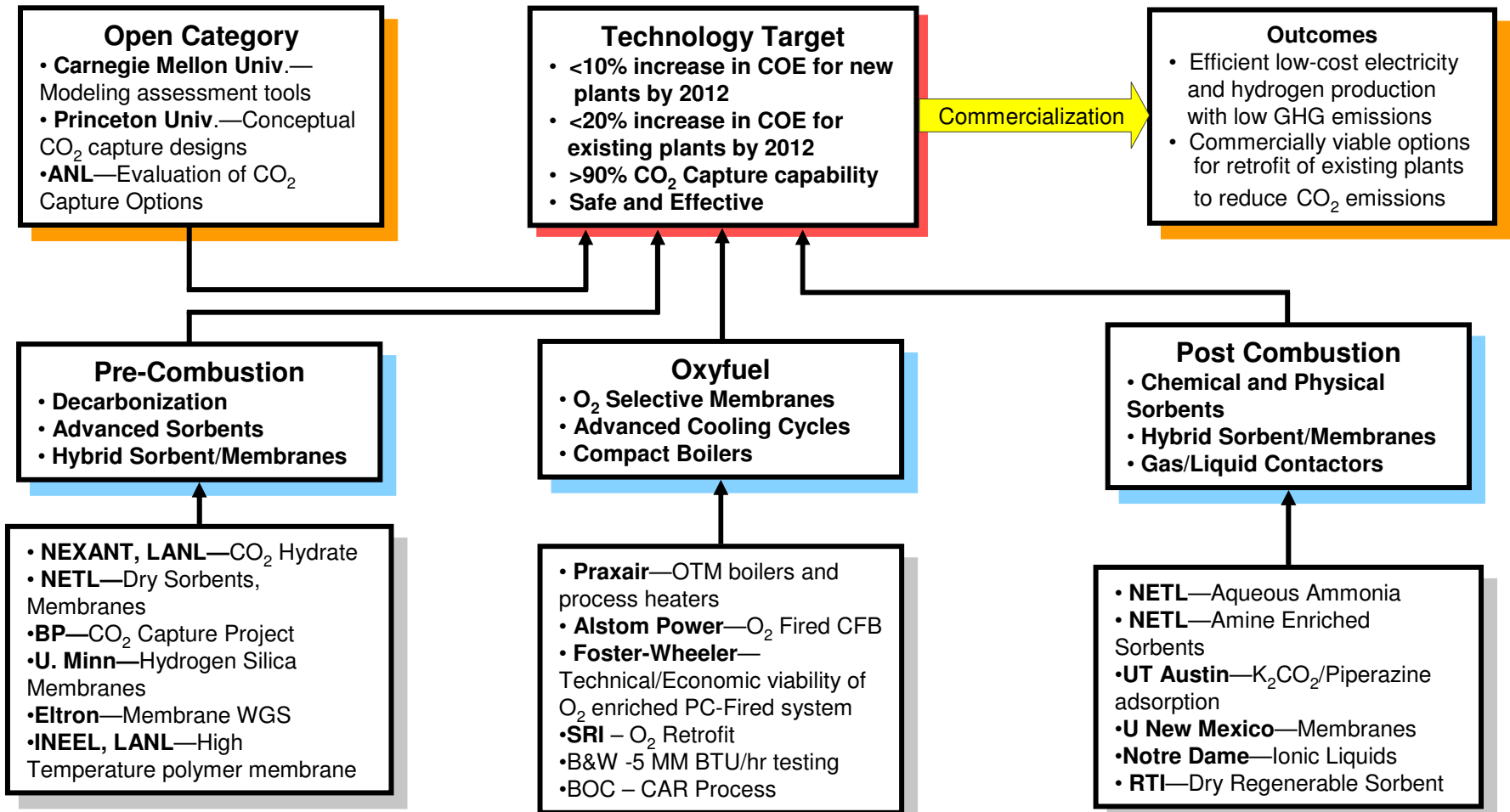
\*Cost/Energy offset from sequestering CO<sub>2</sub> with criteria pollutants NO<sub>x</sub>, SO<sub>x</sub>, H<sub>2</sub>S (gasification)



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

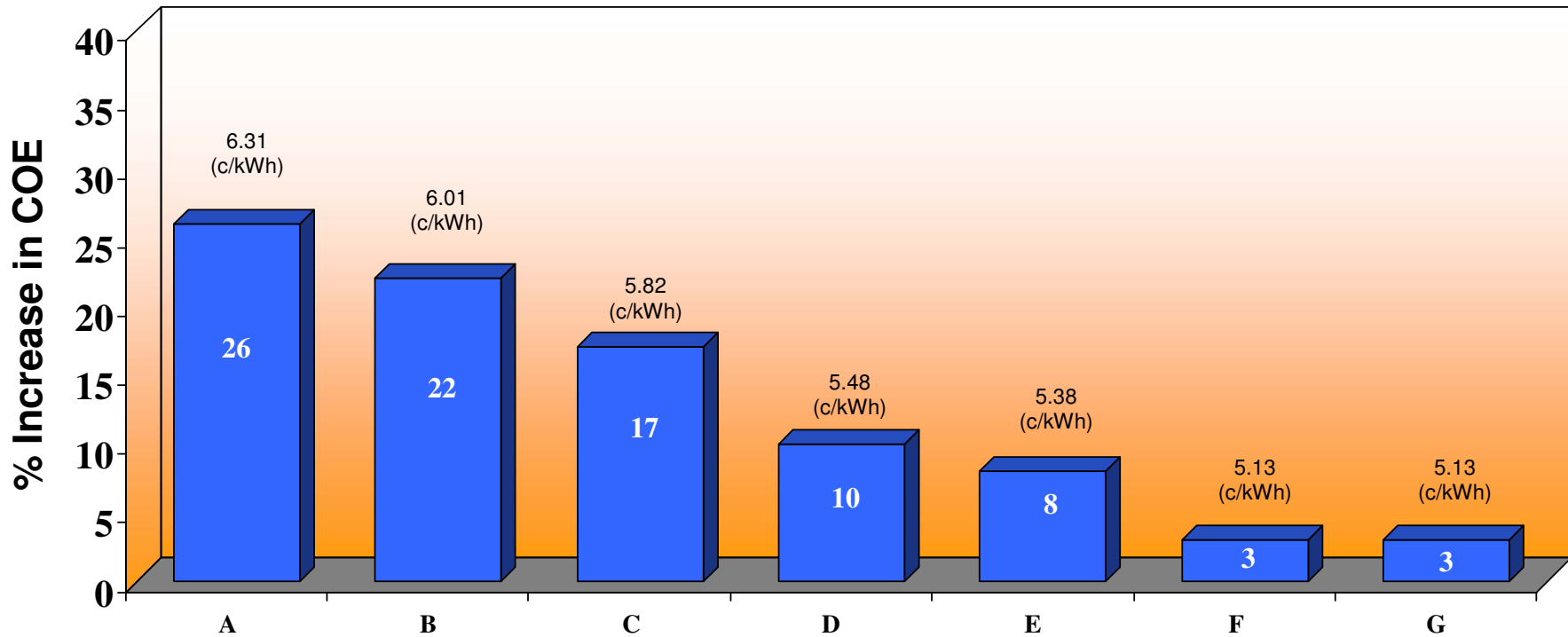


# Separation and Capture Overview



# Systems Analysis

## CO<sub>2</sub> Sequestration Economics for IGCC



**Basis:**

No Capture = 5 cents/kWh

A—2000 Selexol Scrubbing

B—2005 Advanced Selexol Scrubbing

C—Advanced Selexol Scrubbing w/Co-Storage H<sub>2</sub>S/CO<sub>2</sub>

D—Adv. Selexol + Ion Transport O<sub>2</sub> Membrane (ITM) + Co-Storage

E—H<sub>2</sub>/CO<sub>2</sub> selective Water Gas Shift (WGS) Membrane + Co-Storage

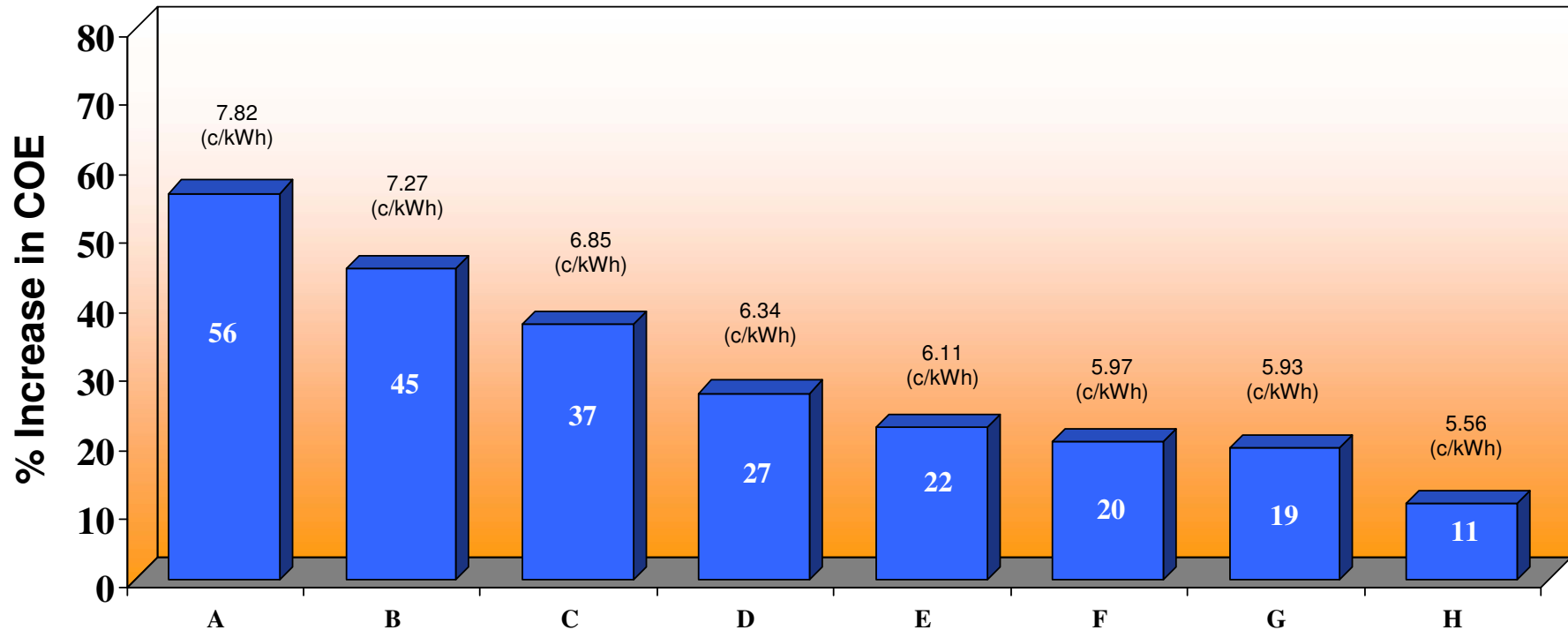
F—ITM + H<sub>2</sub>/CO<sub>2</sub> selective WGS Membrane + Co-Storage

G—Chemical Looping with Co-Storage H<sub>2</sub>S/CO<sub>2</sub>



# Systems Analysis

## CO<sub>2</sub> Sequestration Economics for PC



**Basis:**

No Capture = 5 cents/kWh

- A—2000 Amine Scrubbing
- B—2005 Advanced Amine Scrubbing
- C—Advanced Amine Scrubbing + Co-Storage SO<sub>x</sub>/CO<sub>2</sub>
- D—Aqueous Ammonia Scrubbing
- E—Amine-Enhanced Solid Sorbents
- F—Aqueous Ammonia Scrubbing + By-product Sales
- G—Ultra Supercritical Oxy-Fuel Combustion + ITM Membrane
- H—USC Oxy-Fuel Combustion + ITM Membrane + Co-Storage SO<sub>x</sub>/CO<sub>2</sub>





# Sequestration/Storage R&D

*“Developing the Infrastructure for Wide Scale Deployment”*

## Technology Goals

- 2012 – predict CO<sub>2</sub> storage capacity with +/- 30% accuracy
- Develop best practice reservoir management strategies that maximize CO<sub>2</sub> trapping

## Issues

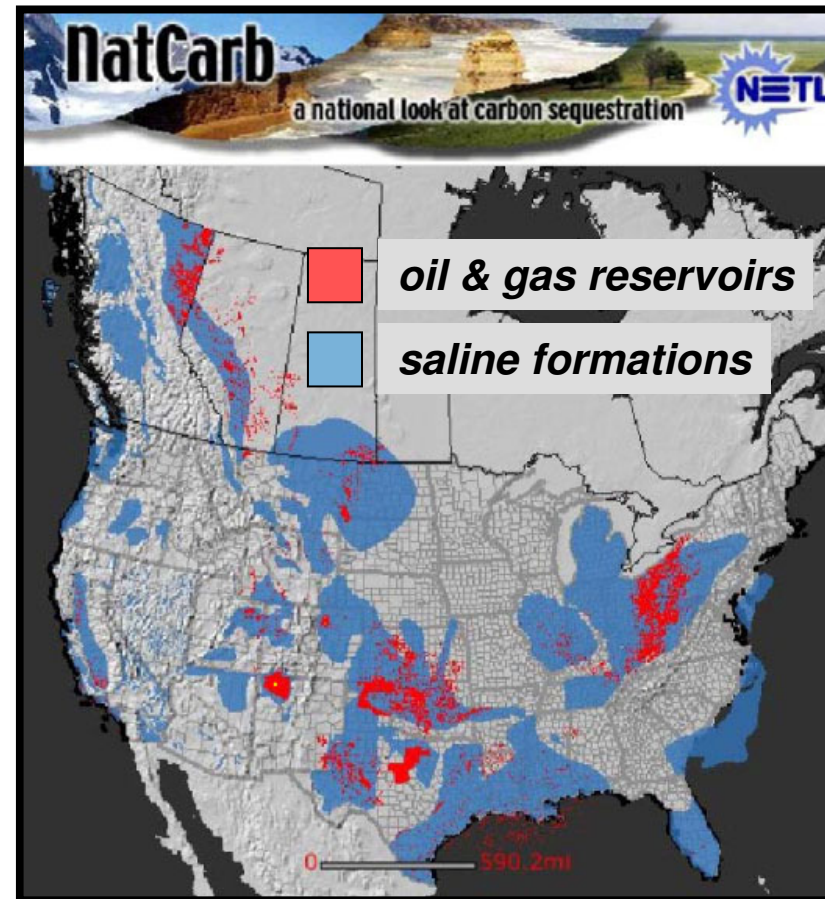
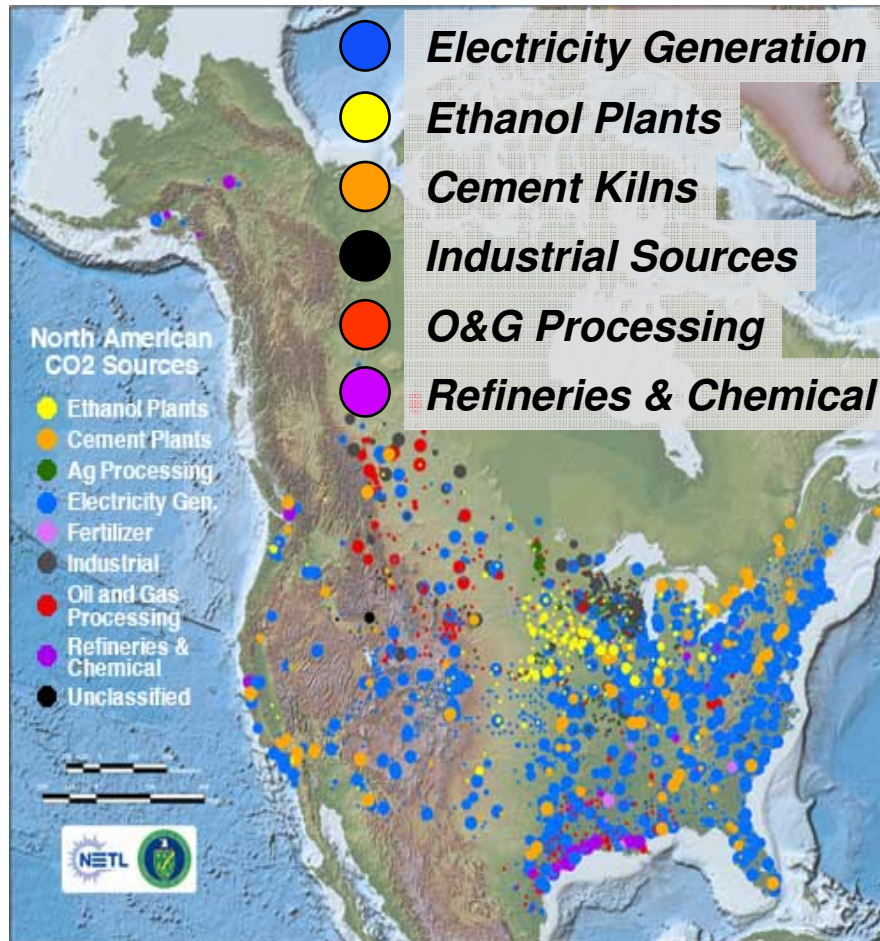
- Health, safety, and environmental risks
- Uncertain regulatory framework
- Site selection

## Pathways

- Field experiments / demos
- Protocols for identifying amenable storage sites
- Capacity evaluation studies
- Underlying science



# CO<sub>2</sub> Sources and sinks vary regionally within the US.



maps from NATCARB database ([www.natcarb.org](http://www.natcarb.org))



# Regional Carbon Sequestration Partnerships

*“Developing the Infrastructure for Wide Scale Deployment”*

## Characterization Phase

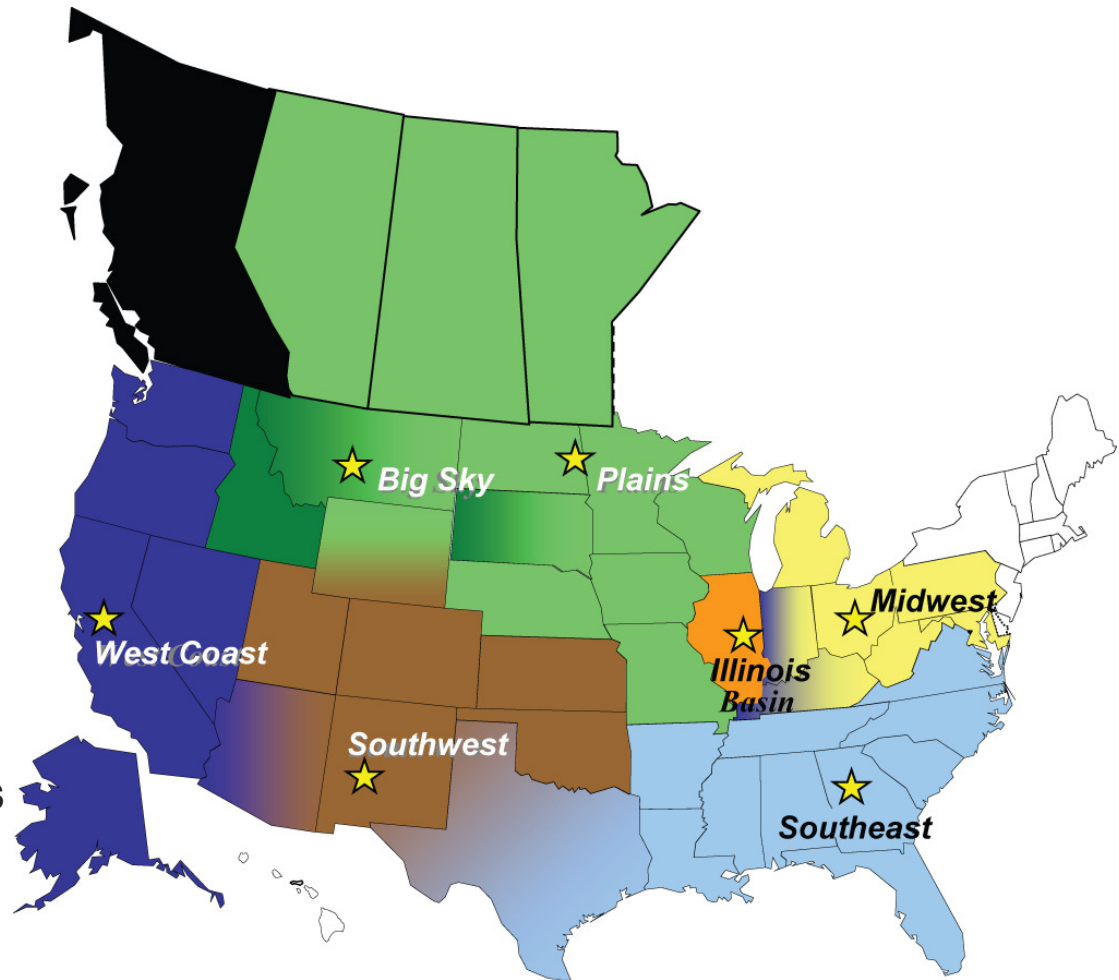
- 24 months (2003-2005)
- \$16M DOE funds

## Validation Phase

- 4 years (2005 - 2009)
- 7 Partnerships (41 states)
- 25 Geologic field validation tests
- \$100M DOE funds

## Deployment Phase

- 10 years (2007-2016)
- Several large injection tests
- \$83 DOE funds per project



# Characterization Phase Accomplishments

**Characterized opportunities for capture and storage of carbon dioxide in North America**

**Developed National Carbon Sequestration Atlas and Geographic Information System (NATCARB)**

**Completed regulatory analysis and published recommendations for states – IOGCC Report 2005**

## **Public outreach**

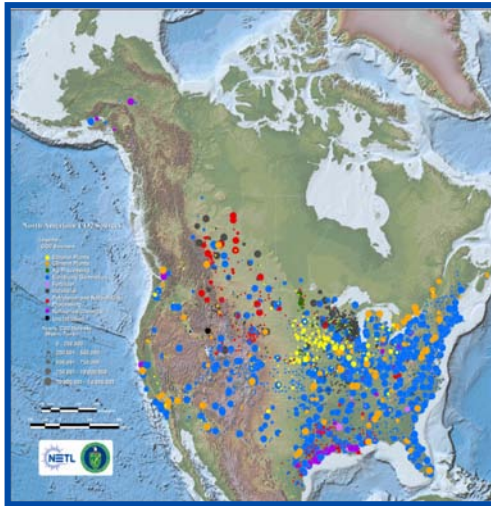
- Documentary of Carbon Sequestration
- Focus groups used to gauge public opinion
- Outreach materials - websites and fact sheets

**Developed regional action plans for regulatory permitting, MMV, outreach, and project implementation**

**Identified promising opportunities for validation phase**

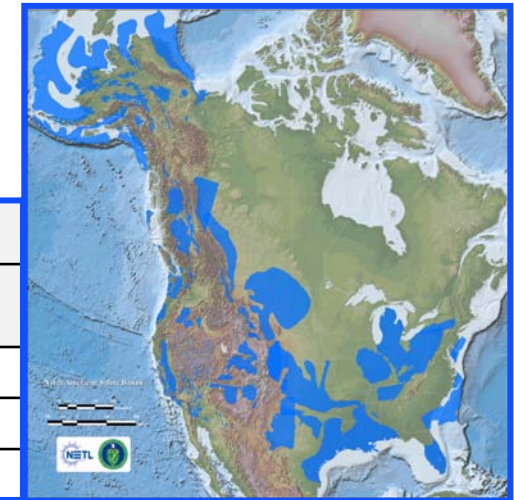


# NATCARB's Carbon Sequestration Atlas (North American Capacity Assessment)



| CO2 Sources |                               |                      |
|-------------|-------------------------------|----------------------|
|             | CO <sub>2</sub> Emission (GT) | Number of Facilities |
| CO2 Sources | 3.8                           | 4365                 |

| CO2 Sinks             |          |           |
|-----------------------|----------|-----------|
| Sink Type             | Low (GT) | High (GT) |
| Saline                | 698      | 2,138     |
| Unmineable Coal Seams | 70       | 97        |
| Oil and Gas Fields    | 82       | 83        |



- Summarize national and regional sequestration opportunities
- North American Geologic Sinks
  - Uses common methodology for saline formations, coal seams, oil/gas fields, other
- Summarize sources of CO<sub>2</sub>
- To be issued in early 2007



# CCS Regulatory Analysis

## *Interstate Oil and Gas Compact Commission*

### Capture

- Existing permitting structure under federal/state versions of CAA
- Measurement and accounting standards required

### Transportation

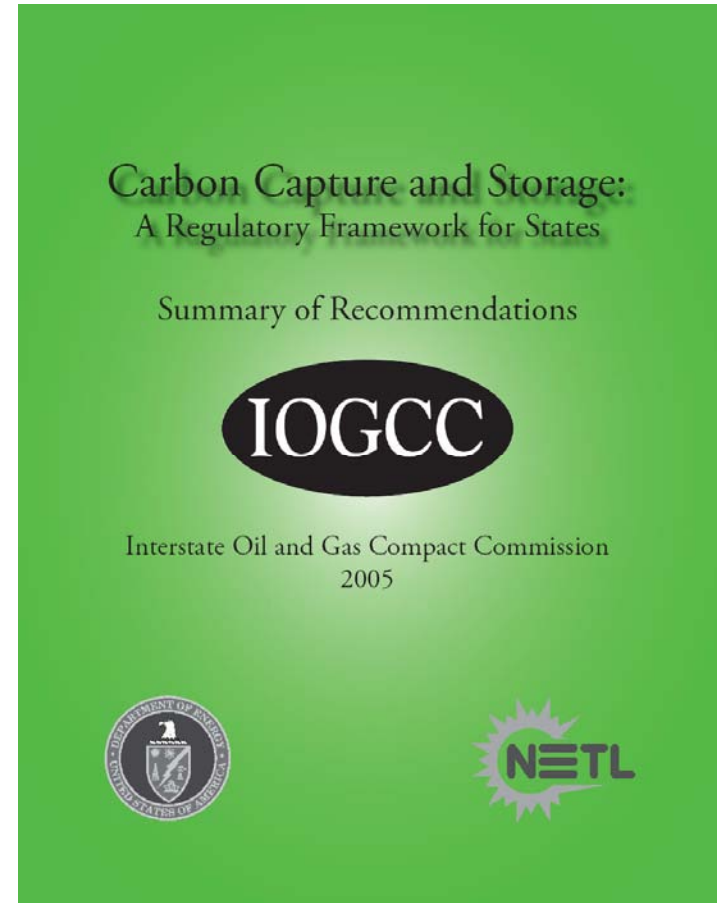
- Existing regulation exist throughout North America for transport of CO<sub>2</sub>
- Industry and professional organizations have developed standards for CO<sub>2</sub> pipeline construction

### Injection

- Class II permitting framework exist under the EPA and States' Underground Injection Control (UIC) programs for oil and gas
- Class V has been used to permit several small tests
- Existing permitting structure needs to be amended to address risk, MMV, reservoir interactions, related to CO<sub>2</sub>

### Post Injection

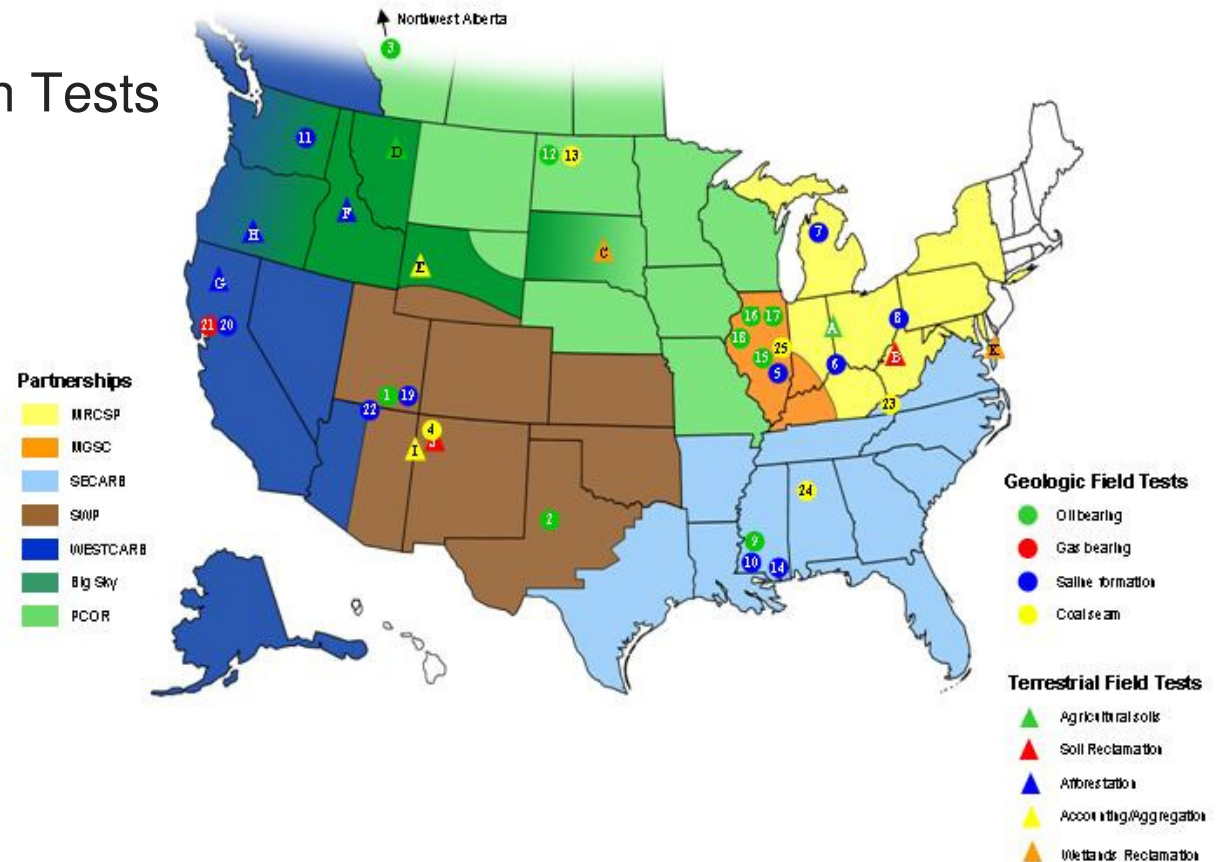
- Framework needed to address the site abandonment, long-term liability, and monitoring requirements.
- Can be developed from the existing UIC program



# Validation Phase Field Tests

## Validating Storage Options Throughout the U.S.

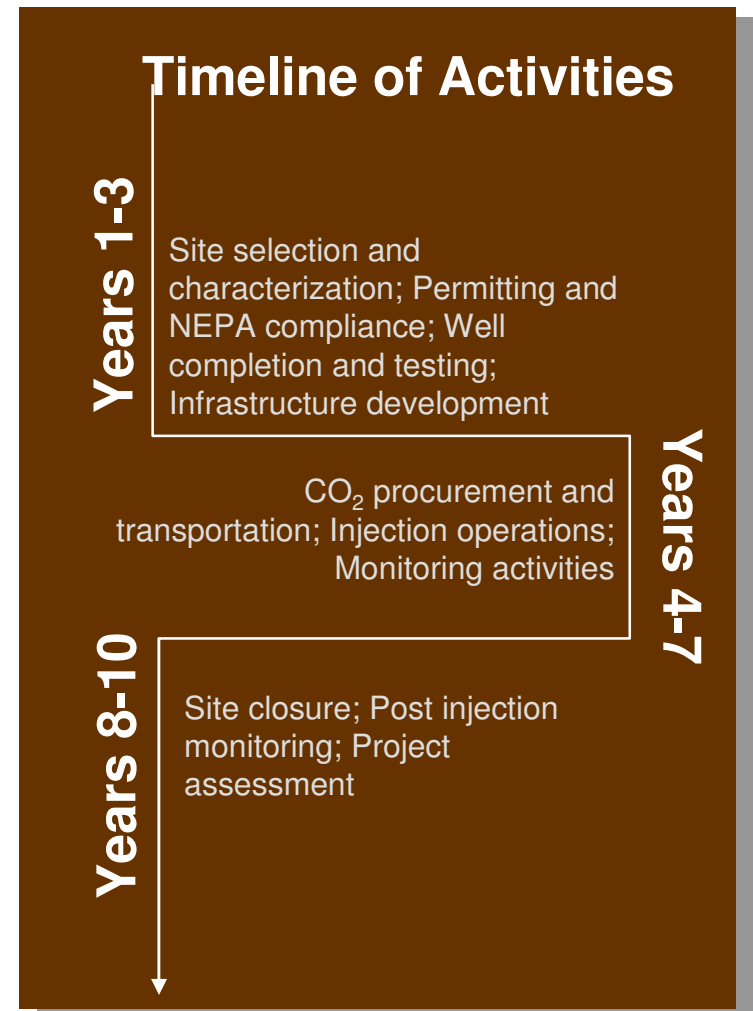
- **25 Geologic Sequestration Injection Tests**
  - 10 Saline Formation Tests
  - 9 EOR Tests
  - 5 ECBM Tests
  - 1 EGR Test
- **11 Terrestrial Sequestration Tests**
  - Croplands
  - Rangelands
  - Wetlands
  - Forestlands



# 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**





# Carbon Sequestration Program Web Resources

The screenshot shows a Microsoft Internet Explorer browser window displaying the NETL Carbon Sequestration website. The browser's address bar shows the URL: [http://www.netl.doe.gov/technologies/carbon\\_seq/index.html](http://www.netl.doe.gov/technologies/carbon_seq/index.html). The website header features the NETL logo and the text "National Energy Technology Laboratory" and "THE ONLY U.S. NATIONAL LABORATORY DEVOTED TO FOSSIL ENERGY TECHNOLOGY". A navigation menu on the left includes sections for "ABOUT NETL", "KEY ISSUES & MANDATES", "ONSITE RESEARCH", "TECHNOLOGIES", "ENERGY ANALYSES", "SOLICITATIONS & BUSINESS", and "CAREERS & FELLOWSHIPS". The "TECHNOLOGIES" section is expanded to show "Carbon Sequestration" with sub-links for "CO<sub>2</sub> Capture", "CO<sub>2</sub> Storage", "Monitoring, Mitigation, Verification", and "Non-CO<sub>2</sub> Greenhouse Gases". The main content area is titled "Technologies Carbon Sequestration" and contains text about NETL's portfolio of laboratory and field R&D, a photograph of a forest, and information about the programmatic timeline. A right-hand sidebar contains sections for "NEWS & FEATURES", "EVENTS CALENDAR", and "PUBLICATIONS & PROJECTS".

[http://www.netl.doe.gov/technologies/carbon\\_seq/index.html](http://www.netl.doe.gov/technologies/carbon_seq/index.html)

