

# A View of DOE's Carbon Sequestration R&D Program



*“Pathways to Sustainable  
Use of Fossil Energy”*

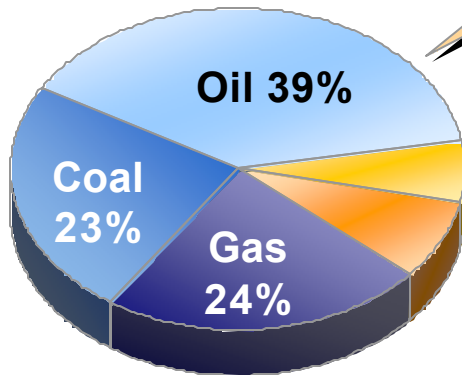


# Fossil Energy - America's Energy Foundation

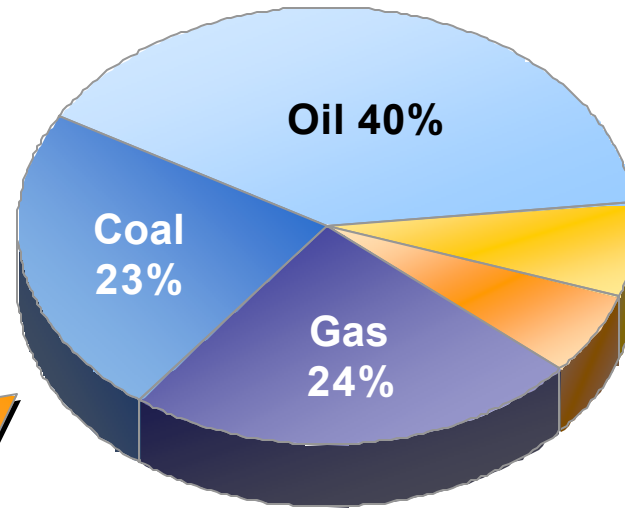
**2002**

*98 Quads*

**Fossil fuels provide  
86% of energy**



+40%



**2025**

*136 Quads*

**By 2020, reliance on  
fossil fuels remains  
stable at 87%**

# 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?

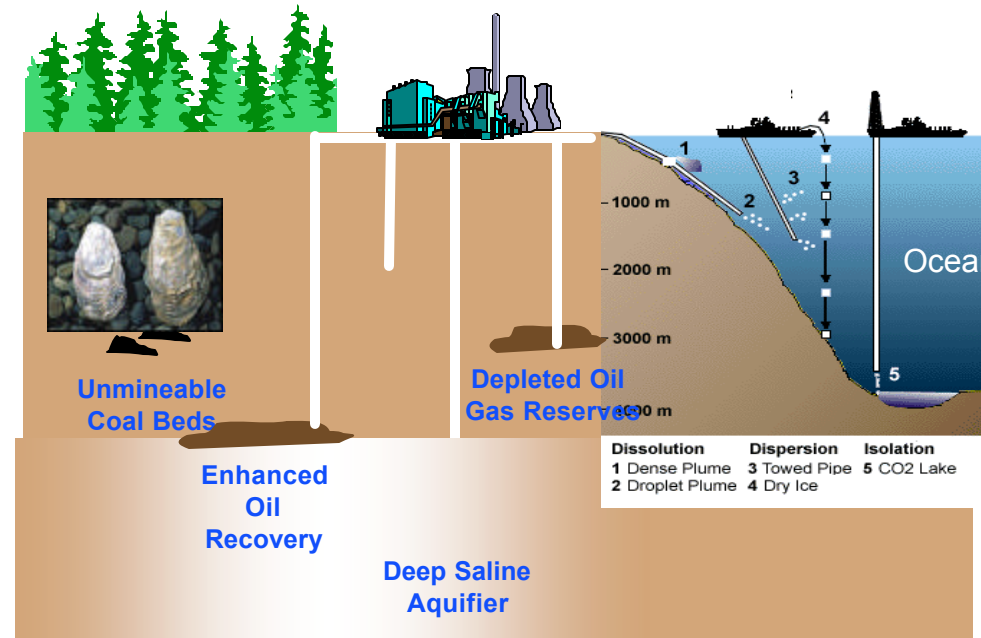
*Capture and storage of CO<sub>2</sub> and other Greenhouse Gases that would otherwise be emitted to the atmosphere*

## Capture can occur:

- at the point of emission
- when absorbed from air

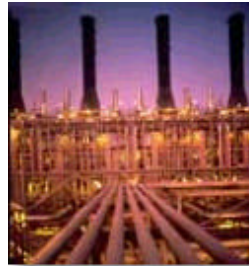
## Storage locations include:

- underground reservoirs
- dissolved in deep oceans
- converted to solid materials
- trees, grasses, soils, or algae



# Sequestration Options

## *Direct Sequestration*



**Capture and storage**

**Oil & Gas Reservoirs**

**Unmineable Coal Seams**

**Saline Formations**

**Oceans**

**Stable Solids**

**Useful Products**

**Fuels**

## *Indirect Sequestration*



**Remove CO<sub>2</sub> from atmosphere**

**Forestation**

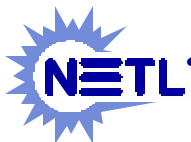
**Mineralization**

**Agricultural Practices**

**Ocean Fertilization**

*Advanced Concepts*

*Convert CO<sub>2</sub>*



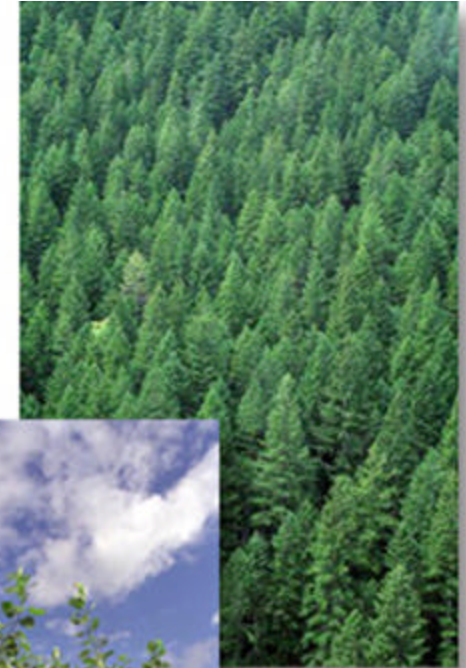
# Major Sequestration Issues...

- Health, safety, and environmental risks
- Permanence and large-scale verification
- Capacity evaluation
- Infrastructure
- Uncertain regulatory frameworks
- Protocols for identifying amenable storage sites
  - Direct CO<sub>2</sub> storage
  - Enhanced natural sinks

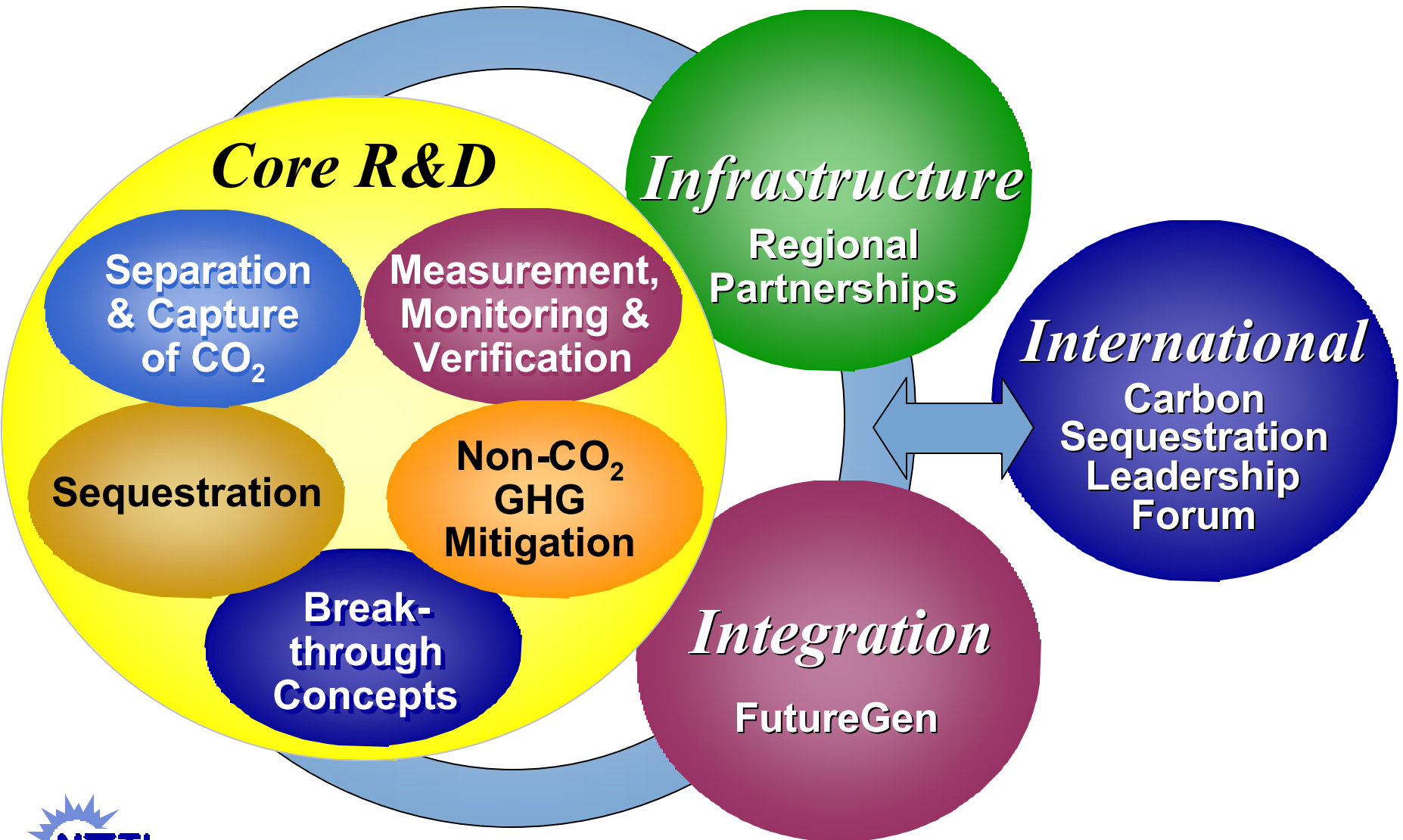


# Requirements for Sequestration

- **Environmentally acceptable**
  - No legacy for future generations
  - Respect existing ecosystems
- **Safe**
  - No sudden large-scale CO<sub>2</sub> discharges
- **Verifiable**
  - Ability to verify amount of CO<sub>2</sub> sequestered
- **Economically viable**



# Sequestration Program Organization

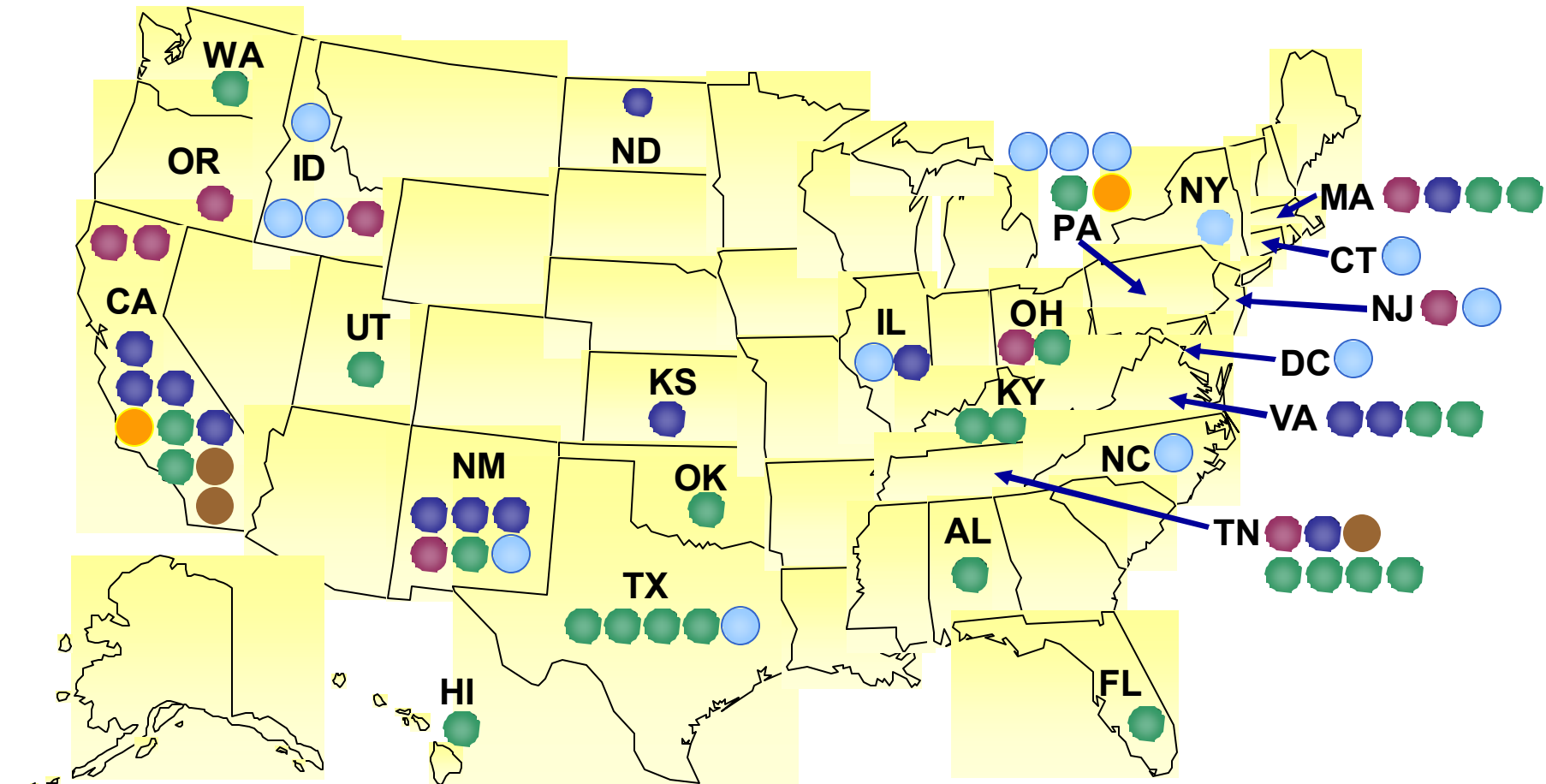




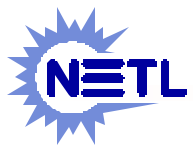
# Major Technology R&D Pathways

<i>Capture</i>	<ul style="list-style-type: none"><li>• Post-combustion Capture</li><li>• Oxygen combustion</li><li>• Pre-combustion capture</li><li>• Chemical looping</li></ul>
<i>Sequestration</i>	<ul style="list-style-type: none"><li>• Depleting oil reservoirs</li><li>• Unmineable coal seams</li><li>• Saline formations</li><li>• Enhanced terrestrial uptake</li><li>• Ocean (injection, fertilization)</li></ul>
<i>MM&amp;V</i>	<ul style="list-style-type: none"><li>• Advanced soil carbon measurement</li><li>• Subsurface measurements</li><li>• Remote sensing/above-ground MMV</li><li>• Fate and transport models</li></ul>
<i>Breakthrough Concepts</i>	<ul style="list-style-type: none"><li>• Advanced Capture</li><li>• Bio-accelerated sequestration</li><li>• Niches</li></ul>

# Sequestration Projects Span Nation



- Capture
- MMV
- Sequestration
- Breakthrough Concepts
- Non-CO<sub>2</sub> GHGs
- Sequestration / MMV



# Separation & Capture of CO<sub>2</sub>

## Issue

- Demonstrated technology is costly

## Pathways

- Pre-combustion capture
- Post-combustion capture
- Oxygen-fired combustion
  - Chemical looping
- Optimized engineering



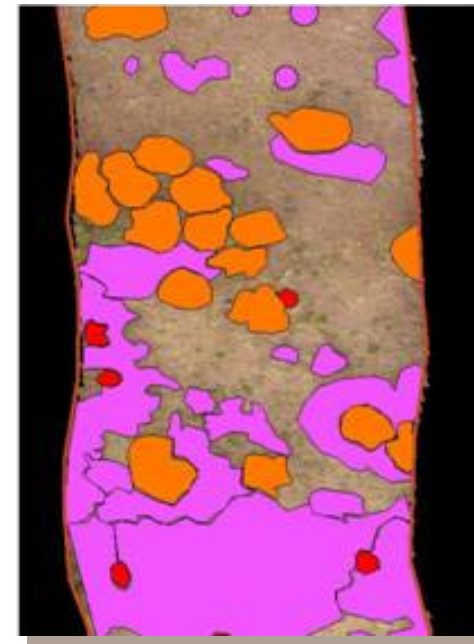
# Measurement, Monitoring & Verification

## Issue

- Proving CO<sub>2</sub> fate

## Pathways

- Surface and subsurface CO<sub>2</sub> leak detection and mitigation tools
- Atmospheric detection systems
- CO<sub>2</sub> fate and transport studies
- Protocols for accounting and permanence



*Digital Aerial Imagery  
to Estimate Carbon  
Stocks in Above-Ground  
Vegetation*

# Sequestration

## Issues:

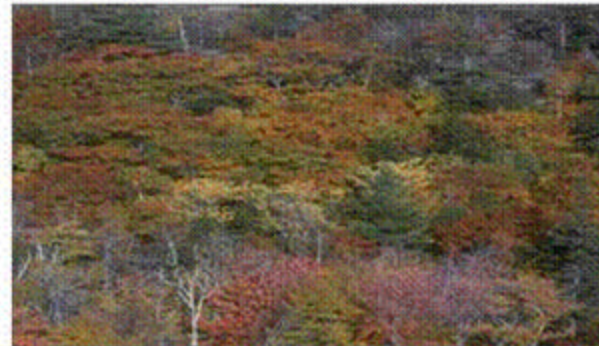
- Health, safety, and environmental risks
- Uncertain regulatory framework
- Site selection

## Pathways:

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



# Diverse U.S. Industrial Conditions and Geologic Environments Require a Regional (Re)Orientation for Sequestration Technology Deployment



# Regional Carbon Sequestration Partnerships

## *Developing Infrastructure for Wide-Scale Deployment*

- **Baseline region for sources and sinks**
- **Address regulatory, environmental, outreach issues**
- **Establish monitoring and verification protocols**
- **Validating sequestration technology & infrastructure**
  - Phase 1 – Planning
  - Phase 2 – Proof of Concepts
- **Determine benefits of sequestration to region**

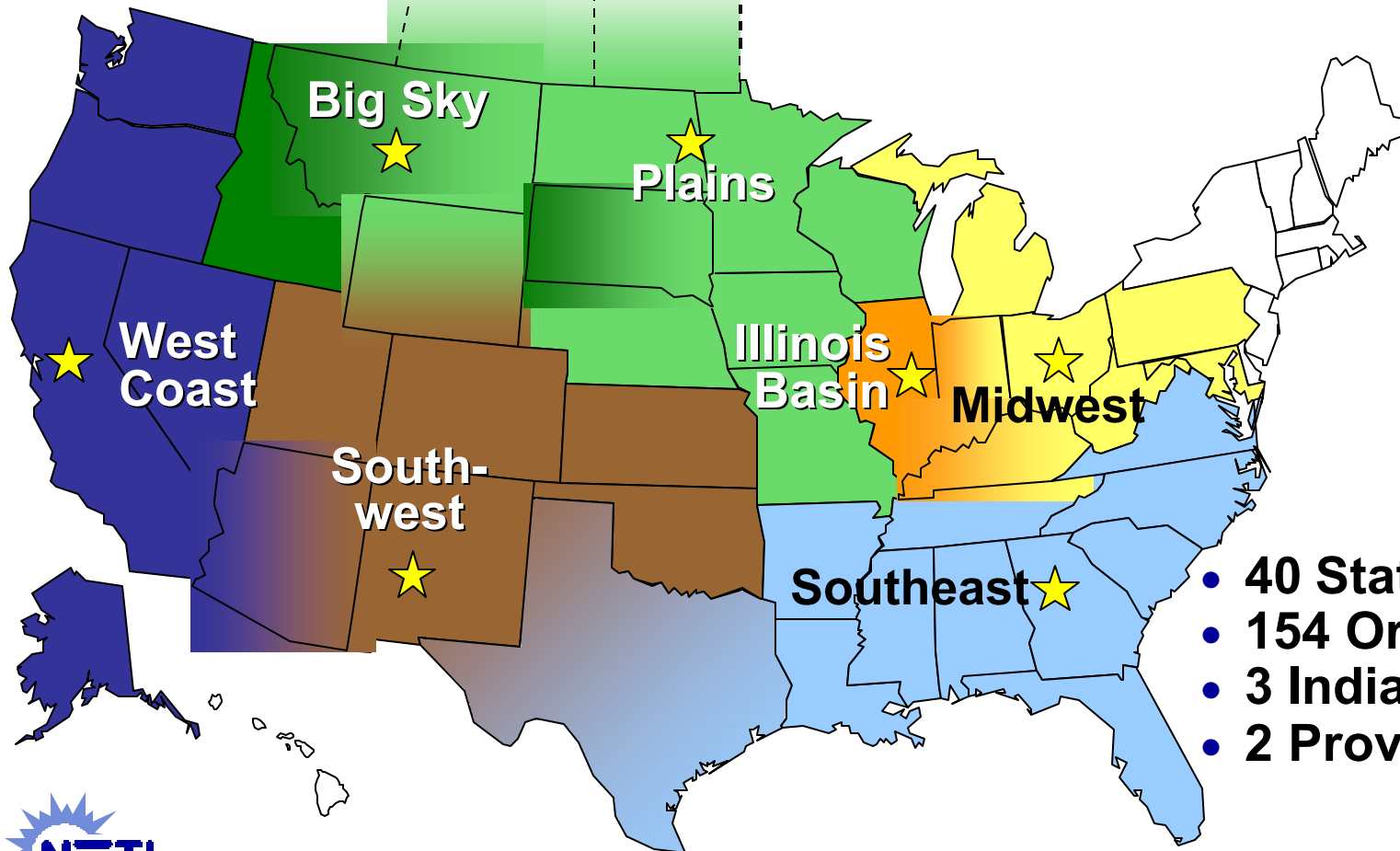
These partnerships - 4 to 10 across the country, each made up of private industry, universities, and state and local governments - will become the centerpiece of our sequestration program. They will help us determine the technologies, regulations, and infrastructure that are best suited for specific regions of the country.

Energy Secretary Spencer Abraham  
November 21, 2002



# Seven Regional Partnerships

*Network of Partnerships to Determine Technologies, Regulations, Infrastructure Needs for Each Region*



- 40 States
- 154 Organizations
- 3 Indian Nations
- 2 Provinces



# Partnership Program has a Two-Phased Approach...

## Current Phase I (Planning)

- 7 Projects
- 18-24 months
- ~\$1.5 million per project
- Overall ~ 40% cost share
- 2 exceed 50% cost share



## Proposed Phase II (Proof-of-Concepts)

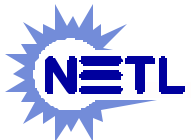
- about 8 years duration
- up to about \$4 million/year-project
- 20% cost share (minimum)



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# Regional Partnerships Phase I Outcomes...

- **Regional Carbon Sequestration Atlases: Sources, transportation, and sinks**
- **Regional Project Implementation Plans: Identify the most promising technologies/ approaches to sequester carbon directly or indirectly and/or capture carbon in the region**
- **Action Plan for Regulatory Compliance**
- **Action Plan for Public Outreach and Education**
- **Implementation Plan for a proposed Phase II**



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## Proposed Phase II Approach...

- **Not a technology development program.**
- **Perform proof-of-concept field tests for technology & infrastructure concepts**
- **Continue characterization efforts for source and sinks; determine appropriate capture methods**
- **Establish wide-scale deployment opportunities**
- **Establish and implement Measurement, Monitoring & Verification protocols**
- **Establish and implement accounting & regulatory approaches**
- **Implement outreach mechanisms**



# Visit the NETL Sequestration Website...

[www.netl.doe.gov/coal/Carbon%20Sequestration/](http://www.netl.doe.gov/coal/Carbon%20Sequestration/)

**NATIONAL ENERGY TECHNOLOGY LABORATORY**  
**CARBON SEQUESTRATION WEBSITE**

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January 13, 2003

## Carbon Sequestration

*Pathways to Sustainable Use of Fossil Fuels--  
enabling the removal and permanent storage  
of carbon dioxide from fossil-energy systems*

Welcome to NETL's **Carbon Sequestration Product** webpage. We seek to define carbon sequestration's role in stabilizing atmospheric carbon dioxide levels by developing a scientific understanding and environmentally acceptable technologies. Our research areas include capture & storage, geologic, ocean, and terrestrial sequestration, advanced CO<sub>2</sub> conversion & reuse, and modeling & analysis.

Our site is designed to answer your questions about carbon sequestration—

- Regional Partnerships
- Capture & Storage
- Geologic Sequestration
- Ocean Sequestration
- Terrestrial Sequestration
- Adv. CO<sub>2</sub> Conversion & Reuse
- Modeling & Analysis

**What's New**  
Events  
Overview  
Capture  
Geologic  
Ocean  
Terrestrial  
Conversion  
Modeling  
In-House R&D  
Ref. Shelf  
Kids Only!  
Links  
Contacts  
GHG Facts

