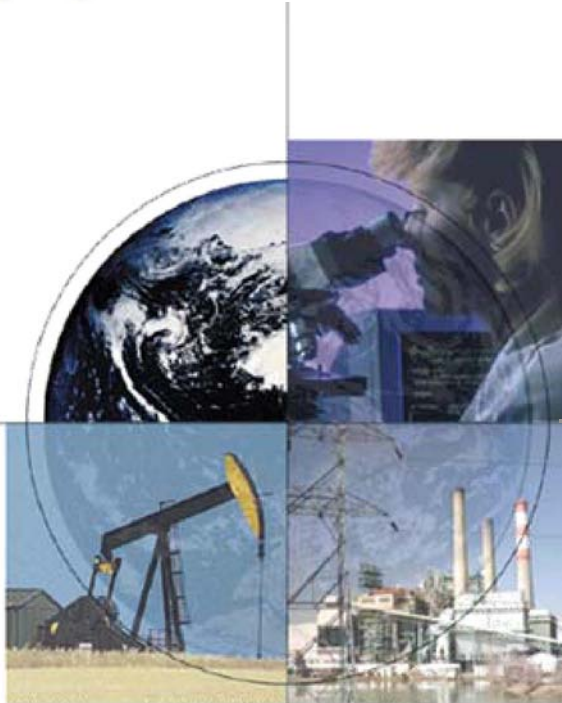




Carbon Sequestration R&D Overview



Justin “Judd” Swift
Assistant Secretary for International Affairs
Office of Fossil Energy
U.S. Department of Energy

**Workshop on Capture and Sequestration
of CO₂ (CCS)**
July 9 – 10, 2008
Mexico City, Mexico



Technological Carbon Management Options

Reduce Carbon Intensity

- Renewables
- Nuclear
- Fuel Switching

Improve Efficiency

- Demand Side
- Supply Side

Sequester Carbon

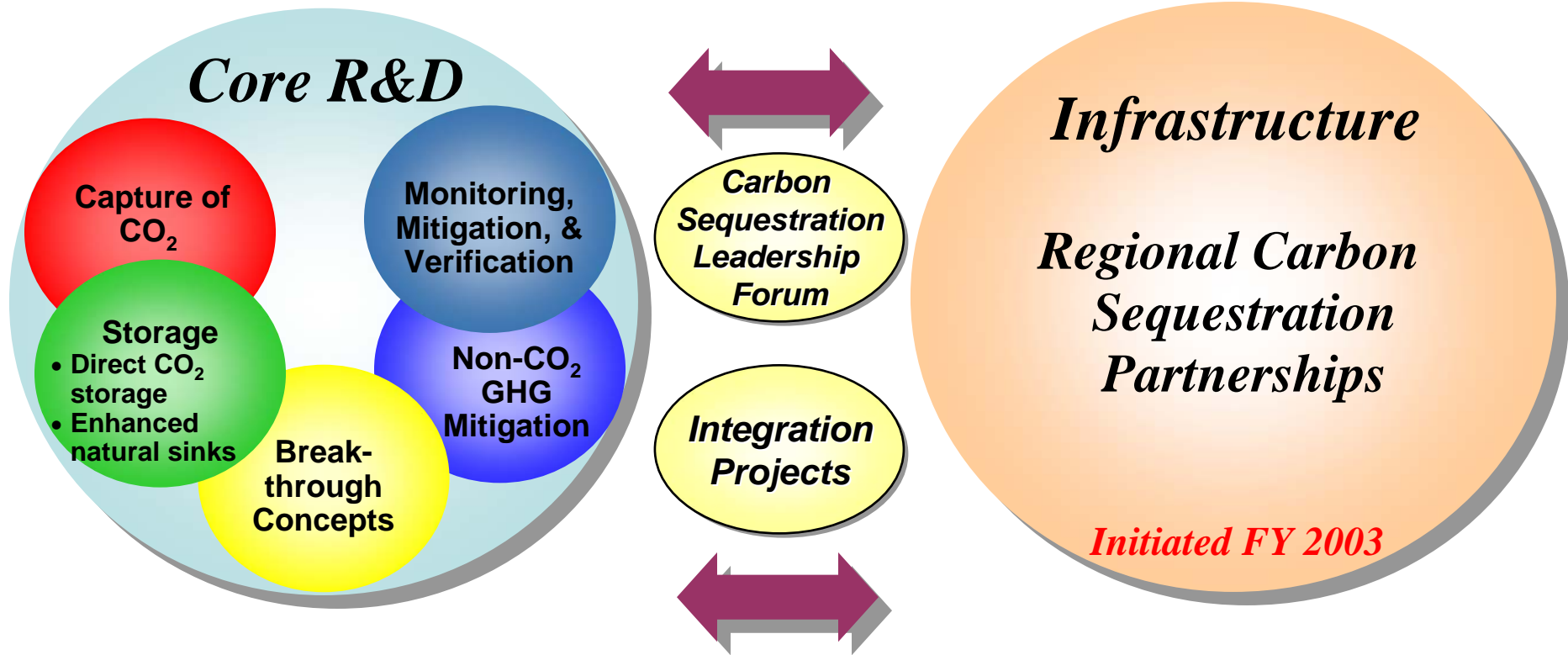
- Capture & Store
- Enhance Natural Sinks

All options needed to:

- Affordably meet energy demand
- Address environmental objectives



DOE's Sequestration Program Structure



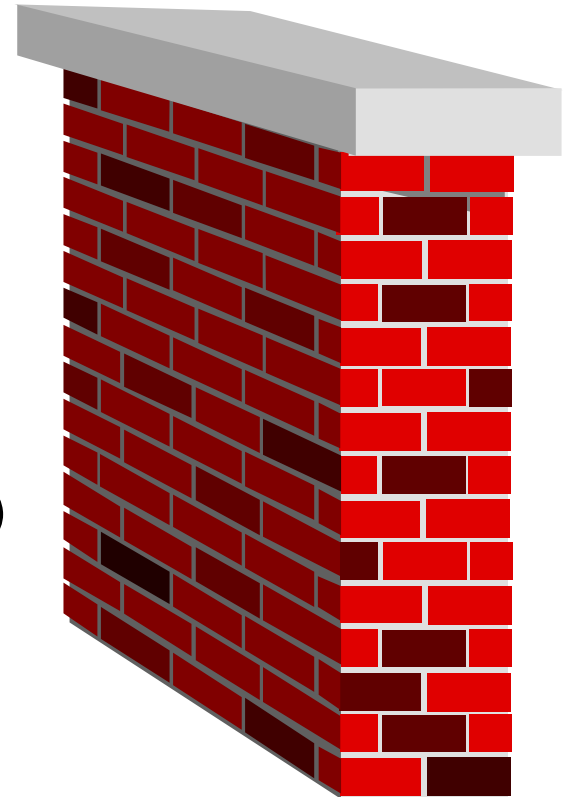
Carbon Sequestration Program Goals

- **Deliver technologies & best practices that validate:**
 - 90% CO₂ capture
 - 99% storage permanence
 - <10% increase in COE (pre-combustion capture)
 - <20% increase in COE (post- and oxy-combustion)
 - +/- 30% storage capacity



Key Challenges to CCS

- **Sufficient Storage Capacity ?**
- **Cost of CCS ?**
- **Permanence ?**
- **Infrastructure ?**
 - Transport Lines
 - Permitting
 - Regulatory framework
 - Public Acceptance (NIMBY → NUMBY)
 - Liability
 - Best Practices
 - Human Capital Resources



Sufficient Storage Capacity ?

- **Validate Storage Capacity to +/- 30% Accuracy**

U.S. Annual CO₂ Emissions Extremely Large

Emissions	U.S. Total Release (short tons/year)
Mercury	120
Sulfur Dioxide (SO ₂)	15,000
Municipal Solid Waste	230,000,000
Carbon Dioxide (CO ₂)	6,300,000,000

1 million metric tons of CO₂:

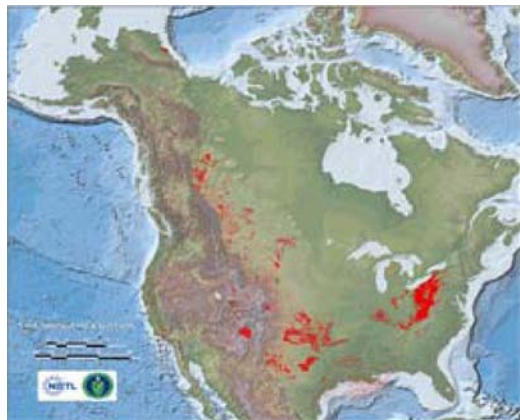
- 32 million cubic feet every year
- *Close to the volume of Empire State Building*

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)

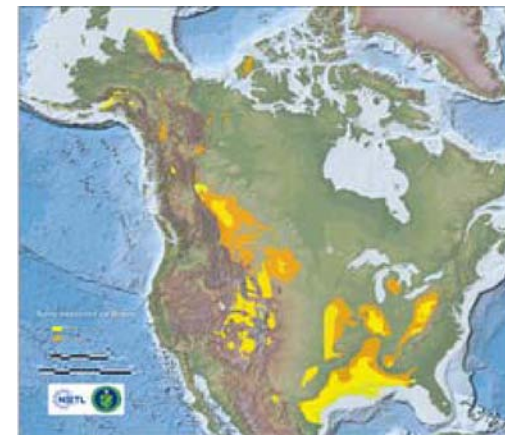
National Atlas Highlights

Adequate Storage Projected

U.S. Emissions ~ 6 GT CO₂/yr all sources



Saline Formations



Oil and Gas Fields

North American CO₂ Storage Potential
(Giga Tons)

Unmineable Coal Seams

**Conservative
Resource
Assessment**

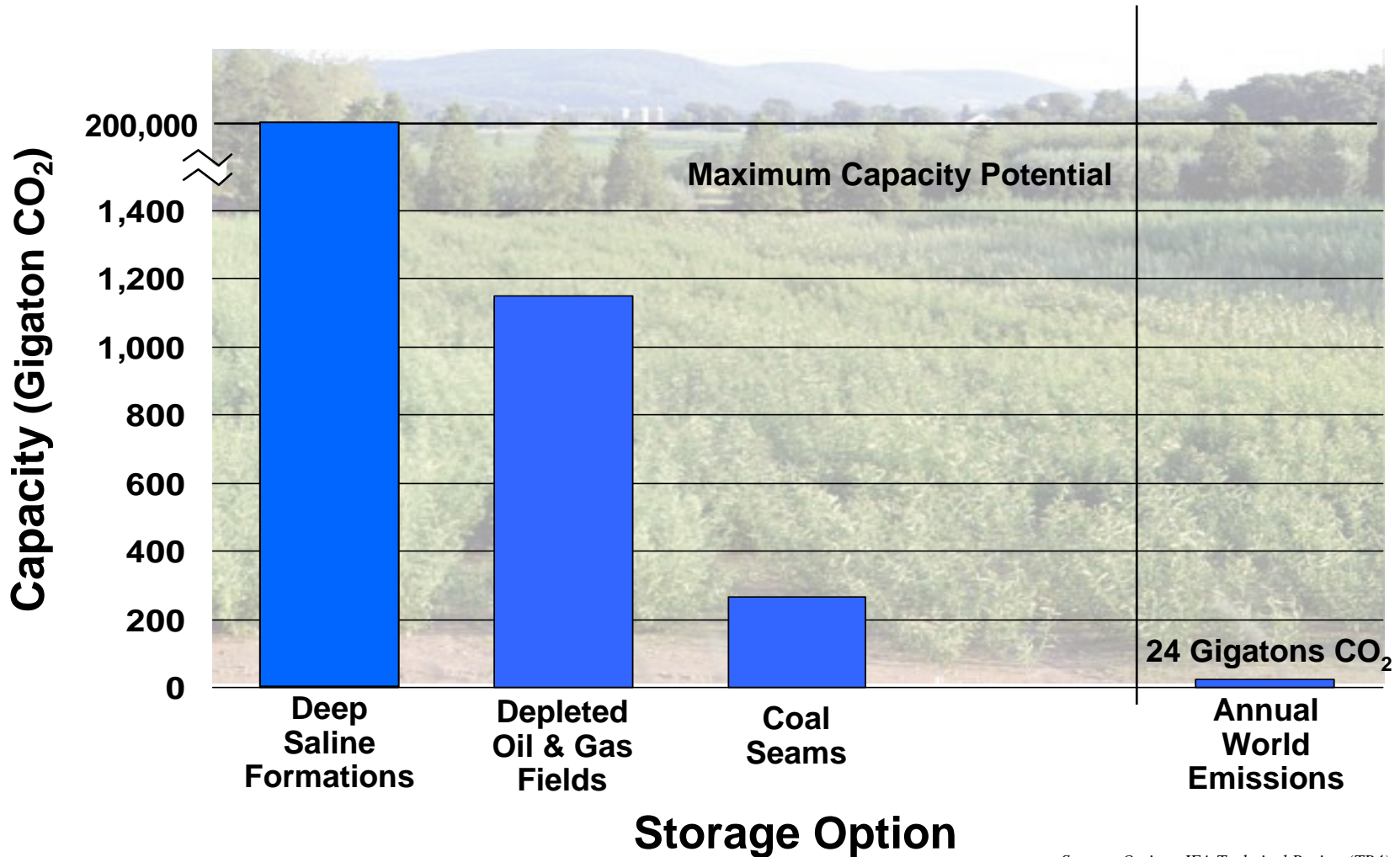
Sink Type	Low	High
Saline Formations	969	3,223
Unmineable Coal Seams	70	97
Oil and Gas Fields	82	83

**Hundreds of
Years of
Storage
Potential**

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

Worldwide Geologic Storage Capacity

Thousands of Years of Potential Storage Capacity



Storage Options: IEA Technical Review (TR4), March 23, 2004
World Emissions: DOE/EIA, International Energy Outlook 2003, Table A10

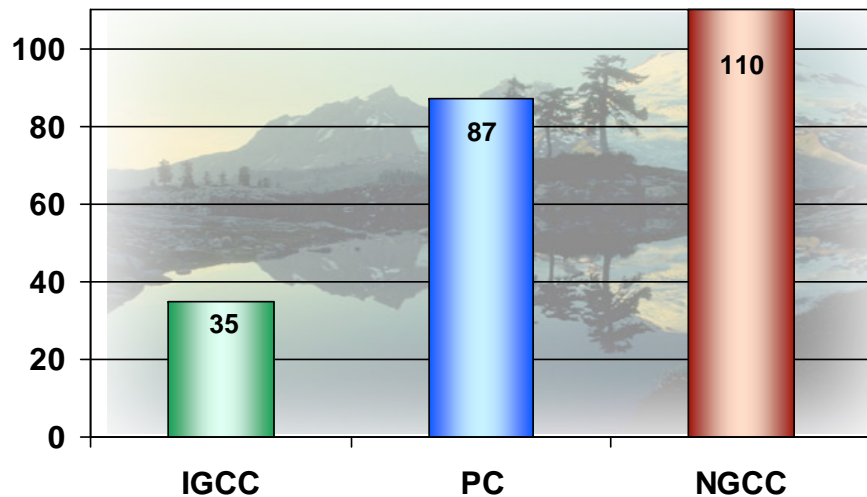
Cost of CCS ?

- **<10% increase in COE (pre-combustion capture)**
- **<20% increase in COE (post- and oxy-combustion)**

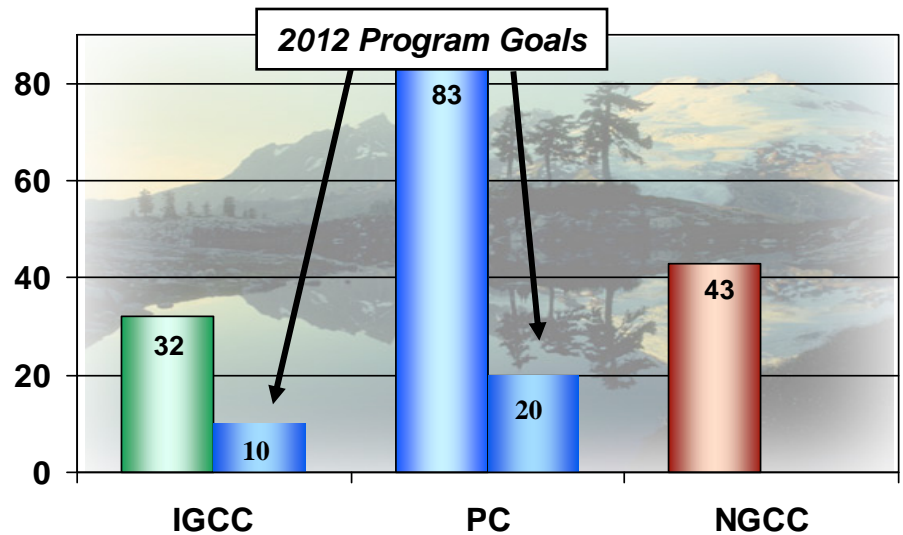
CCS is Expensive !

- 5–30% parasitic energy loss
- 35–110% increase in capital cost
- 30–80% increase in cost of electricity

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

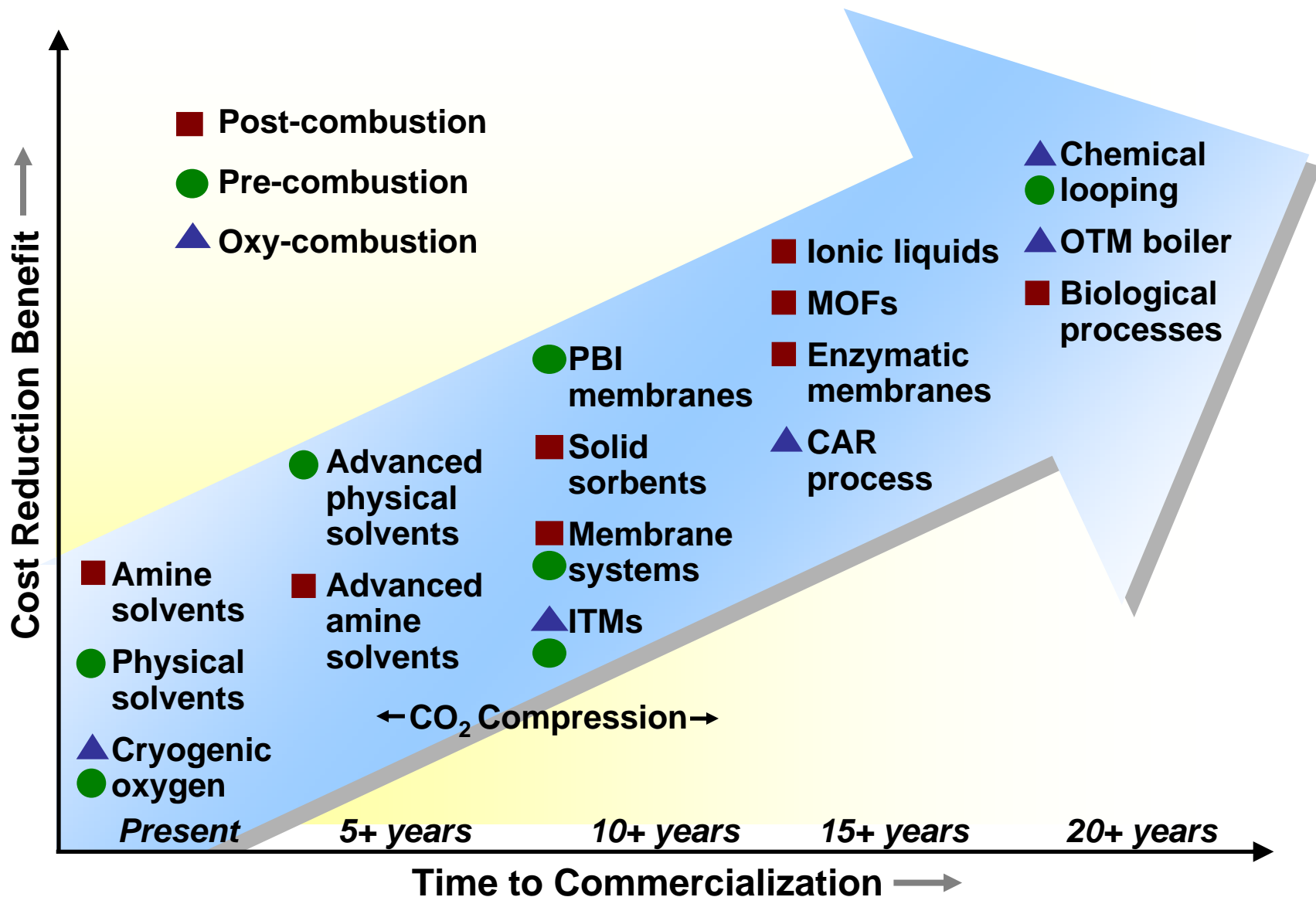


Effect of CO₂ Capture on Cost of Electricity
(% Increase Resulting From CO₂ Capture)



Source: Cost and Performance Baseline for Fossil Energy Power Plants Study, Volume 1: Bituminous Coal and Natural Gas to Electricity

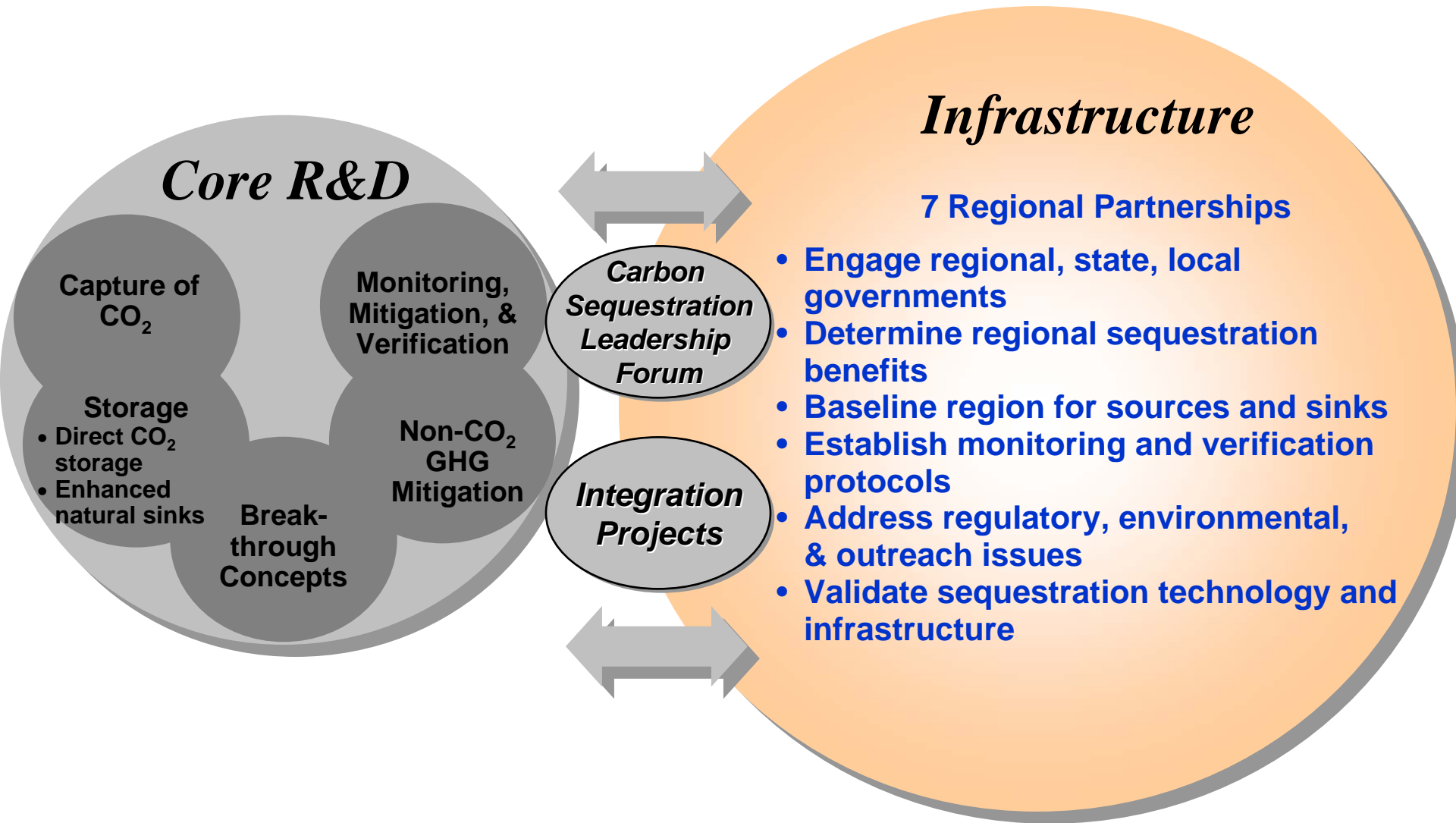
Technology Advances are Starting to Emerge



Permanence ?

- **Develop tools, protocols & best practices**
- **Verify 99% storage retention**

DOE's Sequestration Program Structure



Regional Carbon Sequestration Partnerships

Creating Infrastructure for Wide-Scale Deployment

Characterization Phase

- 24 months (2003-2005)

Validation Phase

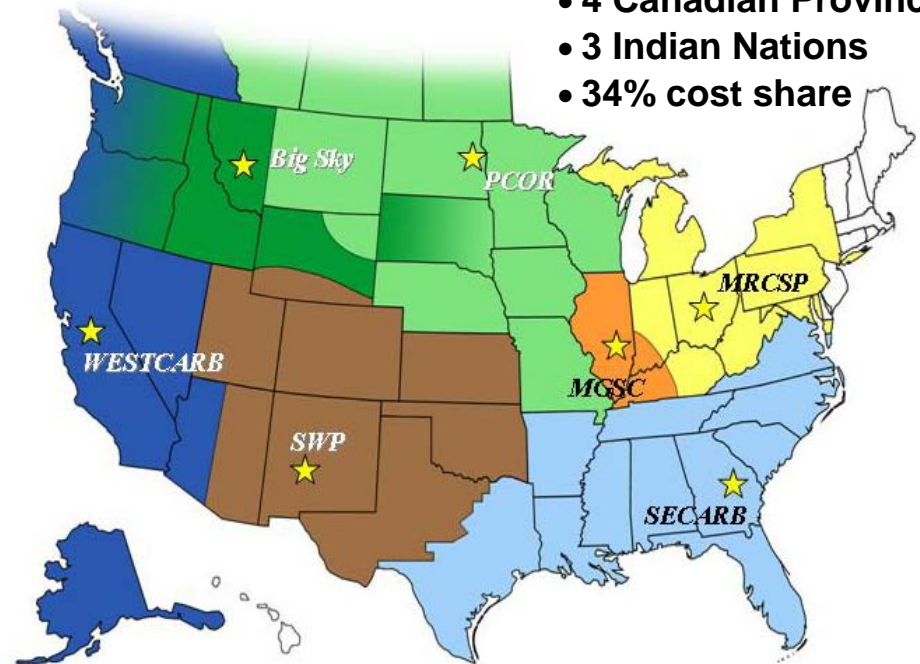
- 4 years (2005 - 2009)
- 7 Partnerships (41 states)
- 25 Geologic field validation tests

Deployment Phase

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

Representing:

- >350 Organizations
- 41 States
- 4 Canadian Provinces
- 3 Indian Nations
- 34% cost share



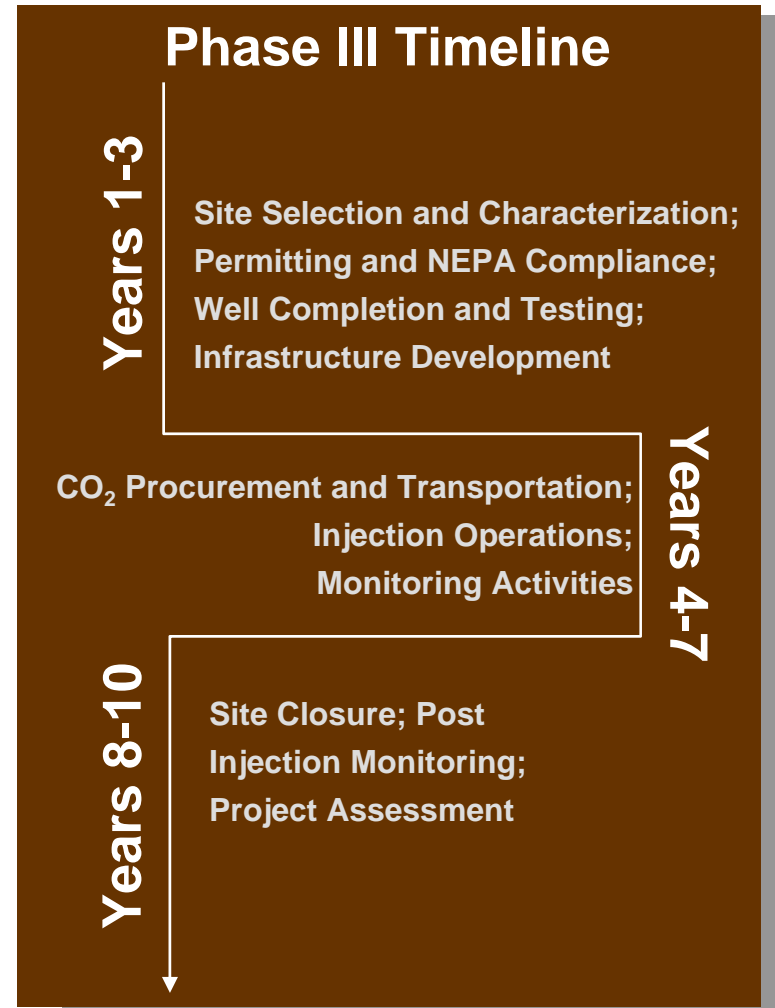
Summary of Regional Carbon Sequestration Partnerships Phase II Field Activities – estimate as of Q2 2007		FY 2006				FY 2007				FY 2008				FY 2009			
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
Partnership	Geologic Field Test																
Big Sky	Basalt and Mafic Rock Field Validation Test		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
MRCSP	Appalachian Basin Geologic Test		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Cincinnati Arch Geologic Test		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Michigan Basin Geologic Test		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
MGSC	Saline Formation Tests	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Enhanced Oil Recovery Tests (Huff 'n Puff)		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Enhanced Oil Recovery Well Conversion		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Enhanced Coalbed Methane Tests	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
PCOR	Lignite in North Dakota Field Validation Test		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Zama Field Validation Test	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Beaver Lodge EOR Field Test	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SECARB	Gulf Coast Stacked Storage Project	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Black Warrior Basin Coal Test	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Central Appalachian Basin Coal Test	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Saline Reservoir Field Test: The Mississippi Test Site	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SWPCS	Paradox Basin, UT: Aneth EOR-Seq and Deep Saline Tests	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Permian Basin, TXe SACROC-Claytonville EOR-Seq Test	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	San Juan Basin, NM: ECBM-Sequestration Test		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WESTCARB	Rosetta Resources Gas Reservoir and Saline Formation		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Northern Arizona Saline Formation CO2 Storage Pilot		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

■ - Baseline
■ - Drilling
■ - Injection
■ - MMV

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**



Large-Scale Test Locations

as of 2/8/2008



PCOR
Fort Nelson
CO₂ Acid Gas
Injection
Project

PCOR
Williston Basin CO₂
Sequestration and
EOR Test

MGSC
Large-Volume
Sequestration Test with
Ethanol Plant Source

SWP
Deep Saline
Deployment
Project

SECARB
Phase III Saline
Formation
Demonstration
1. Early Test
2. Anthropogenic Test

 - Test Location  - Partnership Headquarters

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**
- **Science Protocols**
- **Best practice manuals**



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Fossil Energy

FOSSIL ENERGY NEWS SPOTLIGHT

DOE to Purchase Heating Oil
The U.S. Department of Energy (DOE) today issued a solicitation seeking to purchase heating oil for the Northeast Home Heating Oil Reserve (NEHOR) using \$3 million in appropriated funds. The Northeast Home Heating Oil Reserve provides an important safety cushion for millions of Americans residing in the Northeast region of the country. Due to the modest volume of heating oil expected to be purchased with the available funds, no impact on market prices is expected. [Read more >](#)

MORE COAL, OIL & GAS NEWS

NETL Highlights Annual Research Innovations
The Office of Fossil Energy's National Energy Technology Laboratory, the research arm of DOE's fossil energy program, has released its annual Accomplishments Report showcasing research and technology successes during the past fiscal year. [Read more >](#)

Hawaii Joins Sequestration Partnership Program
The state of Hawaii is the newest member of the Department of Energy Regional Carbon Sequestration Partnership Program -

OFFICE OF FOSSIL ENERGY
Ensuring that we can continue to rely on clean, affordable energy from our traditional fuel resources is the primary mission of DOE's Office of Fossil Energy. Fossil fuels supply 85% of the nation's energy, and we are working on such priority projects as pollution-free coal plants, more productive oil and gas fields, and the continuing readiness of federal emergency oil stockpiles.

Read more about:
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NETL Mercury-Control Program Achieves Success
A comprehensive NETL program to develop technologies to reduce mercury emissions from coal-powered power plants has met its goal, resulting in the commercial sale of advanced mercury-control technologies for both new and retrofit installations. [Read more!](#)

NETL 2007 Accomplishment Report //
NETL has just released its 2007 Accomplishments Report. The report showcases many of the research and technology successes that have occurred during the past fiscal year. [Read More!](#)

Hawaii Joins DOE's Carbon Sequestration Regional Partnership Program
Hawaii is the newest member of the DOE Regional Carbon Sequestration Partnership Program - the centerpiece of national efforts to validate and deploy carbon sequestration technologies.

IA Finds U.S. CO₂ Sequestration Program World's Most Ambitious
The International Energy Agency finds DOE's Regional Carbon Sequestration Partnerships and their large-scale CO₂ tests as world's most ambitious and will significantly advance carbon capture and storage.

SECA Fuel Cell Program Selects Two Projects

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<http://fossil.energy.gov/>

<http://www.netl.doe.gov>

Carbon Sequestration Leadership Forum (CSLF)

- **International climate change initiative**
- **Facilitates development of cost-effective technologies**
- **Promotes technical, political, and regulatory environments to develop such technology**



Charter Signing Ceremony, June 2003, Washington, DC

CSLF Meeting

Cape Town, South Africa

April 13-17, 2008

- **Declaration of support for G8 recommendations for near-term deployment of CCS**
- **Agreement on mechanism leading to updated CSLF strategic plan**
- **Recognition of 20th demonstration project – zero emissions production of electricity and hydrogen from fossil fuels**
- **Initiatives to remove barriers for CCS**
- **Agreement on pathways for capacity building as vehicle for transfer of technologies and knowledge about CCS**
- **Resolution to increase role of stakeholders in implementing policy priorities – as they are ultimately responsible for deploying CCS technologies**

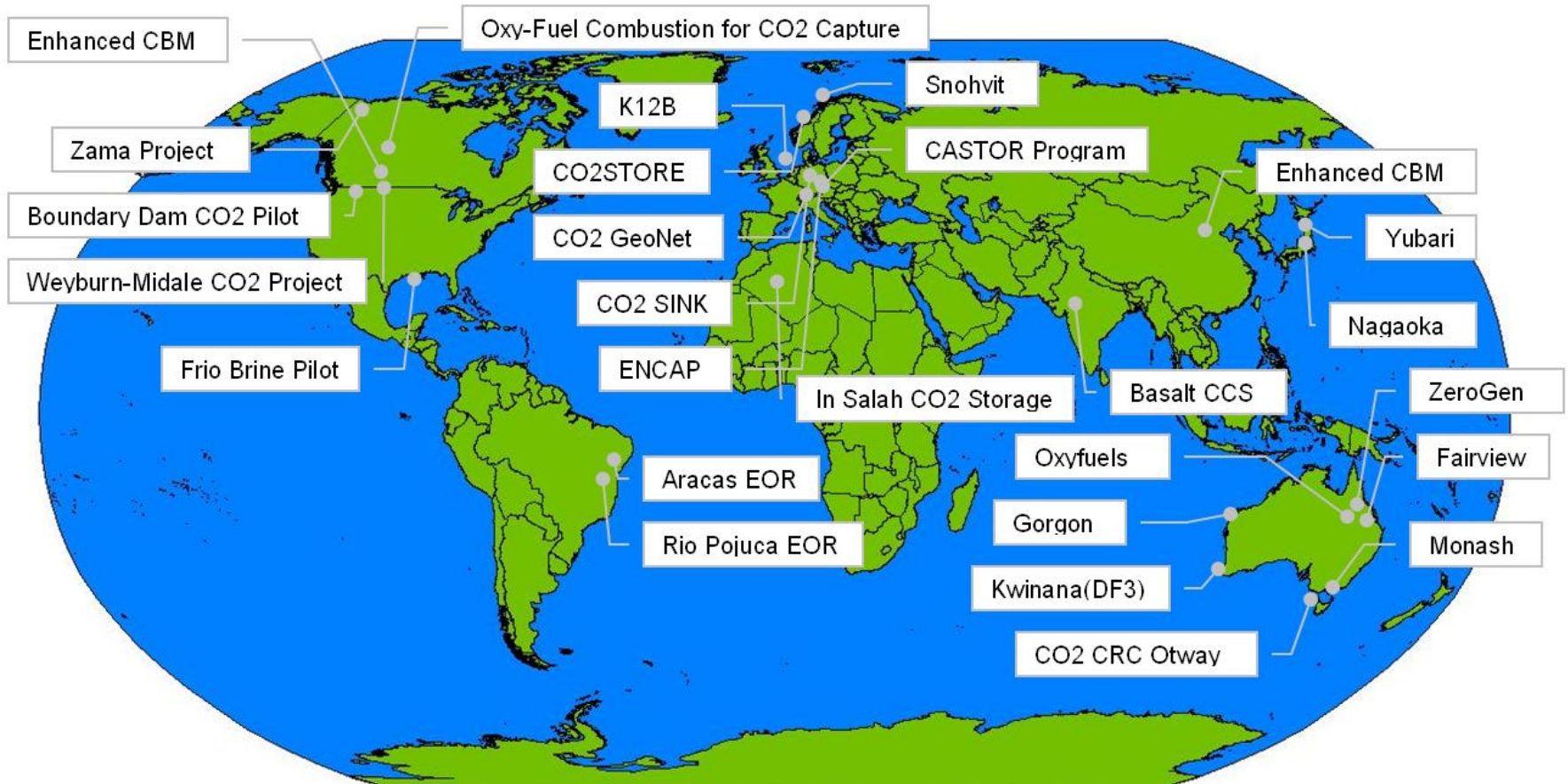
Capacity Building Task Force Workshops

- **Pittsburgh, PA, USA – May 7-11, 2007**
 - Convened parallel with 6th Annual Conference on Carbon Capture and Sequestration
 - 50 participants from 7 countries
 - Provided overview of CCS basics
- **Porto Alegre, Brazil – October 16-17, 2007**
 - Provided in-depth tutorial of topics presented in Pittsburgh
 - 130 participants from 10 countries
- **Al-Khobar, Saudi Arabia – January 27-29, 2008**
 - Focused on CCS related to oil and gas
 - 100 participants from 12 countries
- **Workshops have evolved and been tailored to meet needs and inputs from participants**

CBTF Moving Forward

- Two-year plan developed, which includes proposed future workshops in Mexico, India, China, Colombia through 2009
- Petrobras to host workshop in Salvador, Brazil, in September 2008
- CBTF is planning workshop in conjunction with 9th International Conference on Greenhouse Gas Technologies (ICGGT-9) in Washington, DC, in November 2008
- Identifying opportunities to collaborate on/join with other bilateral and multilateral CCS capacity building activities being conducted (APP, APEC, IEA GHG, and others)

CCS Projects Worldwide



Supporting CCS in Developing Countries

Potential actions to encourage funding:

- Assessment of current and potential funding options
 - European Investment Bank and OPIC programs
 - Clean energy technology funds – U.S., Australia, EU, UK, OPEC and Japan
 - GEF, IFC, WB, ABD and UNEP finance initiative
 - Private-private, MDB-private and government-MDB partnerships

- Improve understanding of financial instruments for CCS
 - Survey of private sector investment criteria
 - Case studies of prior-MDB supported clean energy (i.e., renewables)
 - Analysis of cost-sharing/leveraging ratios used by different entities

- Identify and evaluate policies international institutions that could promote
 - Fiscal incentives, e.g., tax breaks, production tax credits, etc.
 - Technology standards