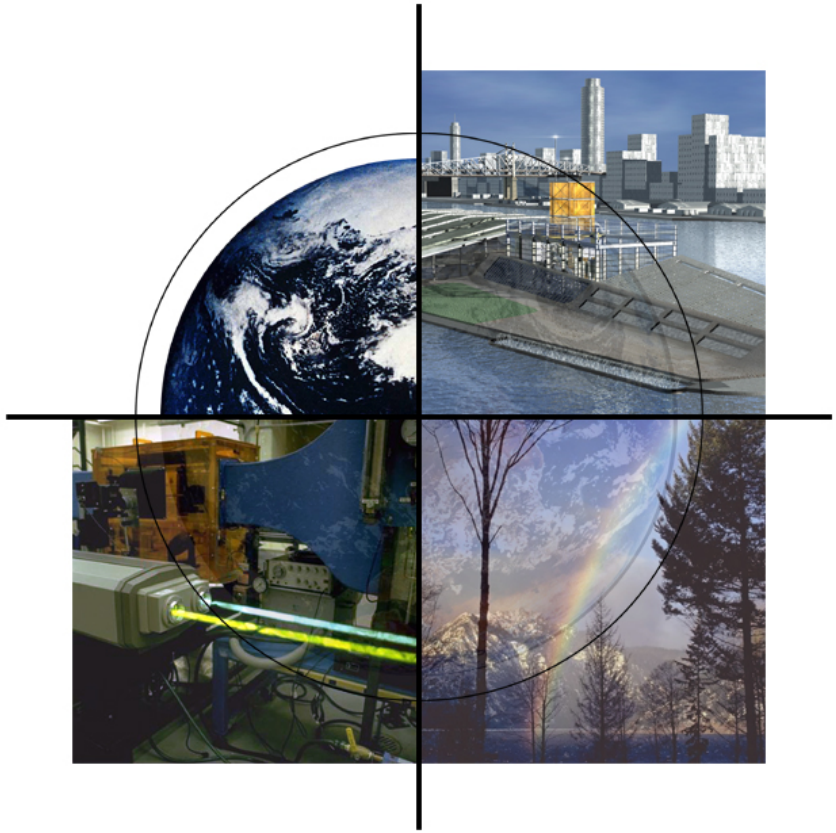
DOE's Perspectives on Carbon Capture and Storage – Directions, Challenges, and Opportunities



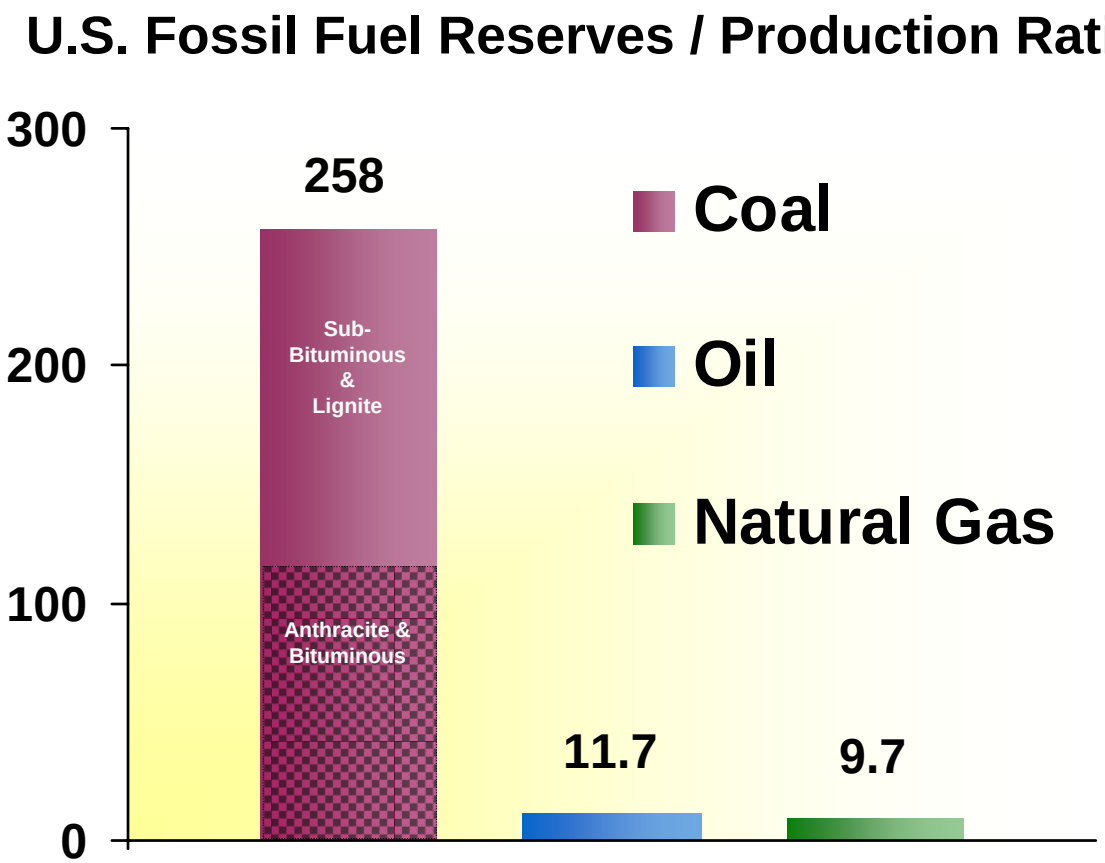
Carbon Capture and Storage

November 13-15, 2007
Austin, Texas

Thomas J. Feeley, III

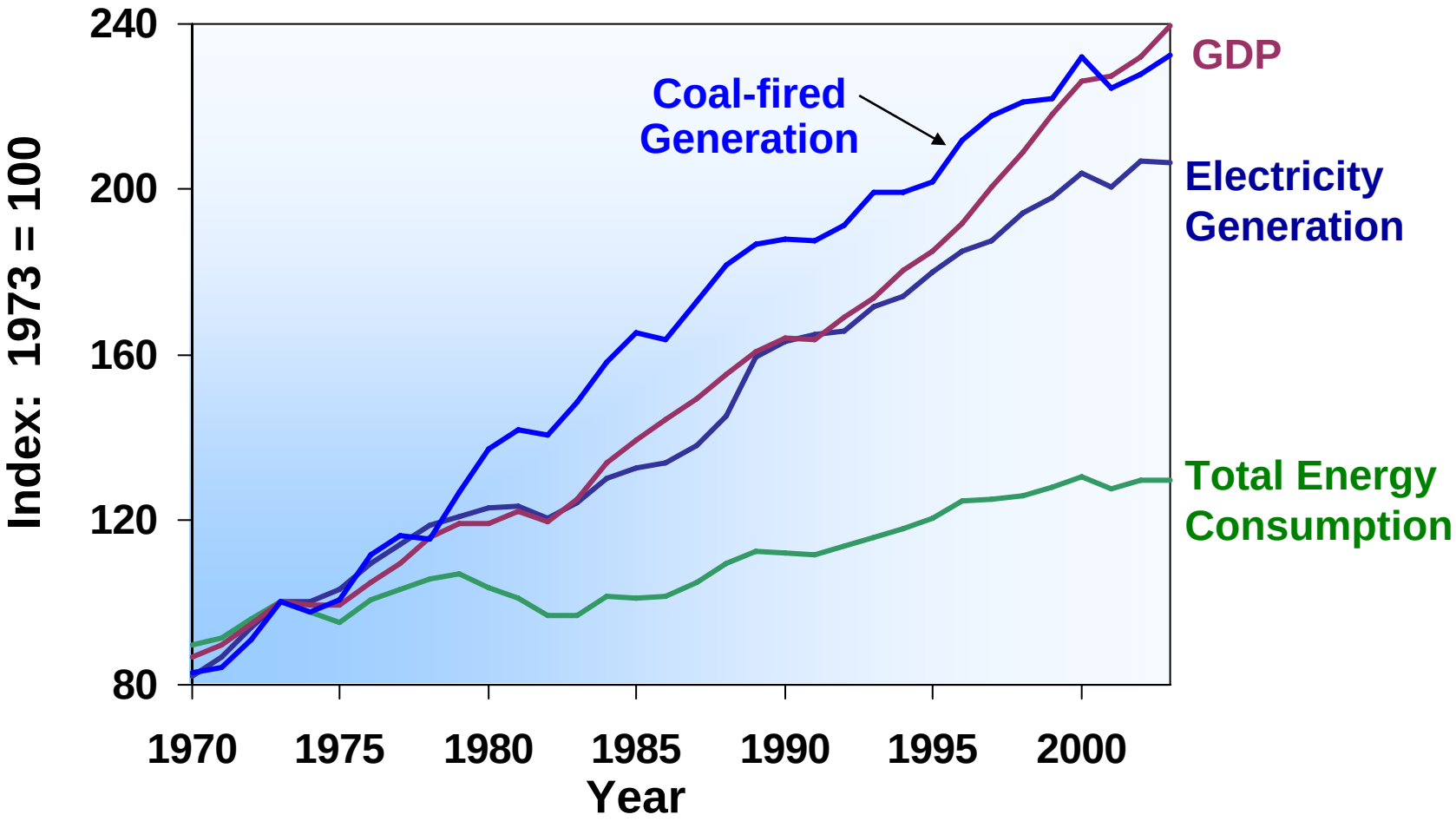
National Energy Technology Laboratory

250+ Year Supply at Current Demand Levels !



Sources: BP Statistical Review, June 2004, - for coal reserves data - World Energy Council; EIA, Advance Summary U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 2003 Annual Report, September 22, 2004 - for oil and gas reserves data.

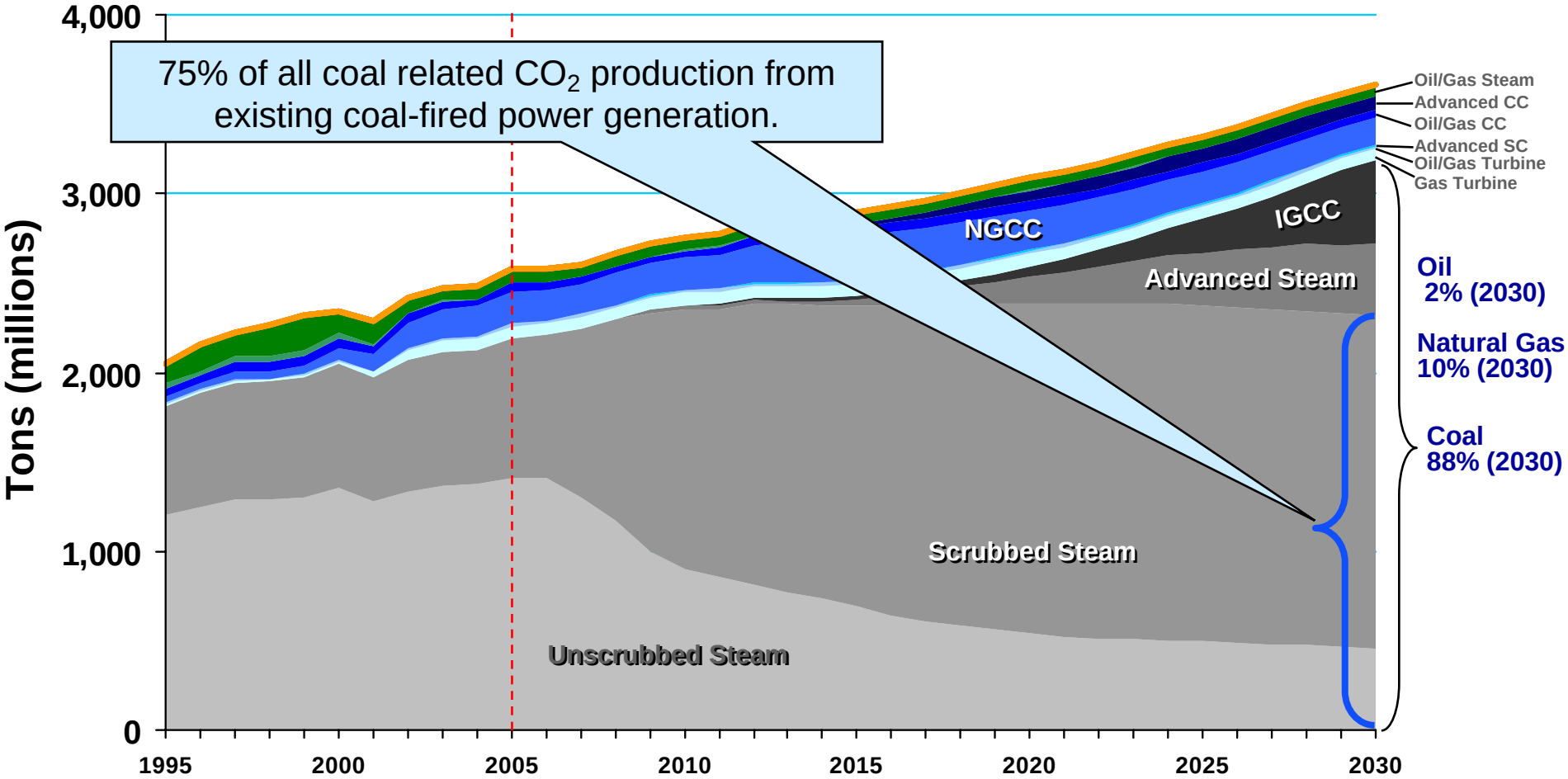
Coal Use Linked to Economic Growth in United States!



Coal-fired Generation and GDP Have Grown at Nearly the Exact Same Pace Over Last 30 Years

GDP: U.S. DOC, Bureau of Economic Analysis Energy & Electricity: EIA, Annual Energy Review 2003

Projected Fossil Energy Power Generation
CO_2 Emissions



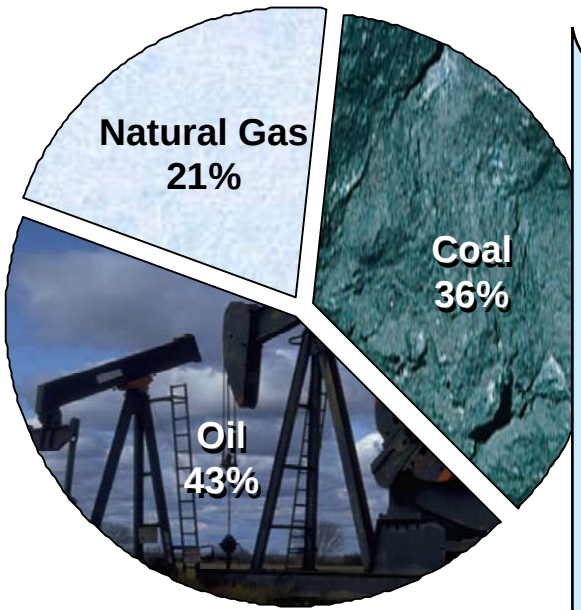
Coal Dominates CO_2 Emissions From Fossil Power Generation As Percent of Coal-fired Generation Grows to 59% (2030)

Source: Energy Information Agency

CCS – It's Not Just About Coal !!!

United States CO_2 Emissions

Emissions By Fuel Type



Natural Gas Power Plants

Natural Gas Processing

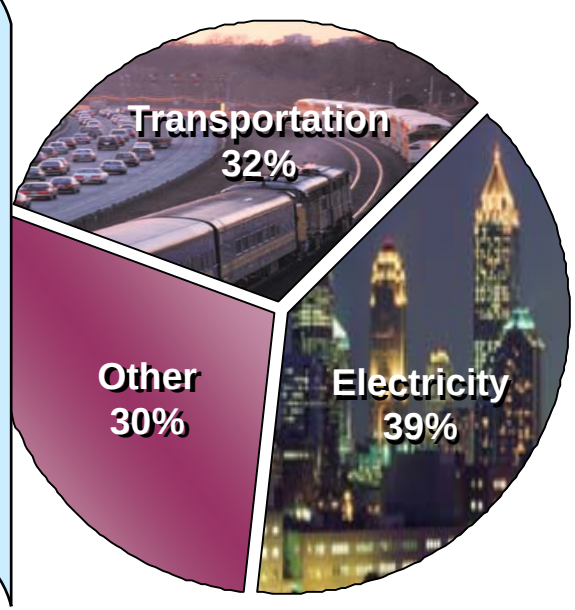
Ethanol Plants

Cement Production

Refineries

Etc….

Emissions By Sector



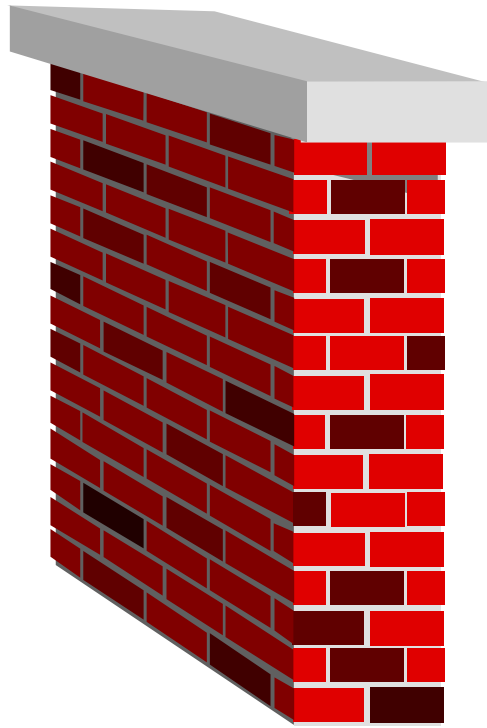
Carbon Sequestration Program Goals

- **Deliver technologies & best practices that validate:**

  - 90% CO_2 capture
  - 99% storage permanence
  - < 10% increase in COE (pre-combustion capture)
  - < 20% increase in COE (post- and oxy-combustion)

Key Challenges to CCS

- **Sufficient Storage & Capture Capacity ?**
- **Cost of CCS ?**
- **Permanence ?**
- **Infrastructure ?**
  - Permitting
  - Regulatory framework
  - Public Acceptance
  - Liability
  - Best Practices



The Challenge:

Sufficient Storage Capacity ?

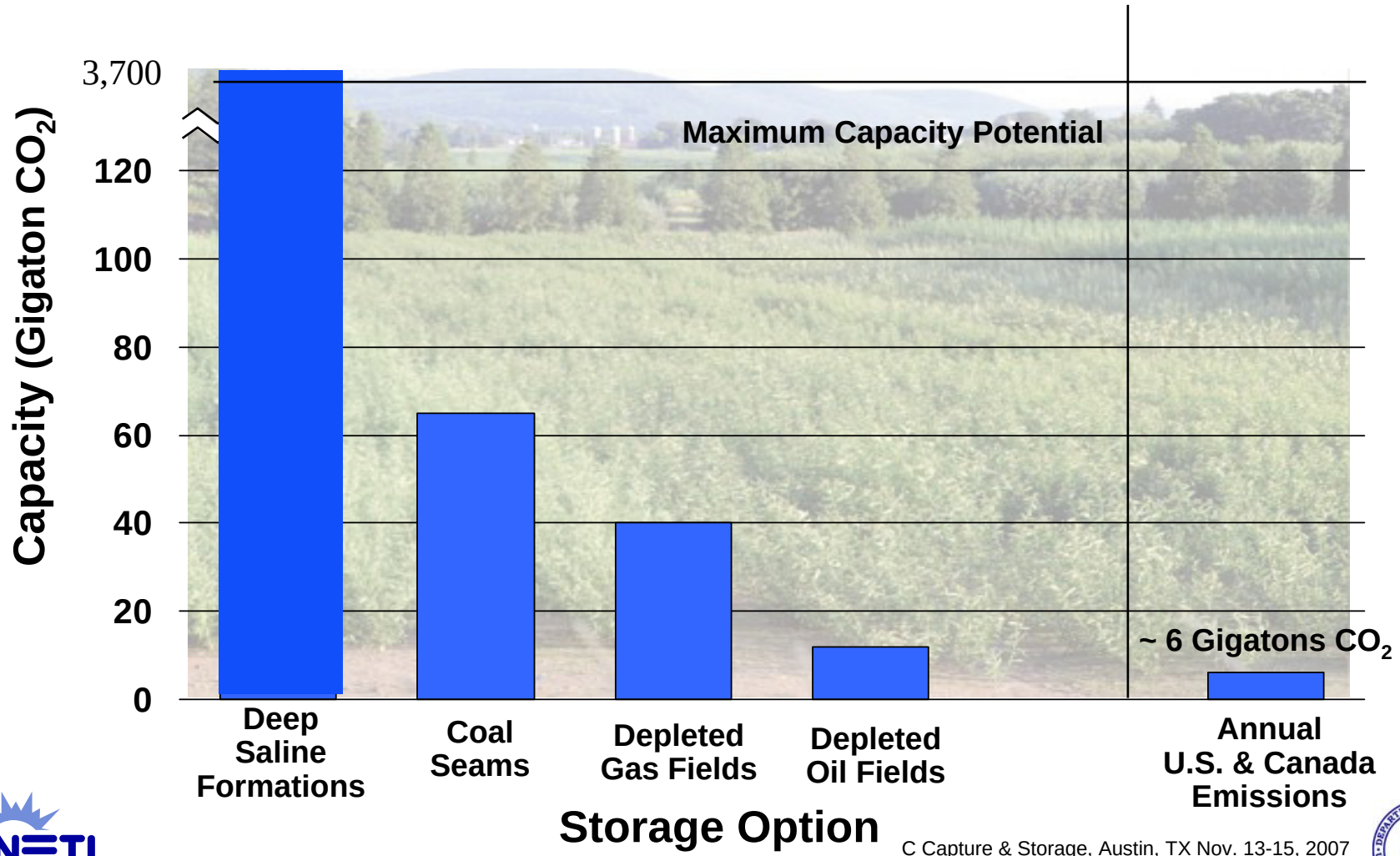
The Direction:

- **Validate Storage Capacity to +/- 30% Accuracy**
- **Validate Ability to Capture > 90% CO_2**

How Much CO_2 Are We Talking About?

- **1 million metric tons of CO_2:**
  - 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 CO_2 per year**
  - Under an EIA reference case scenario cumulative CO_2 emissions 2004-2100 are expected to be 1 trillion tons
  - *Enough to fill Lake Erie with liquid CO2 almost twice*

North America Geologic Storage Capacity
(> 600 Year Storage Capacity for U.S. & Canada)



Source: Battelle, "A CO2 Storage Supply Curve for North America", September 2004, PNWD-3471

Technology Must Show Ability for Significant Capture

- **To stabilize emissions, future emission reductions likely to be quite large**
- **Off the shelf capture technologies can already achieve greater than 90% capture of the CO_2 that it "sees"**
- **Emerging technologies must be at least that good**
- **90% capture capability does NOT imply 90% capture requirement !!!**

The Challenge:

Cost of CCS ?

The Direction:

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

Before CO_2 Can be Stored….it Must be Captured

Separation and concentration of CO_2 from fuel or flue streams:

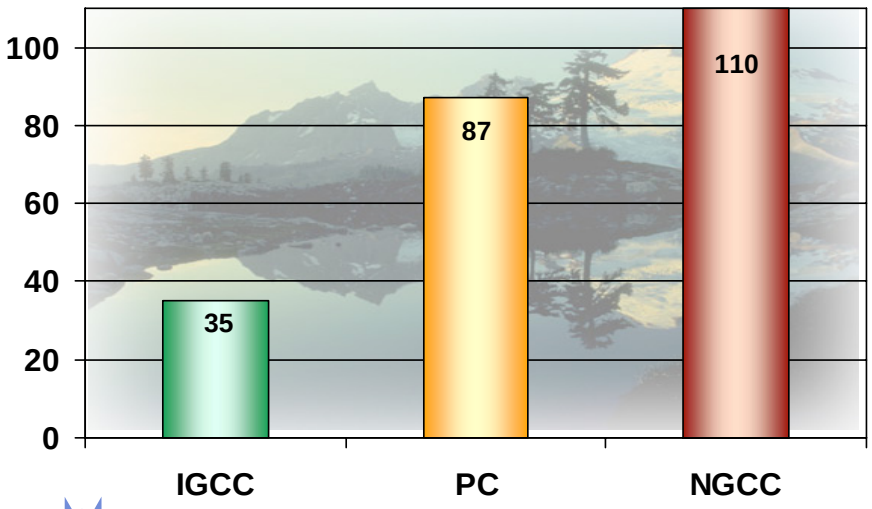
Three general classes of capture technology:

- **Pre-combustion (IGCC)**
- **Post-combustion**
- **Oxy-firing combustion**

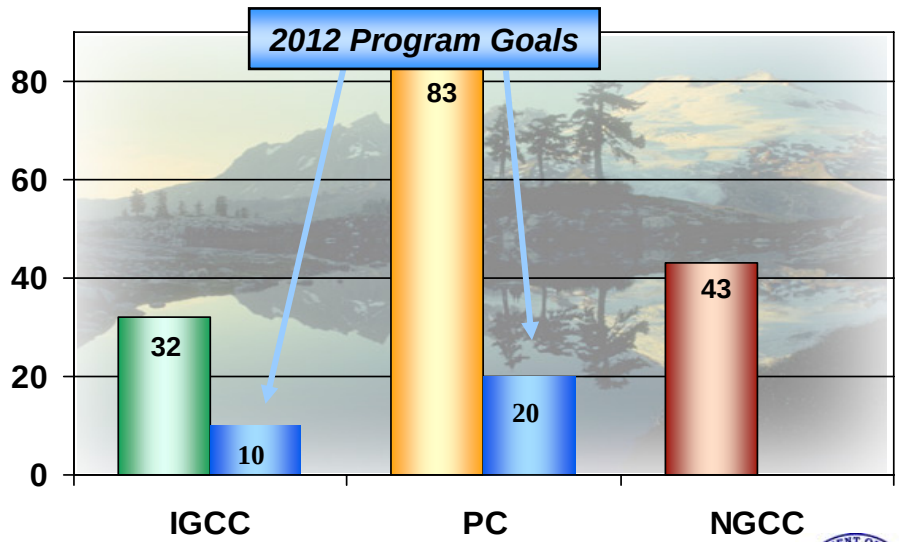
CCS Is Expensive !

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

Effect of CO_2 Capture on Capital Cost
(% Increase Resulting From CO_2 Capture)



Effect of CO_2 Capture on Cost of Electricity
(% Increase Resulting From CO_2 Capture)



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

Scale-Up Is An Issue

Laboratory Scale

Technically Possible?

Scale-up

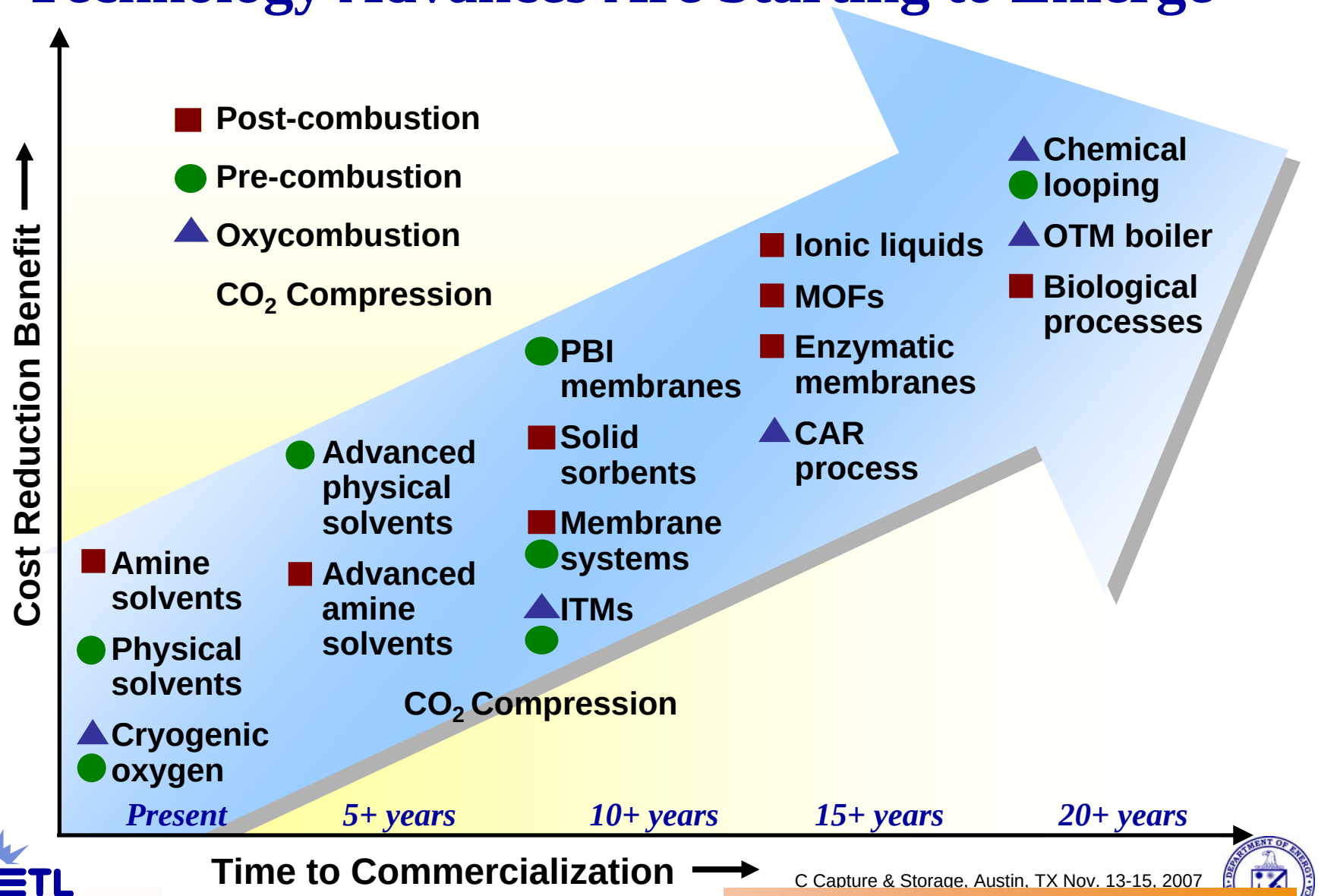
Economically Feasible?

500 MW Commercial Power Plant

- **0.1 ft^3 Reactor Volume**
- **0.27 scf per minute**

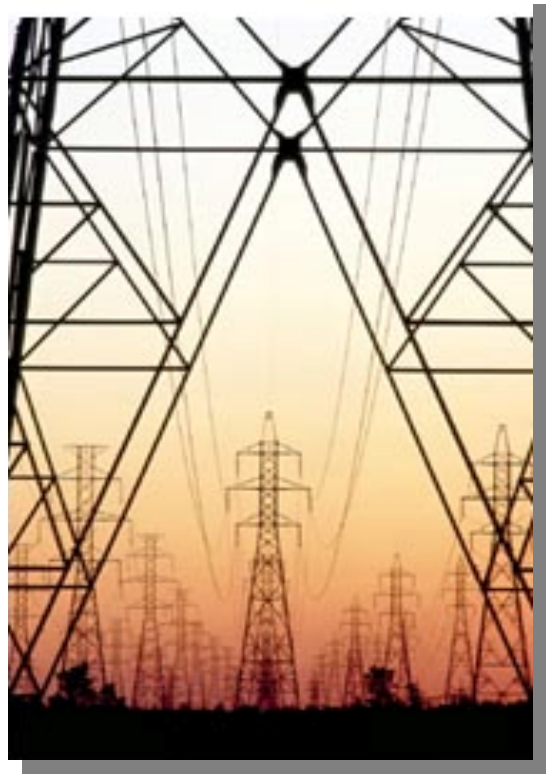
- **57,000 ft^3 Reactor Volume**
- **1,800,000 scf per minute**

Technology Advances Are Starting to Emerge



Anticipated FY08 CO_2 Capture Solicitations

- **Contingent upon FY08 funding and associated language, competitive C capture R&D solicitation(s) will be issued in the following areas:**
  - Pre-combustion capture (i.e., IGCC)
  - Post-combustion and oxy-combustion capture
- **CCPI Round 3 – Commercial Demonstration**
  - Up to $250 Million may be available
  - Demonstrate significant progress toward 90% carbon capture and less than 10% increase in the cost of electricity



The Challenge:

Permanence ?

The Direction:

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

All Risks & Leakage Pathways Are Being Studied

- **Environmental Risks**
  - Increases atmospheric CO_2
  - Accumulation of CO_2 pockets on earth
  - Migration into other strata and contamination of fresh water
  - Leakage of CO_2 into a marine environment
  - Damage to nearby hydrocarbon resources
  - Displacement of underground fluids
  - Initiation of seismic activity

- **Health and Safety Risks**
  - Human and animal exposure
  - NIOSH defines CO_2 as a nontoxic, inert gas that displaces oxygen
  - Work hazard

- **Economic Risks**
  - Enhanced oil recovery is a commercially proven process
  - Additional research needed
  - Liability
  - Operational considerations

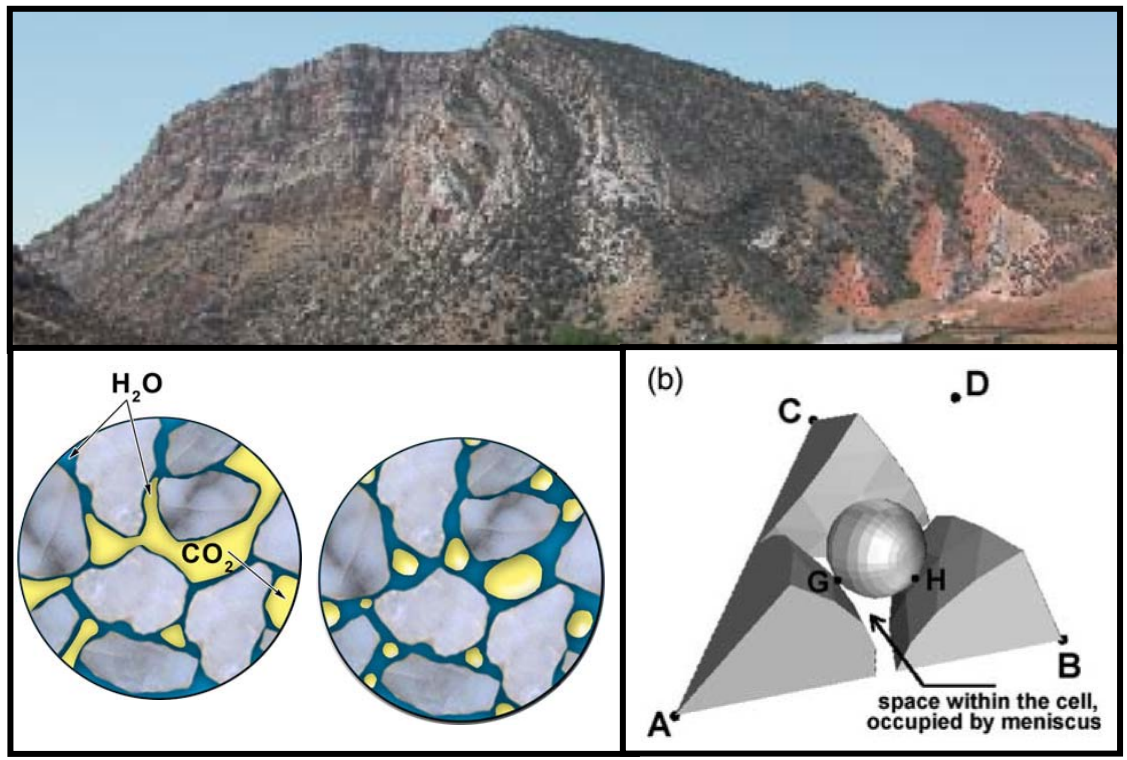
Once Injected, CO_2 is Difficult to Remove

Physical trapping

Residual phase trapping

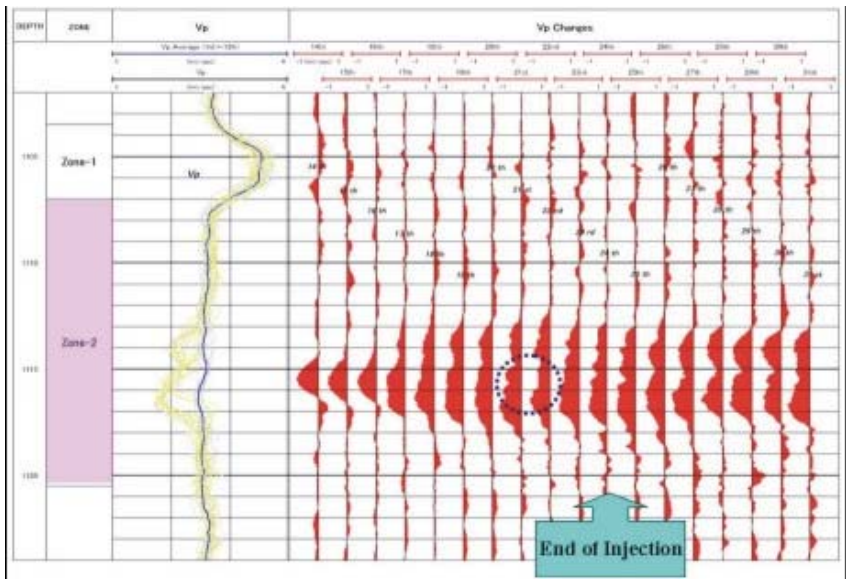
Solution/Mineral Trapping

Gas adsorption

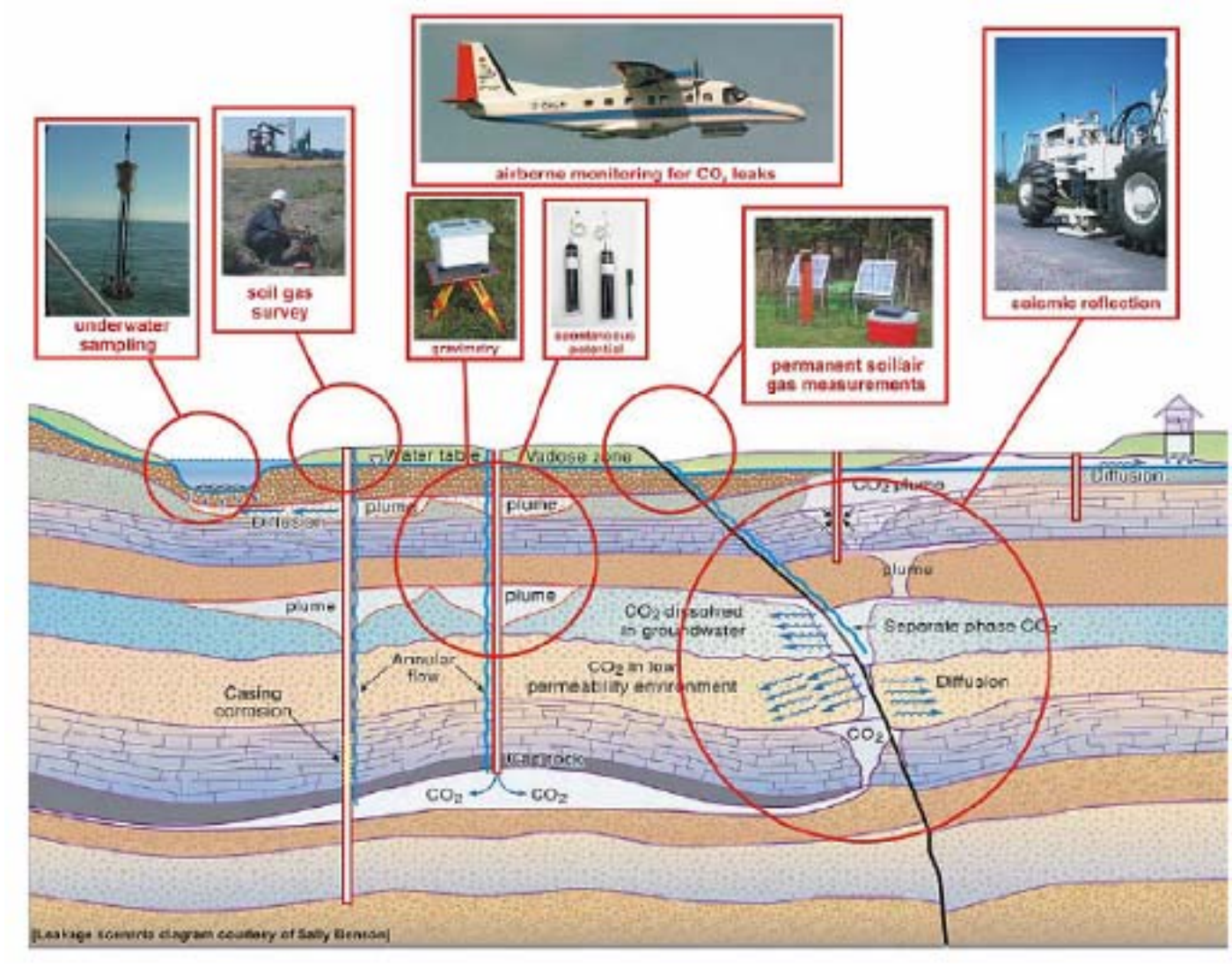


Japan CO_2 Injection Site … Following Earthquake

- On 10/23/04, a 6.8 magnitude quake hit the Niigata Japan
- Epicenter was ~20 kms away from the Nagaoka CO_2 injection site
- Notably, there was no seismic activity observed during CO_2 injection before the earthquake.
- Absolutely no CO_2 leakage or well damage observed



Monitoring, Mitigation, and Verification Technologies & Protocols Are Emerging



2007

The Challenge:

Infrastructure ?

The Direction:

- **Put “first of kind” projects in place**
- **Develop protocols & best practices**
- **Regional Carbon Sequestration Partnerships**

Regional Carbon Sequestration Partnerships

Creating Infrastructure for Wide Scale Deployment

Characterization Phase

- **24 months (2003-2005)**

Validation Phase

- **4 years (2005 - 2009)**
- **Field validation tests**
  - 25 Geologic
  - 11 Terrestrial

Deployment Phase

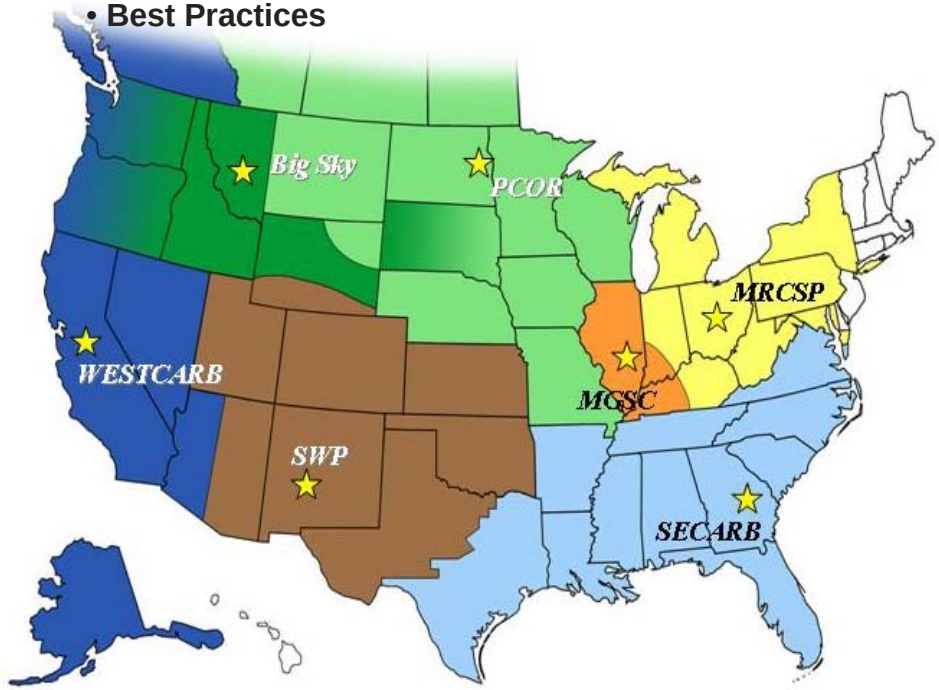
- **10 years (2007-2016)**
- **Up to 7 large volume injection tests**

Addressing:

- **Permitting**
- **Regulatory framework**
- **Public Acceptance**
- **Liability**
- **Best Practices**

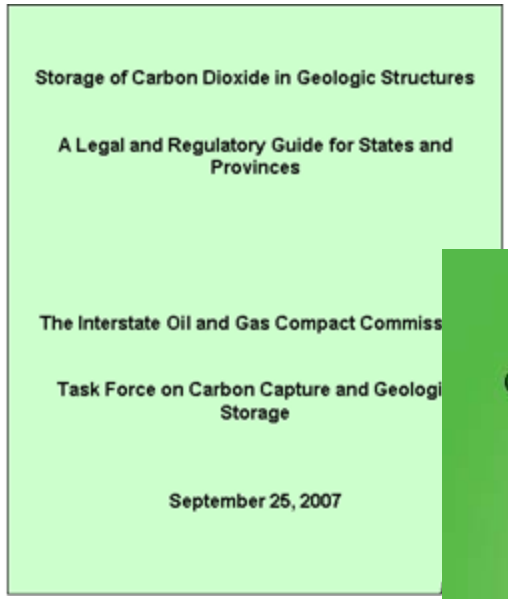
Representing:

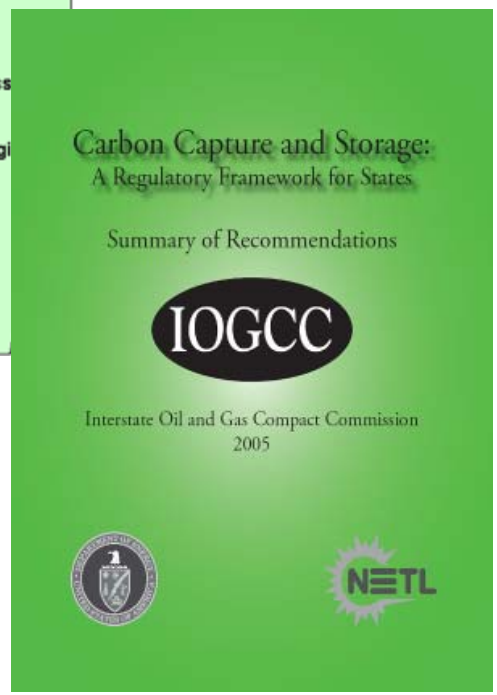
- **>350 Organizations**
- **41 States**
- **4 Canadian Provinces**
- **3 Indian Nations**
- **34% cost share**



Regulatory Guidelines Emerging

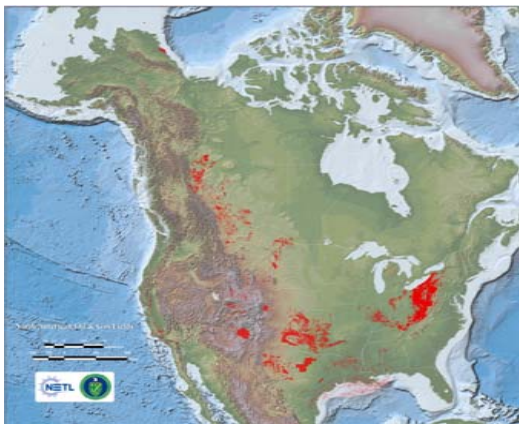
- EPA taking a lead role
- EPA & DOE Working Group
- IOGCC Framework Released May 2005
- IOGCC Legal & Regulatory Framework Released in September 2007



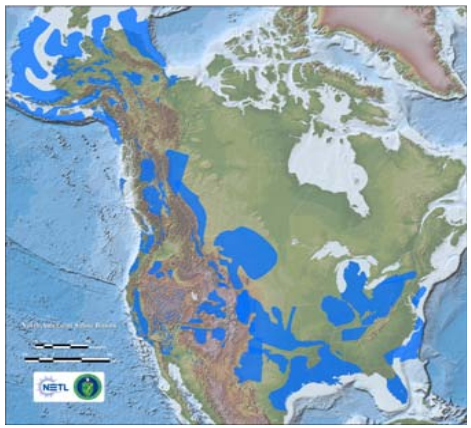


First Ever National Sequestration Atlas

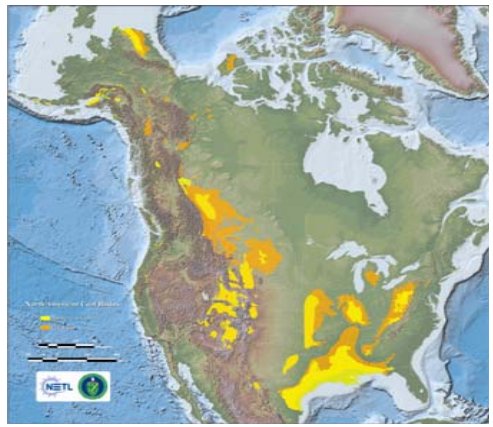
U.S. ~ 6 GT CO2/yr all sources



Oil and Gas Fields



Saline Formations



Unmineable Coal Seams

North American CO_2 Storage Potential (Giga Tons)

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

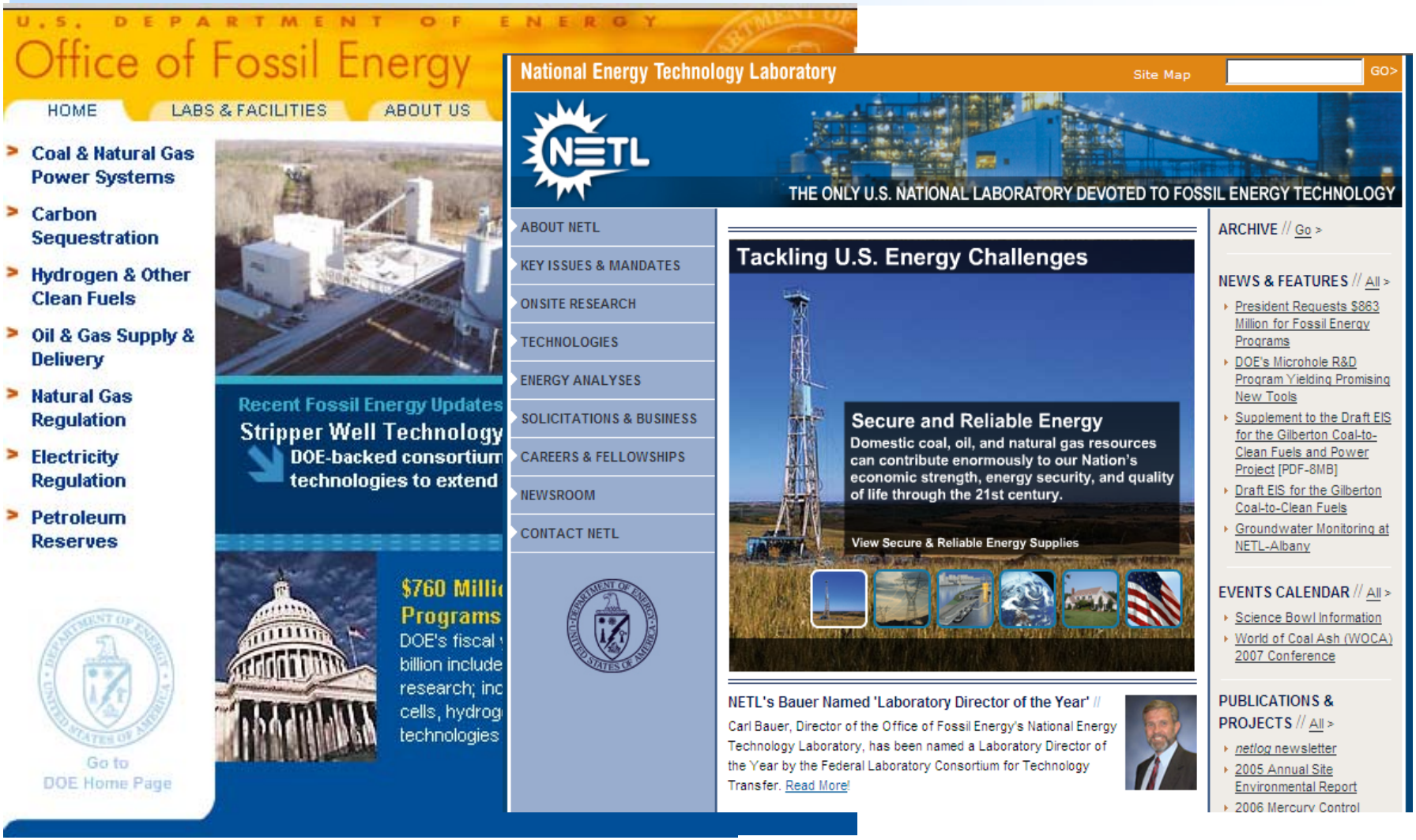
Hundreds of Years of Storage Potential

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

NATCARB

National Carbon Sequestration Database and Geographical Information System

- **Integrate data across Partnerships**
- **National perspective of sequestration potential**
- **Decision support tools**
- **Outreach tool**
  - Web-site gets 200-400 unique visitors every month



http://fossil.energy.gov/

http://www.netl.doe.gov