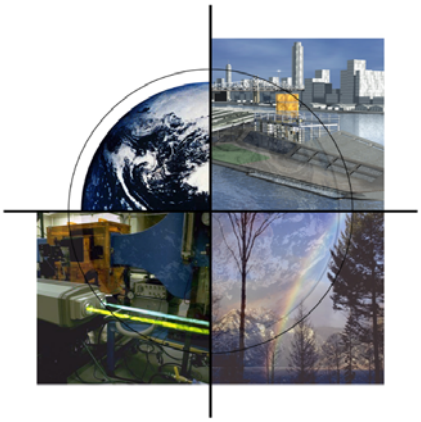
Sequestration Overview



Carbon Sequestration Briefing

November 1, 2007

Office of Fossil Energy

Annual CO_2 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); SO_2 - EPA air trends (2002 data); MSW - EPA OSWER fact sheet (2001 data); CO_2 - EIA AEO 2004 (2002 data)

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*

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?

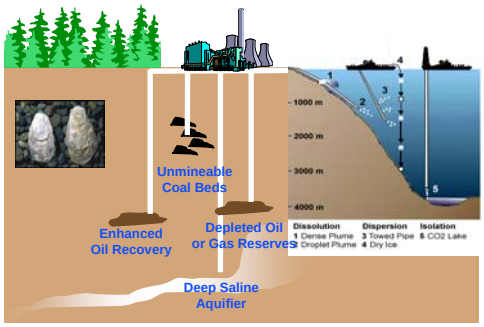
Capture and storage of CO_2 and other Greenhouse Gases that would otherwise be emitted to the atmosphere

Capture can occur:

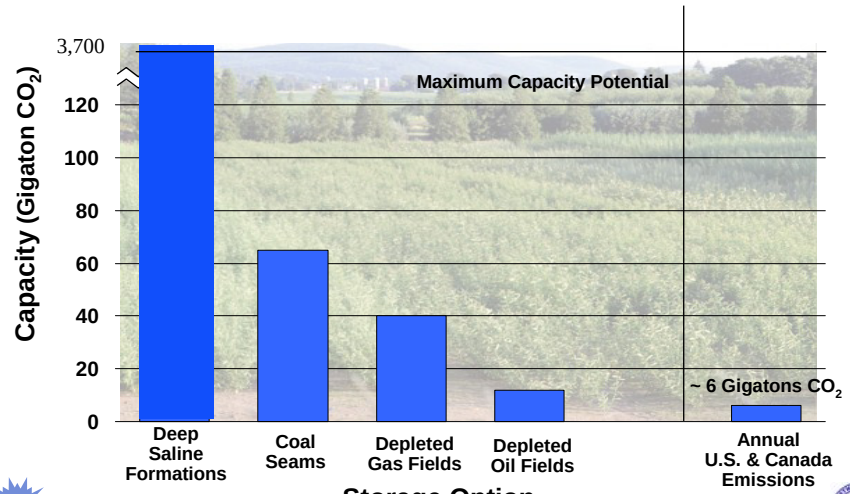
- at the point of emission
- when absorbed from air

Storage locations include:

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



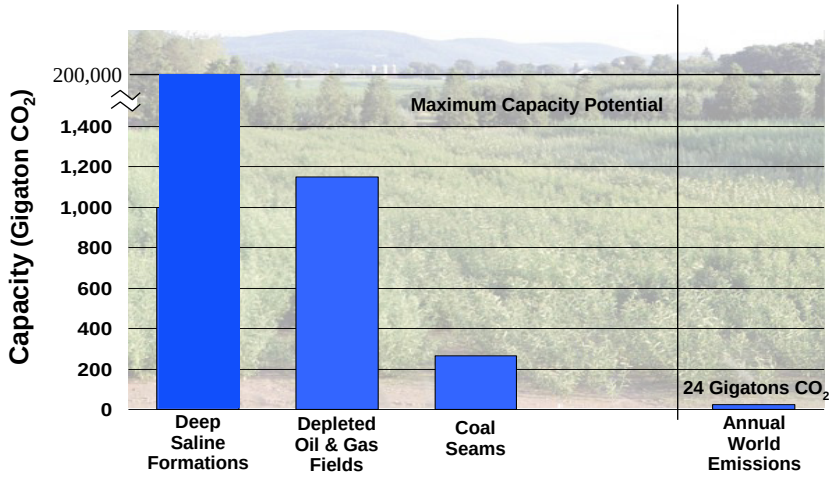
North America Geologic Storage Capacity
(> 600 Year Storage Capacity for U.S. & Canada)



Source: Battelle, "A CO2 Storage Supply Curve for North America", September 2004, PNWD-3271

Worldwide Geologic Storage Capacity

(Thousands of Years of Potential Storage Capacity)



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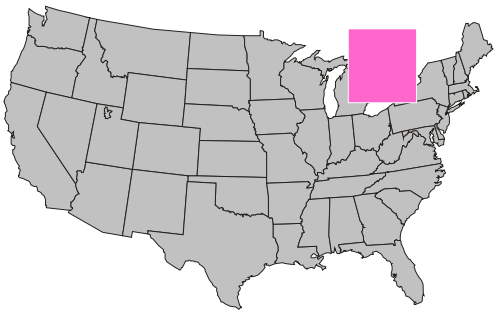
Storage Options: IEA Technical Review (TR4), March 2004
World Emissions: DOE/EIA, International Energy Outlook 2003, Table A10

CO_2 Storage Very Large But Within the Capability of U.S. Geologic Storage Capacity

Stabilization Thru 2100



- **Would fill Lake Erie twice**

This is equal to:

- **5% of the land mass of the contiguous U.S.**

Assume CO2 capture and geosequestration represents 40% of the total GHG emissions reduction need in 2100 (up from 30% in 2050) 200 x 109 tons CO2 / 1.32 x106 tons CO2 / sq. mile = 150,000 square miles

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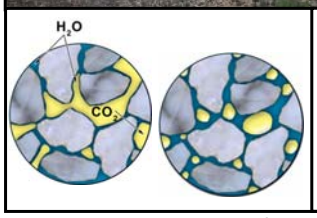
Carbon Storage – How does it work?

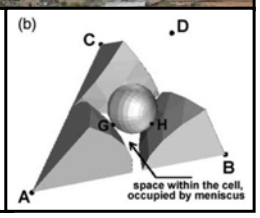
Physical trapping

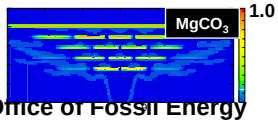
Residual phase trapping

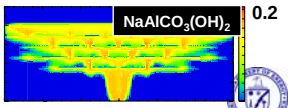
Solution/Mineral Trapping

Gas adsorption









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Worldwide CO_2 Storage Activity

Projects that are part of the Regional Carbon Sequestration Partnership

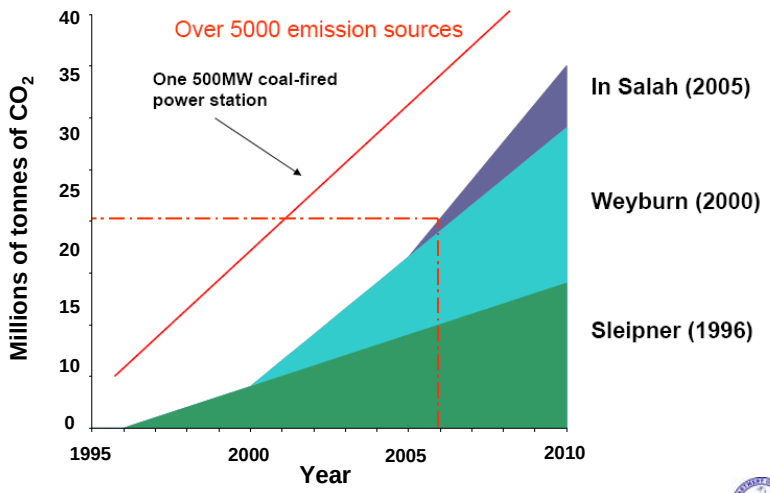
	Partnership	Geologic Province	Total CO_2 Injection (tons CO_2)	Approximate Depth (ft)
A	SRCSP	Paradox Basin	525,000	5,800
B	SRCSP	Permian Basin	300,000	5,700
C	PCOR	Keg River Formation	250,000	4,900
D	SRCSP	San Juan Basin	75,000	3,000
E	MGSC	Illinois Basin	10,000	5,000-10,000
F	MRCSP	Cincinnati Arch	10,000	8,000-10,000
G	MRCSP	Michigan Basin	10,000	4,000
H	MRCSP	Appalachian Basin	10,000	2,500-4,000
I	SECARB	Gulf Coast	7,500	8,000
J	SECARB	Gulf Coast	7,500	10,000
K	Big Sky	Grand Ronde Basalt	3,000	2,700
L	PCOR	Duperow Formation	3,000	1,000
M	PCOR	Williston Basin	3,000	>500
N	SECARB	Mississippi Salt Basin	3,000	7,500
O	MGSC	Illinois Basin	2,500	1,200-2,000
P	MGSC	Illinois Basin	2,500	Up to 3,150
Q	MGSC	Illinois Basin	2,500	2,800-3,150
R	MGSC	Illinois Basin	2,500	2,800-3,150
S	SRCSP	Paradox Basin	2,000	6,000
T	WESTCARB	Central Valley CA	2,000	5,000
U	WESTCARB	Central Valley CA	2,000	4,000
V	WESTCARB	Kaiparowits Basin	2,000	8,000
W	SECARB	Central Appalachian	1,000	1,000
X	SECARB	Black Warrior Basin	1,000	2,300-5,000
Y	MGSC	Illinois Basin	750	1,000

Worldwide CO_2 Storage Projects

	Project Name	Injection Start Date	Total CO_2 Injection (tons CO_2)	Approximate Depth (ft)
1	Carson	2011	40,000,000[a]	TBD
2	Gorgon	2009	>36,000,000[b]	7,500
3	Sleipner	1996	20,000,000	2,600-3,300
4	Weyburn	2000	20,000,000	4,800
5	Miller Field	2009	18,000,000[c]	13,000
6	In Salah	2004	17,000,000	5,900
7	K12B	2004	8,000,000	13,000
8	Snohvit	2006	>7,000,000[d]	8,500
9	Secunda	2010	TBD	TBD
10	Allison Unit	1995	360,000	3,100
11	Otway Basin	2006	100,000	6,500
12	Ketzin	2006	60,000	2,300
13	Minami-Nagaoka	2002	10,000	3,600
14	West Pearl Queen	2002	2,100	TBD
15	Frio	2004	1,600	4,900
16	Fenn Big Valley	1998	200	4,300
17	Yubari	2004	200	2,950
18	Qinshui Basin	2003	150	1,650
19	RECOPOL	2003	10	3,600

[a] 4 MMt/yr * 10 yrs | [b] 10,000 t/d * 365 * 10 yrs | [c] 1.2 MMt/yr * 15 yrs | [d] 2,000 t/d * 365 * 10 yrs

Commercial Experience – But Not Enough !!

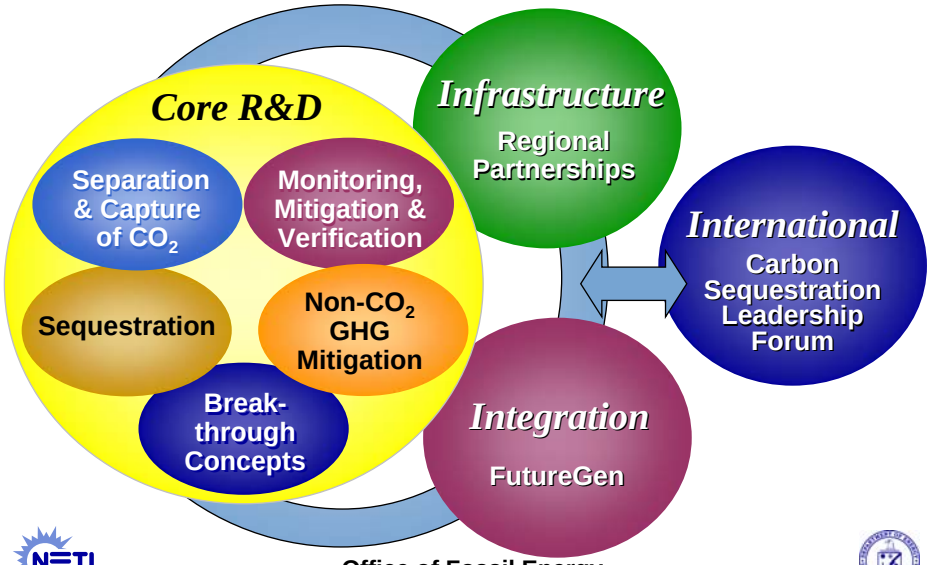


John Gale, IEA Greenhouse Gas R&D Programme

Challenges to Carbon Capture and Storage

- Magnitude of emissions
- Scale up
- Economics
- Regulatory framework
- Long-term assurance and acceptance

U.S. DOE/ Fossil Energy Program Organization



Requirements for Geologic Sequestration
Risks Involved Must Be Acceptable

- **Environmentally acceptable**
  - No legacy for future generations
  - Respect existing ecosystems
- **Safe**
  - No sudden large-scale CO_2 discharges
- **Verifiable**
  - Ability to verify amount of CO_2 sequestered
- **Economically viable**

Geologic Sequestration Risks

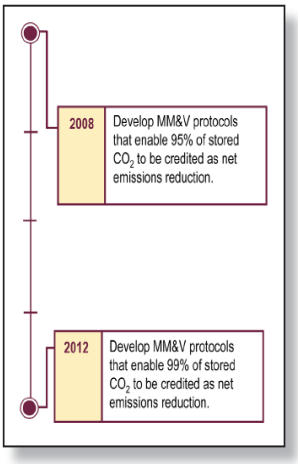
- **Environmental Risks**
  - Increases atmospheric CO_2
  - Accumulation of CO_2 pockets on earth
  - Migration into other strata and contamination of fresh water
  - Leakage of CO_2 into a marine environment
  - Damage to nearby hydrocarbon resources
  - Displacement of underground fluids
  - Initiation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

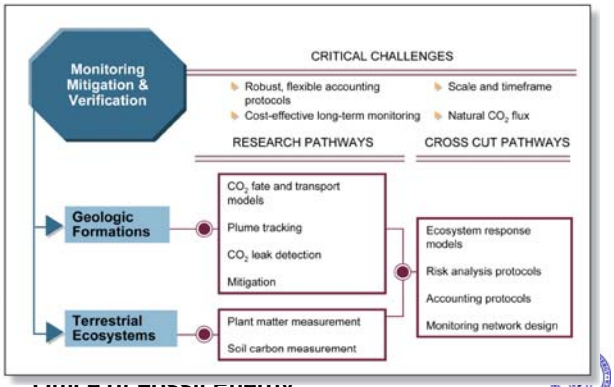
- **Health and Safety Risks**
  - Human and animal exposure can lead to asphyxiation
  - NIOSH defines CO_2 as a nontoxic, inert gas that displaces oxygen
  - Work hazard

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

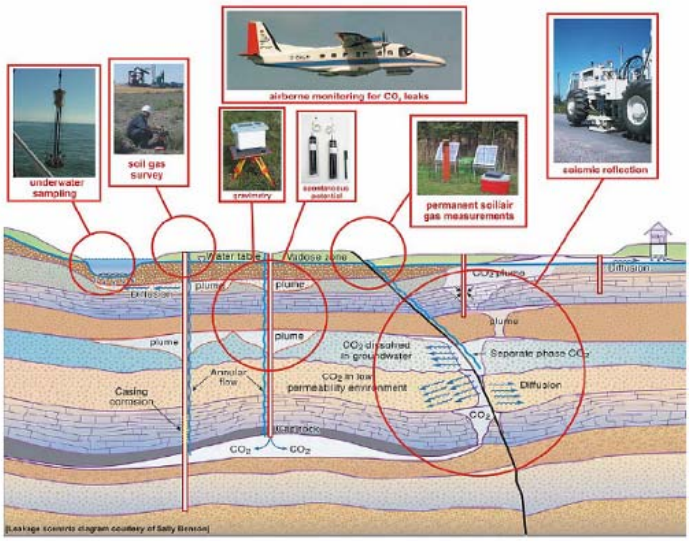
Monitoring, Mitigation & Verification - MMV Goals and Challenges

MM&V goals focus on ensuring permanence, which support the overarching Program goal of achieving 90% carbon capture with 99% storage permanence





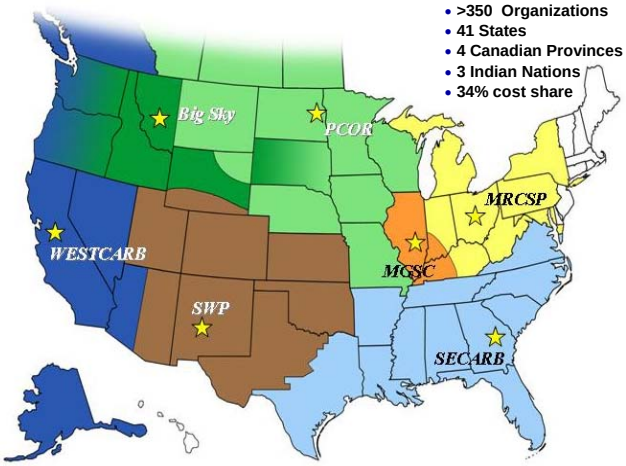
Monitoring, Mitigation, and Verification
Ensuring Permanent Storage !!



Regional Carbon Sequestration Partnerships

Creating Infrastructure for Wide Scale Deployment

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



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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

Representing:
- **>350 Organizations**
- **41 States**
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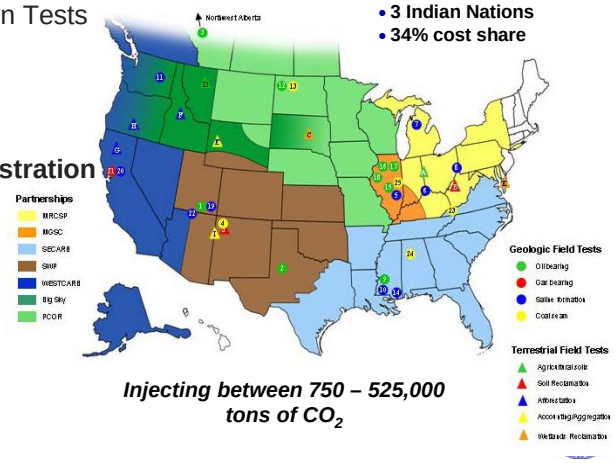
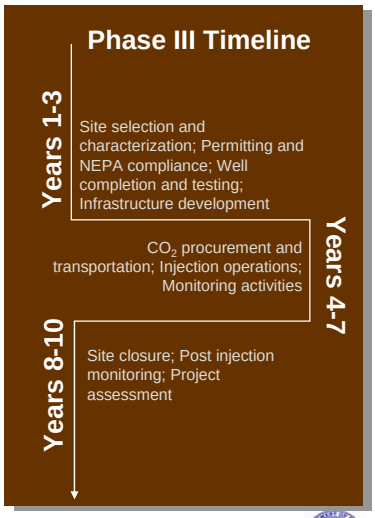


Injecting between 750 – 525,000 tons of CO_2

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**



Thank You !!!