NATIONAL ENERGY TECHNOLOGY LABORATORY

Carbon Storage Program Infrastructure Annual Review Meeting

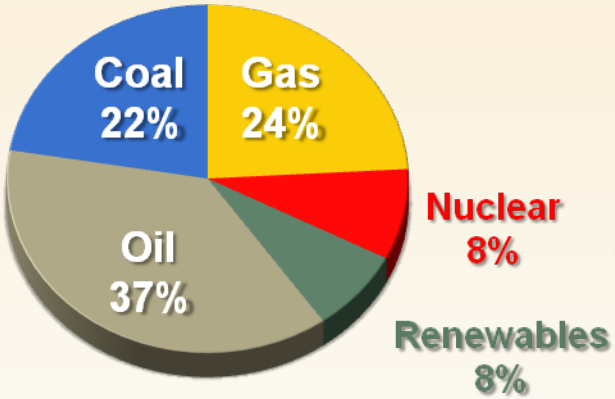
Nov 15-17, 2011

U.S. DOE Carbon Storage Program

John Litynski, PE
Carbon Storage Technology Manager

Energy Demand 2008

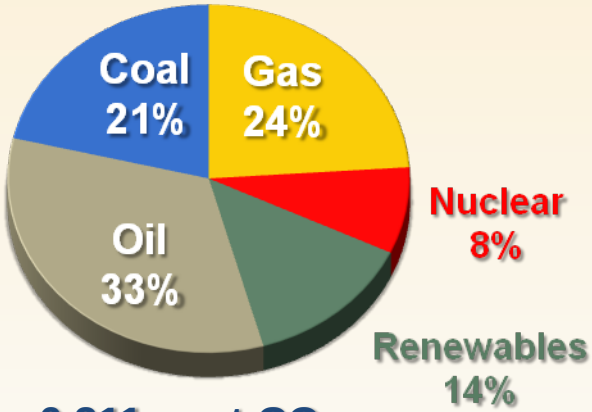
100 QBtu / Year
84% Fossil Energy



5,838 mmt CO_2

Energy Demand 2035

114 QBtu / Year
78% Fossil Energy

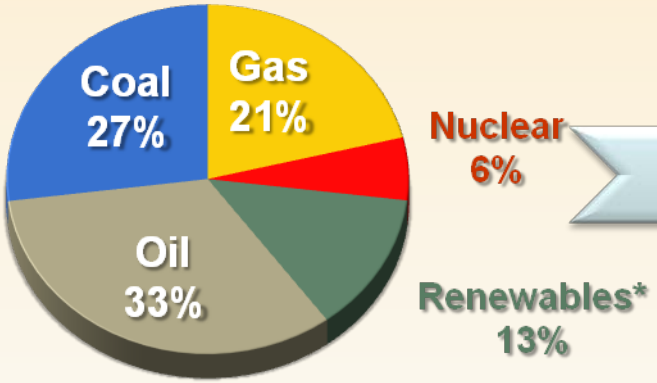


6,311 mmt CO_2

+ 14%

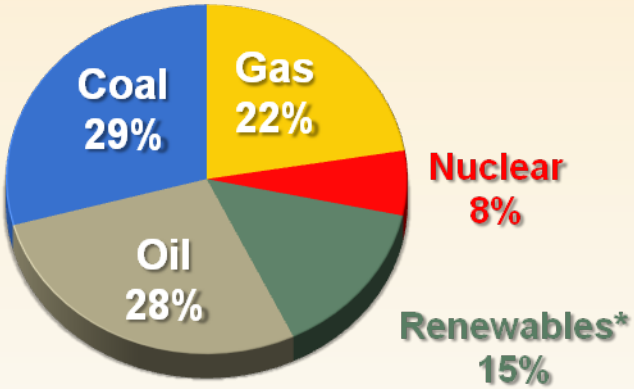
United States

487 QBtu / Year
81% Fossil Energy



29,259 mmt CO_2

716 QBtu / Year
79% Fossil Energy



42,589 mmt CO_2

+ 47%

World

Sources: U.S. data from EIA, Annual Energy Outlook 2011; World data from IEA, World Energy Outlook 2010, Current Policies Scenario

* Primarily traditional biomass, wood, and waste.

U.S. DEPARTMENT OF ENERGY • OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

CARBON STORAGE PROGRAM with ARRA Projects

Core R&D

2012 Structure

- Geologic Storage
- Monitoring, Verification, and Accounting (MVA)
- Simulation and Risk Assessment
- CO_2 Utilization
- ARRA: University Projects

Benefits

- Reduced cost of CCS
- Tool development for risk assessment and mitigation
- Accuracy/monitoring quantified
- CO_2 capacity validation
- Indirect CO_2 storage

Technology Solutions

Infrastructure

Regional Carbon Sequestration Partnerships

- Characterization
- Validation
- Development

ARRA: Development of Technology Transfer Centers

ARRA: Site Characterization

Other Small and Large-Scale Projects

Benefits

- Human capital
- Stakeholder networking
- Regulatory policy development
- Visualization knowledge center
- Best practices development
- Public outreach and education

Lessons Learned

Technology Solutions

Global Collaborations

- North America Energy Working Group
- Carbon Sequestration Leadership Forum

International Demonstration Projects

Canada (Weyburn, Zama, Ft. Nelson)
Norway (Sleipner and Snovhit)
Germany (CO2Sink),
Australia (Otway)
Africa (In-Salah)
Asia (Ordos Basin)

Lessons Learned

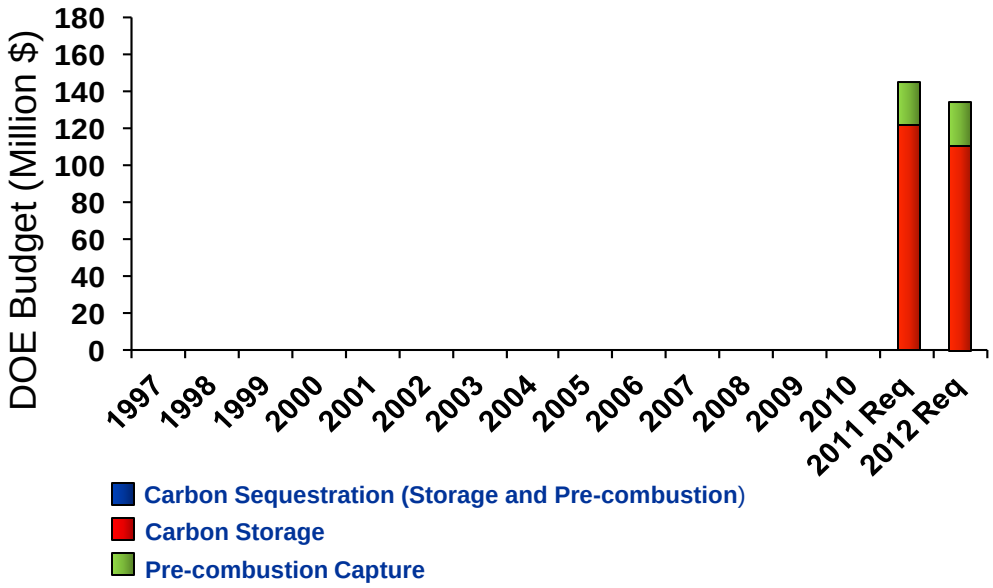
Benefits

- Knowledge building
- Project development
- Collaborative international knowledge
- Capacity/model validation
- CCS commercial deployment

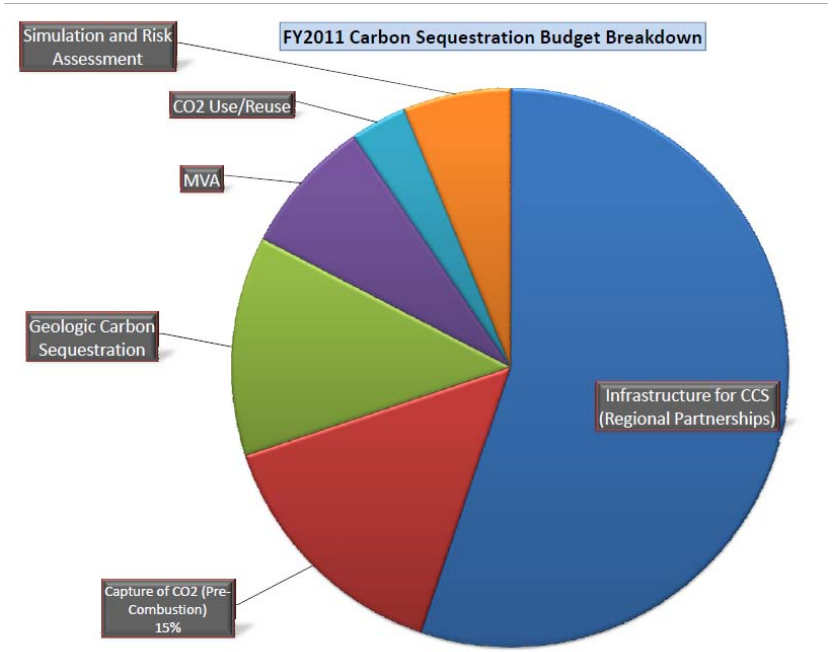
Demonstration and Commercialization Carbon Capture and Storage (CCS)

Sequestration Program Total Funding

2011 *Program Statistics*



Strong industry support
~ 39% cost share on projects



Diverse research portfolio

105 Active R&D Projects

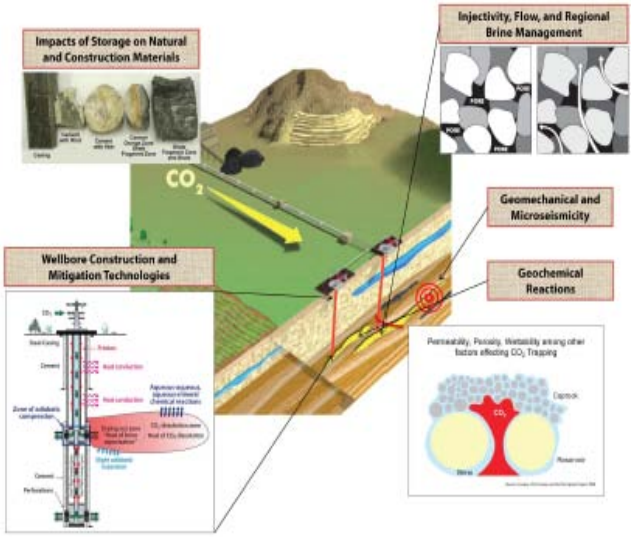
60 ARRA Projects (FY10 -$120M)

Geologic Storage

Technology Development and Understanding

Research Pathways

- Wellbore construction and materials technologies
- Mitigation technologies for wells and natural pathways
- Managing fluid flow, reservoir pressure, and brines
- Geochemical effects of CO_2 injection
- Geomechanical effects on reservoirs and seals



Summary of Focus Area

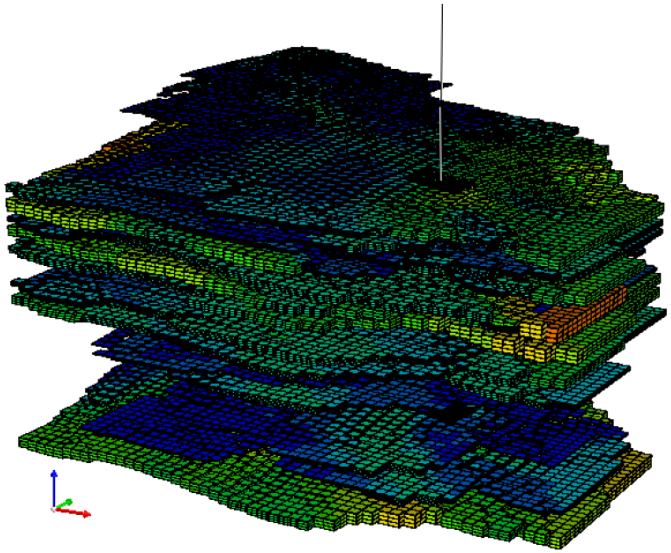
- 16 cooperative agreements awarded - FY10
- 14 Tasks with 6 National Labs
- China Energy Research Center $1.25M per year
- Targeting 99% permanence and +/-30% capacity goals

Research Partners

University of Texas at Austin, Columbia University, Stanford University, Paullson Inc., University of Wyoming, Fusion Technologies, Consol, Montana State University – Bozeman, Indiana University, Clemson University, Yale University, New Mexico Inst of Mining and Tech, Advanced Resources International, Colorado School of Mines, West Virginia University, LBNL, LLNL, LANL, PNNL, ORNL

Geologic Storage
Simulation and Risk Assessment

Research Pathways
- Thermal and hydrologic fate and transport
- Geochemical simulations
- Geomechanical simulations
- Predicting biologic impacts on storage formations
- Risk assessment and quantification



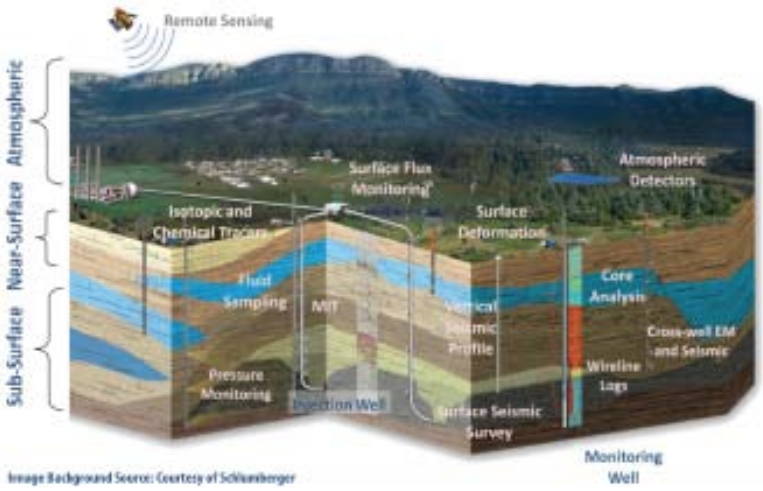
Summary of Focus Area
- 9 (5 SIM/4RA) cooperative agreements – FY10
- 5 Tasks with 4 National Labs
- Targeting 99% permanence and +/-30% capacity

Research Partners -
Missouri University of Science and Technology, New Mexico Inst of Mining and Tech., Battelle Memorial Institute, Advanced Resources International, Colorado School of Mines, Headwaters Clean Carbon Services, Princeton University, Goldsim, University of Texas at Austin, BNL, LANL, LBNL, PNNL, LLNL

Monitoring, Verification, and Accounting

Research Pathways

- Atmospheric and Remote Sensing Technologies
- Near surface monitoring of soils and vadose zone
- Subsurface monitoring in and near injection zone
- Intelligent monitoring systems for field management



Summary of Focus Area

- 13 cooperative agreements awarded – FY09
- 9 Tasks with 6 National Labs
- Targeting 99% permanence and +/-30% capacity

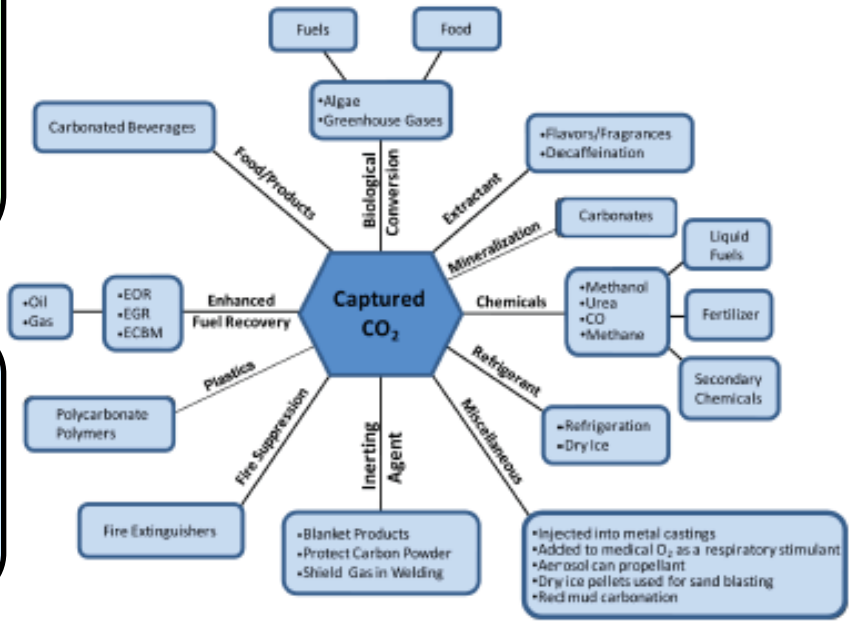
Research Partners –

Massachusetts Institute of Technology, PTRC, University of San Diego Scripps, University of Wyoming, Columbia University, West Virginia University, University of Miami, University of Texas at Austin, Fusion Petroleum Technologies, Planetary Emissions Management, Schlumberger Carbon Services, Montana State University, Stanford University, ORNL, LANL, PNNL, LBNL, LLNL, BNL

CO_2 Utilization

Research Pathways

- Conversion chemicals and plastics
- Non-geologic storage in cement and minerals
- Indirect storage
- Beneficial use of produced waters



Summary of Focus Area

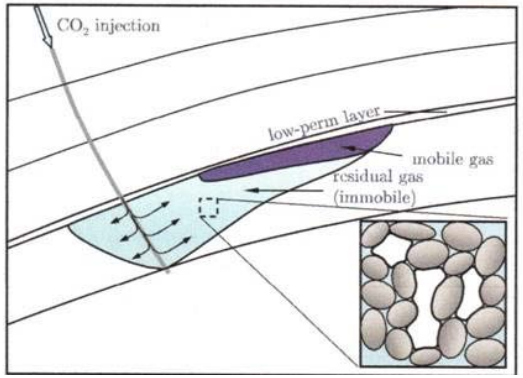
- 6 cooperative agreements awarded - FY10
- 2 Tasks with 1 National Lab
- Targeting <$10 per CO_2 tonne

Research Partners –

Brown University, Massachusetts Institute of Technology, Research Triangle Institute, McGill University, CCS Materials Inc, Phosphortech Corporation, ANL

Challenges for Geologic Storage

- **Ultimate plume size, and time for stabilization have many implications for project developers**
  - Surface and subsurface access
  - Regulatory requirements
    - Class VI 50 year post-injection monitoring
    - Area of review requirements for GHG reporting
  - Liability; public acceptance
  - Cost
- **A diverse set of monitoring techni demonstrated, but**
  - Leakage detection threshold
  - Quantification of CO_2
  - Long term experience
- **Different depositional systems**



Anatomy of a plume

Strandplain and fluvial depositional environments

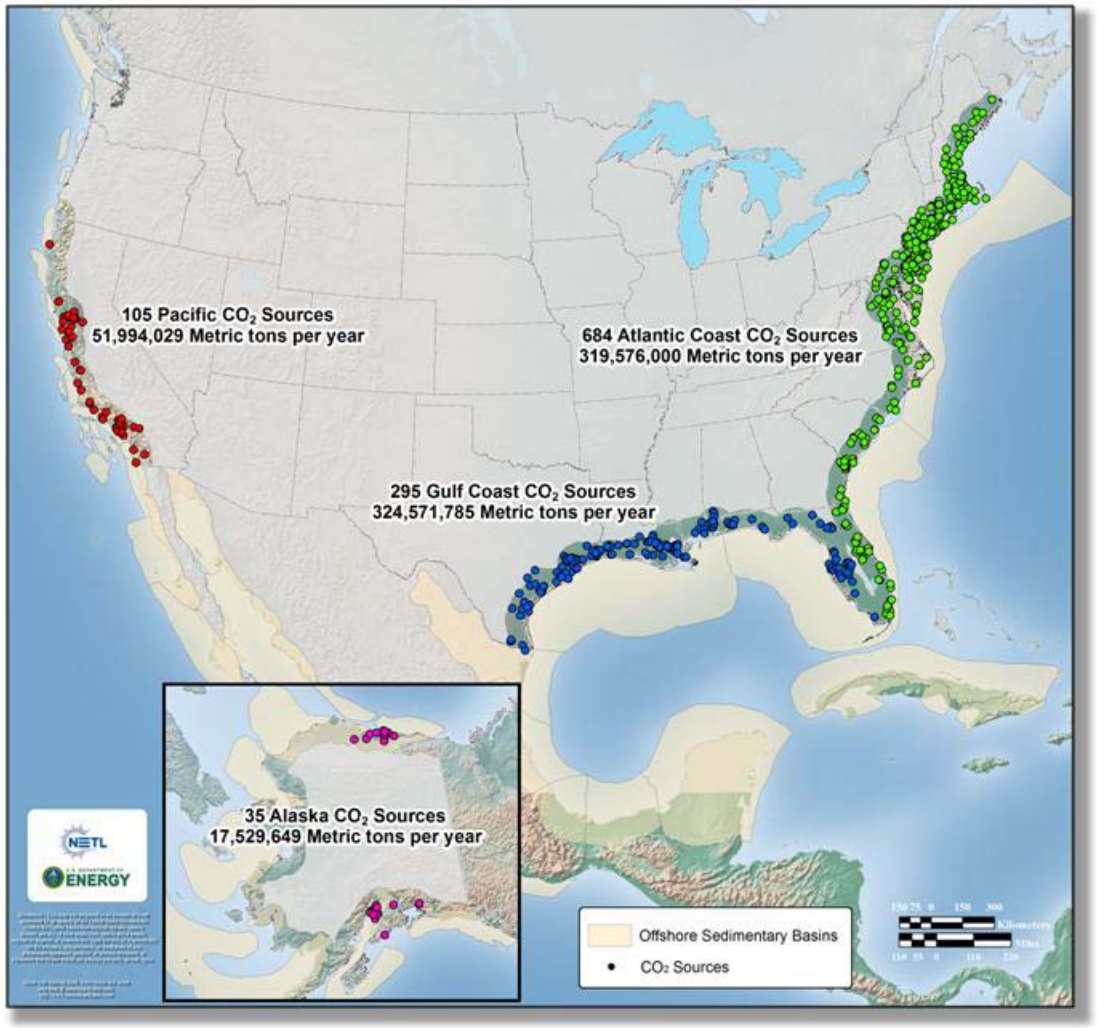
Optimizing Storage through Fluids Management

- **Water may be extracted for reservoir management:**
  - Avoid impact to other mineral rights
  - Increased storage volume.
  - CO_2 distribution and pressure management

- **Significant engineering challenges for wide-scale beneficial use**
  - Quality; quantity; cost

U. S. Offshore Storage Opportunities

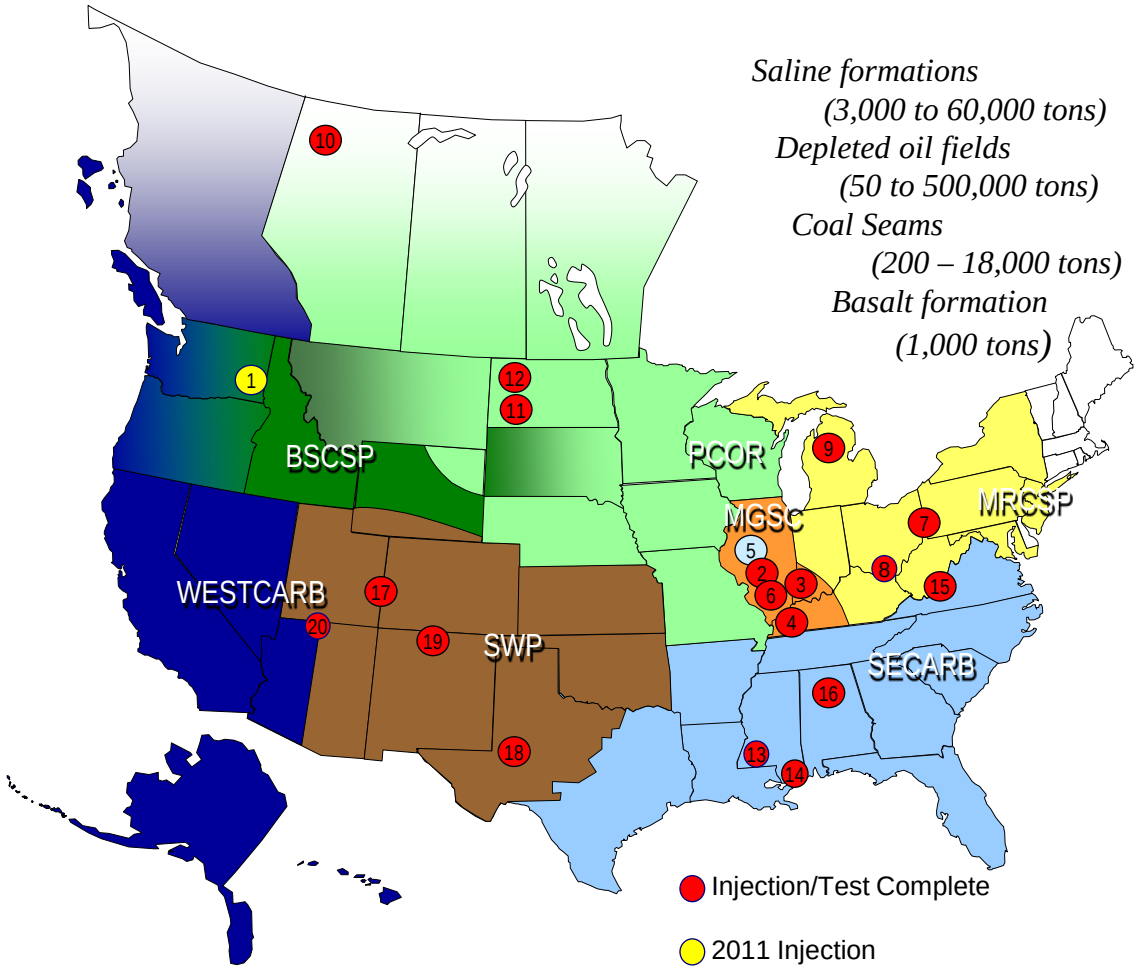
- **Advantages**
  - Large capacity
  - Away from populated areas
  - Avoids USDW issues
  - Single entity ownership
- **Issues**
  - Technology Application
  - Sparse subsurface data outside oil/gas fields
  - Infrastructure costs
  - Regulatory certainty



Supporting Infrastructure for Carbon Storage

A Proving Ground for New Technologies

Small-Scale Geologic Field Tests



Saline formations
(3,000 to 60,000 tons)
Depleted oil fields
(50 to 500,000 tons)
Coal Seams
(200 – 18,000 tons)
Basalt formation
(1,000 tons)

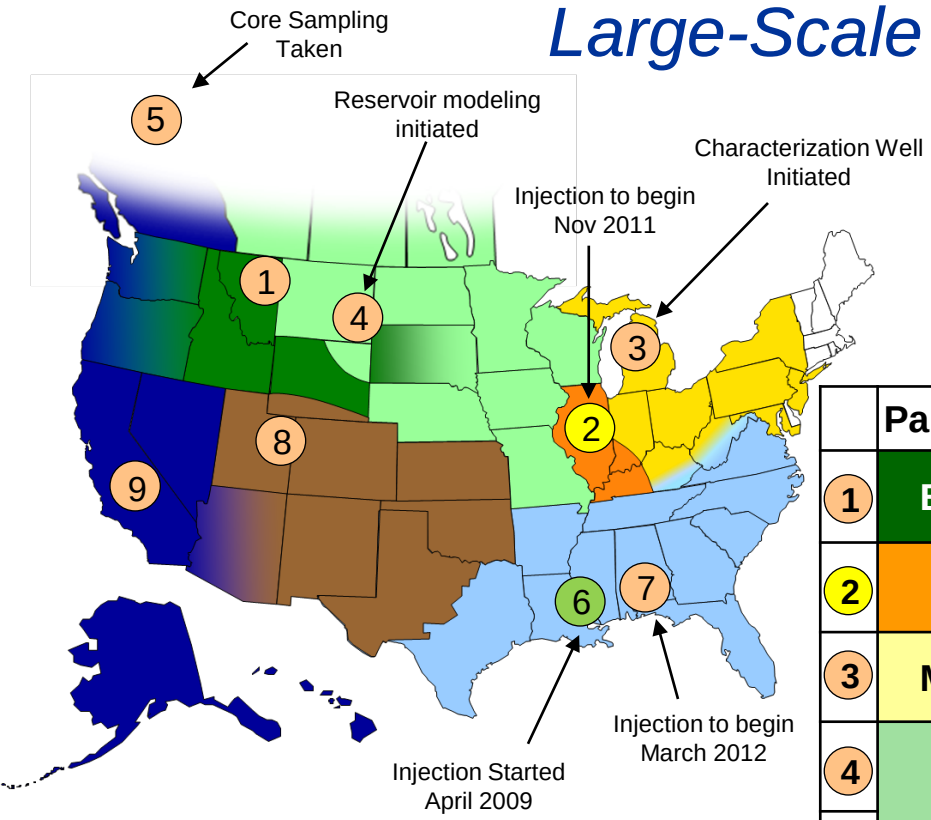
Completed 18 Injections

Over 1.35 M Tons injected

RCSP	Formation Type	Geologic Province
Big Sky	Saline 1	Columbia Basin
MGSC	Oil-bearing 2 3 4 Saline 5 Coal seam 6	Illinois Basin
MRCSP	Saline 7 8 9	Cincinnati Arch, Michigan Basin, Appalachian Basin
PCOR	Oil-bearing 10 11 Coal seam 12	Keg River, Duperow, Williston Basin
SECARB	Oil-bearing 13 Saline 14 Coal seam 15 16	Gulf Coast, Mississippi Salt Basin, Central Appalachian, Black Warrior Basin
SWP	Oil-bearing 17 18 Coal seam 19	Paradox Basin, Aneth Field, Permian Basin, San Juan Basin
WESTCARB	Saline 20	Colorado Plateau

RCSP Phase III: Development Phase

Large-Scale Geologic Tests



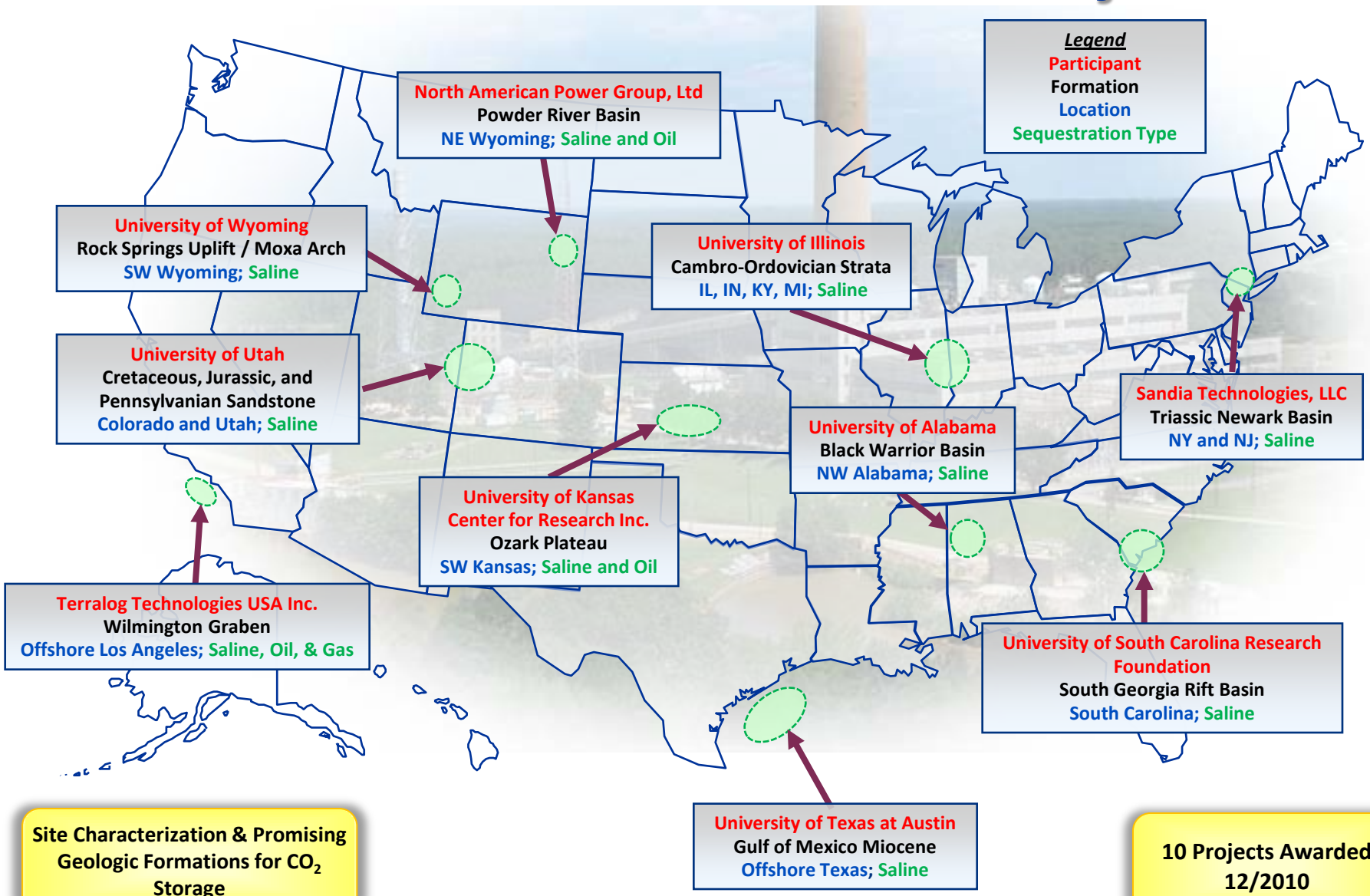
- Injection Ongoing
- 2011 Injection Scheduled
- Injection Scheduled 2012-2015

Note: Some locations presented on map may differ from final injection location

- ✓ *Injection Targets -minimum planned volumes*
- ✓ *One injection commenced April 2009*
- ✓ *Remaining injections scheduled 2011-2015*

	Partnership	Geologic Province	Storage Type
1	Big Sky	Sweetgrass Arch-Duperow Formation	Saline
2	MGSC	Illinois Basin-Mt. Simon Sandstone	Saline
3	MRCSP	Michigan Basin-St Peter SS or Niagaran Reef	Saline/Oil
4	PCOR	Powder River Basin-Muddy Formation	Oil Bearing
5		Alberta Basin-Sulphur Point Formation	Saline
6	SECARB	Interior Salt Basin-Tuscaloosa Formation	Oil/Saline
7		Interior Salt Basin-Paluxy Formation	Saline
8	SWP	Wasatch Plateau-Navajo Sandstone	Saline
9	WESTCARB	Regional Characterization	TBD

ARRA Site Characterization Projects



Site Characterization & Promising Geologic Formations for CO_2 Storage

10 Projects Awarded 12/2010

Storing CO2 in Geologic Formation Classes

2011 FOA Focused on Filling Gaps

Matrix of Field Activities in Different Formation Classes

Geologic Formation Classes	High Potential					Medium Potential				Lower or Unknown Potential	
	Deltaic	Shelf Clastic	Shelf Carbonate	Strandplain	Reef	Fluvial Deltaic	Eolian	Fluvial & Alluvial	Turbidite	Coal	Basalt (LIP)
Large Scale	–	1	–	–	1	3	–	1	–	–	–
Small Scale	3	2	4	1	2	–	–	2	–	5	1
Characterization	1	–	8	6	–	3	3	2	2	–	1

Notes:

The number in the cell is the number of investigations per depositional environment.

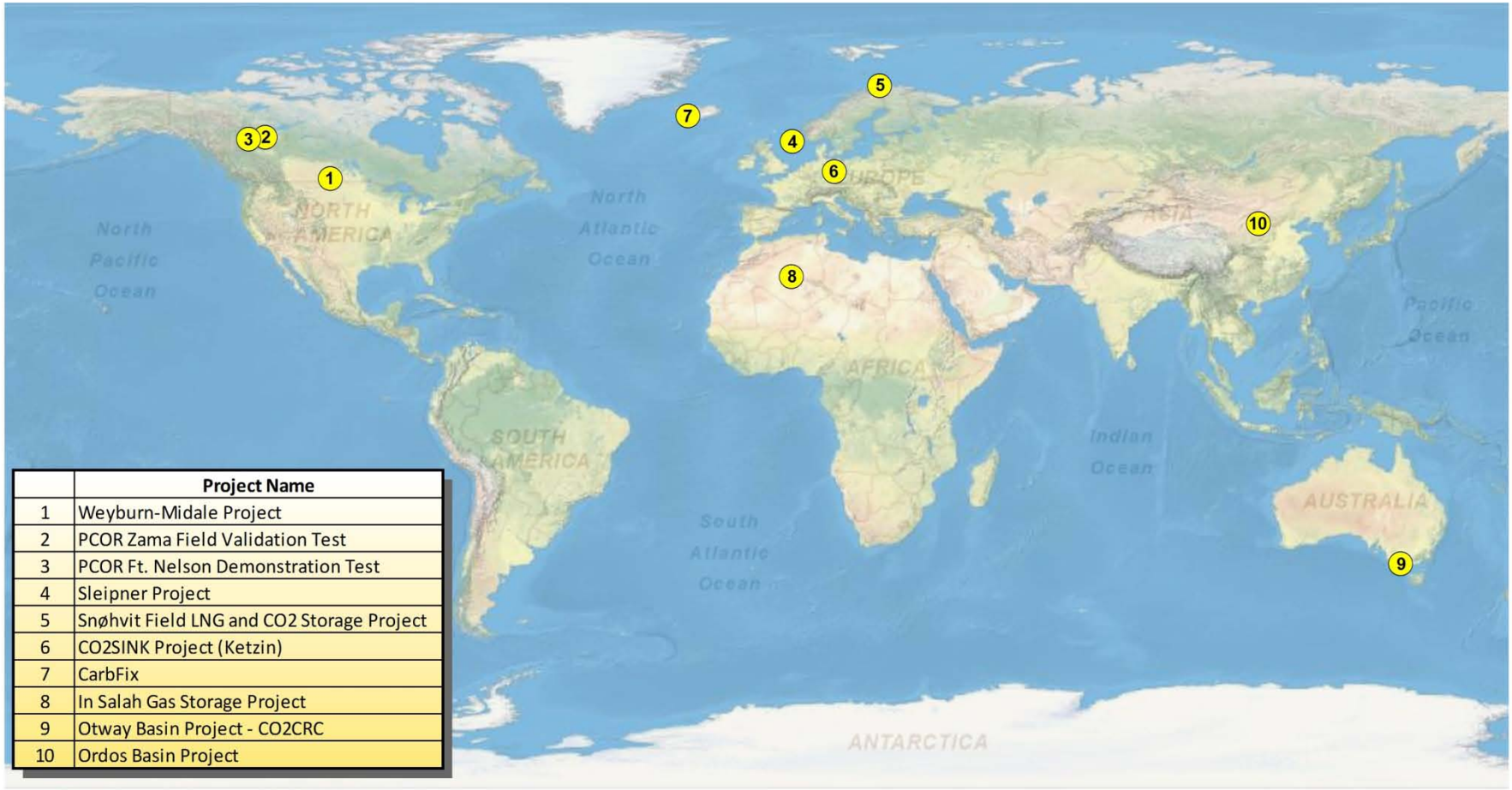
Large Scale Field Tests – Injection of over 1,000,000 tons of CO_2

Small Scale Field Tests – Injection of less than 500,000 tons of CO_2

Site Characterization – Characterize the subsurface at a location with the potential to inject at least 30,000,000 tons of CO_2

Reservoir potentials were inferred from petroleum industry data and field data from the sequestration program.

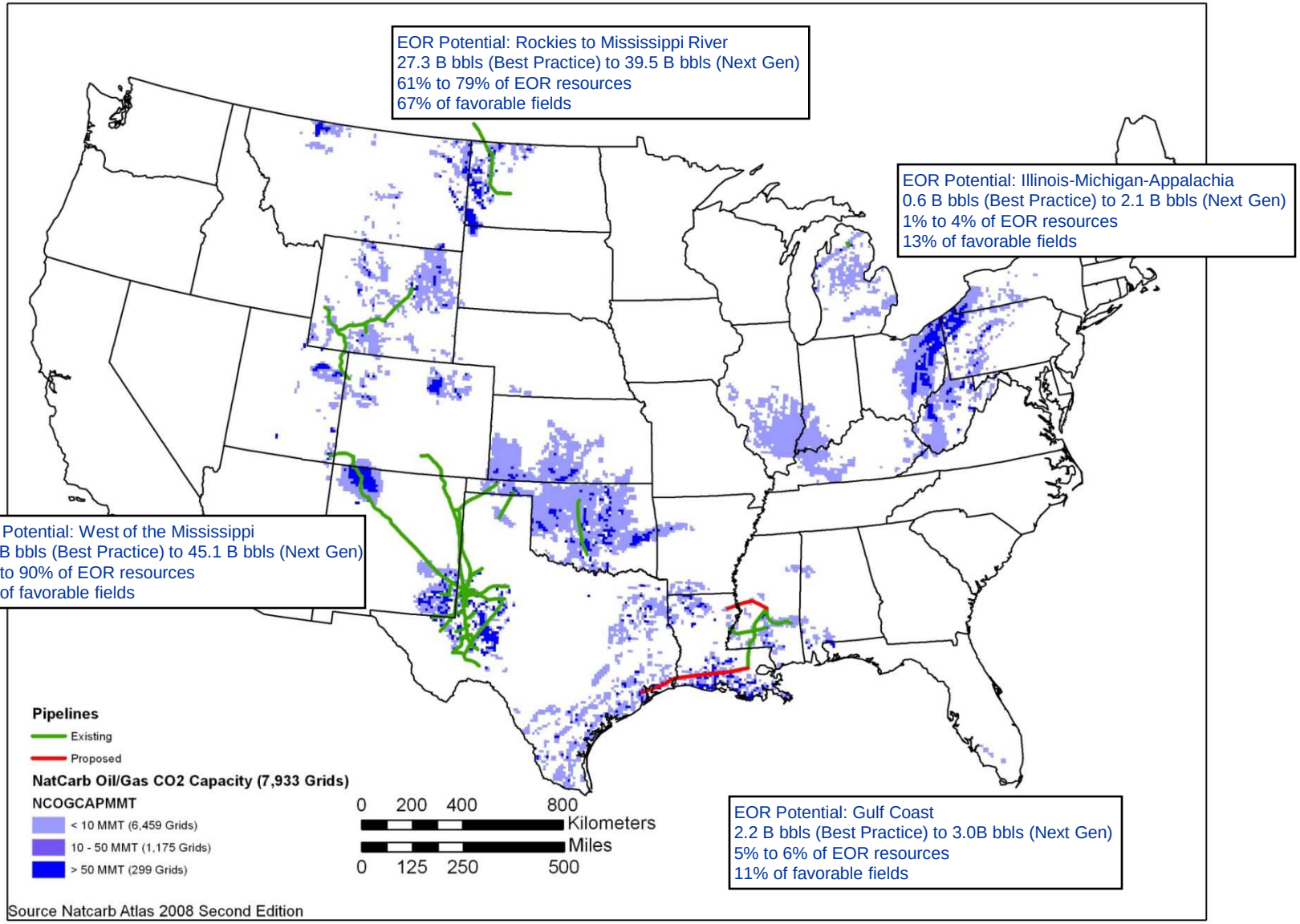
Leveraging International Geologic Storage R&D Projects



	Project Name
1	Weyburn-Midale Project
2	PCOR Zama Field Validation Test
3	PCOR Ft. Nelson Demonstration Test
4	Sleipner Project
5	Snøhvit Field LNG and CO2 Storage Project
6	CO2SINK Project (Ketzin)
7	CarbFix
8	In Salah Gas Storage Project
9	Otway Basin Project - CO2CRC
10	Ordos Basin Project

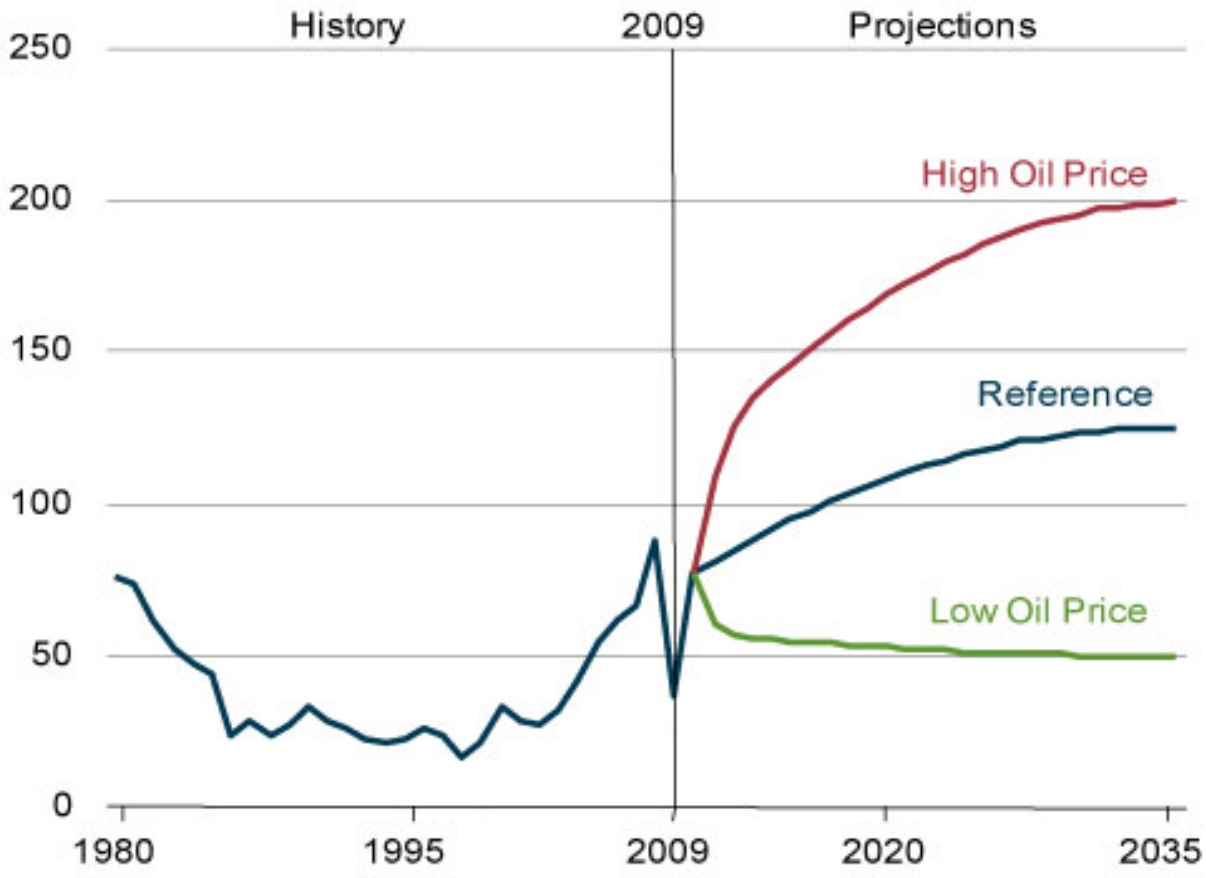
Enhanced Recovery and Storage

Enhanced Hydrocarbon Recovery



IEA Projects U.S. Crude Oil Prices

Figure 52. Average annual world oil prices in three cases, 1980-2035
(2009 dollars per barrel)

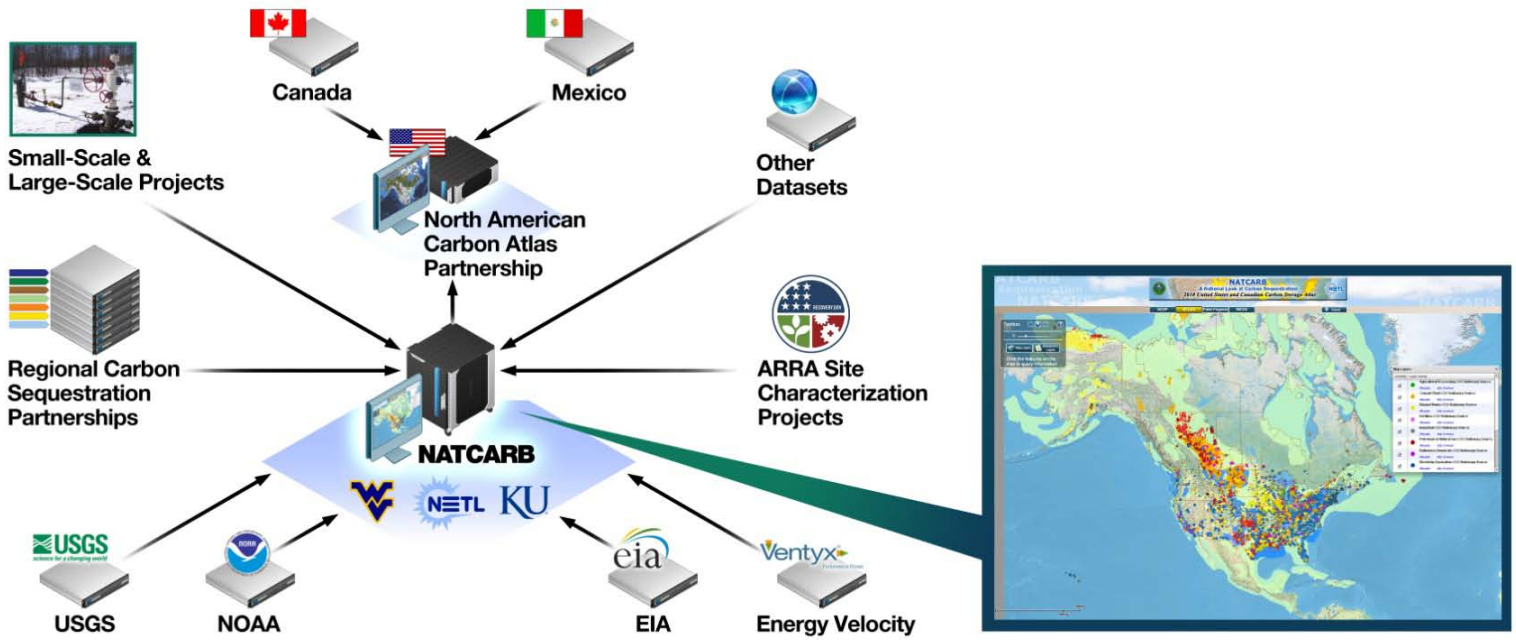


Enhanced Recovery/Storage Opportunities
…needing additional research

- **Optimizing storage during EOR**
- **Coal bed methane storage**
- **Organic shale gas storage**
- **Gas storage and pressure maintenance**
- **Geothermal working fluid**
- **Saline backup for 100% off take agreements**

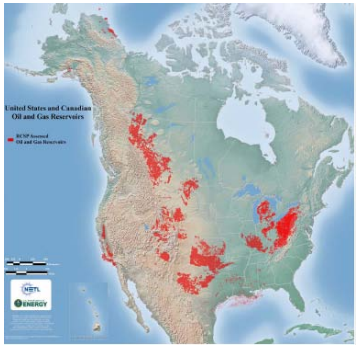
Knowledge Sharing

National Carbon Sequestration Database and Geographic Information System (NATCARB)



Hundreds of Years of Storage Potential

U.S. Emissions ~ 6 GT CO_2/yr (all sources)



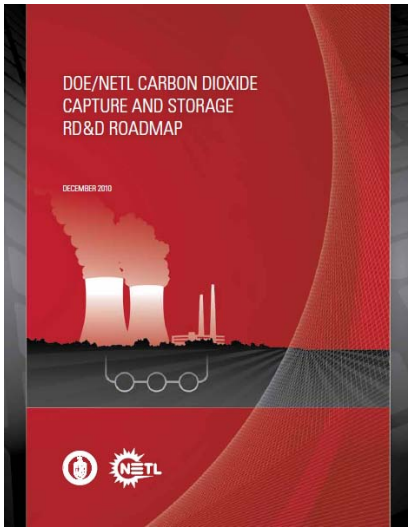
Oil and Gas Fields
143 GT CO_2
Storage Resource

Saline Formations
1,653 - 20,213 GT CO_2
Storage Resource

Unmineable Coal Seams
60-117 GT CO_2
Storage Resource

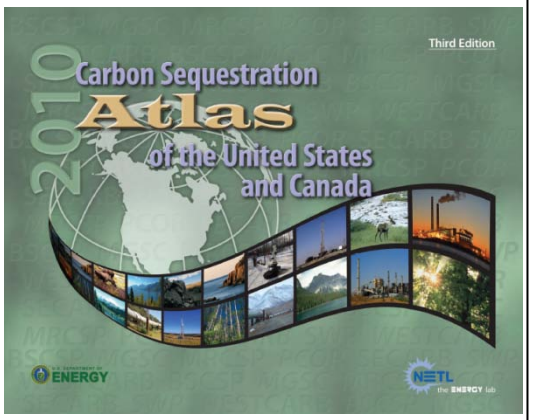
Carbon Storage
Key FY2011 Program Documents

- **DOE CCS Roadmap – Dec 2010**

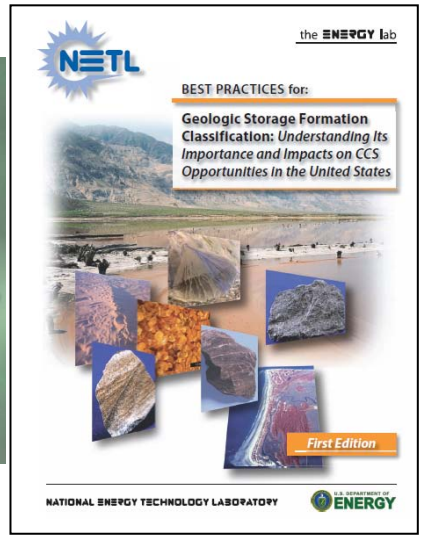


- **Carbon Sequestration (Storage)Technology Program Plan – Feb 2011**

- **2010 Carbon Sequestration Atlas of the United States and Canada – 3rd Edition**

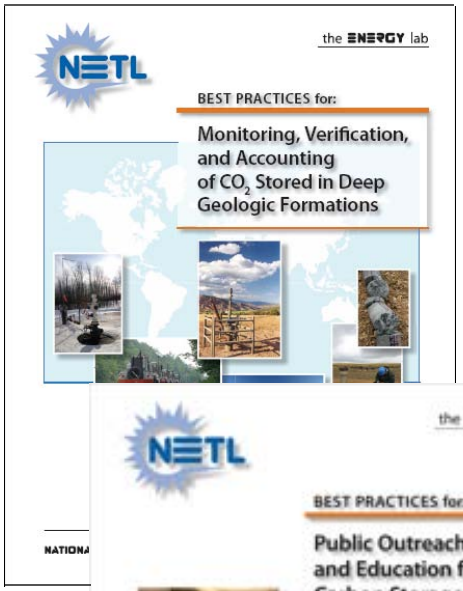


- **Best Practice Manuals**
  - Storage classes
  - Technical manuals



CCS Best Practice Manuals

Critical Requirement For Significant Wide Scale Deployment - Capturing Lessons Learned



Best Practices Manual	Version 1 (Phase II)	Version 2 (Phase III)	Final Guidelines (Post Injection)
Monitoring, Verification and Accounting	2009/2012	2016	2020
Public Outreach and Education	2009	2016	2020
Site Characterization	2010	2016	2020
Geologic Storage Formation Classification	2010	2016	2020
**Simulation and Risk Assessment	2010	2016	2020
**Well Construction, Operations and Completion	2011	2016	2020
Terrestrial	2010	**2016 – Post MVA Phase III**	

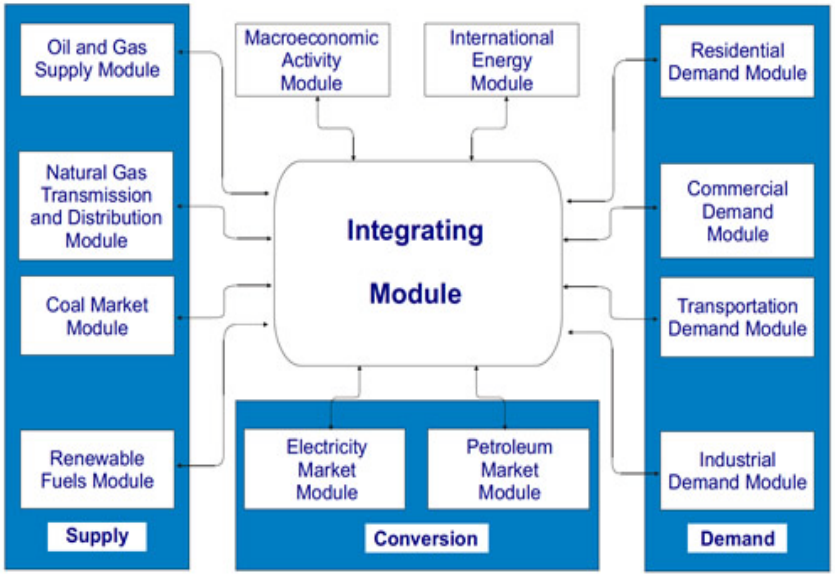
***Regulatory Issues will be addressed within various Manuals*

http://www.netl.doe.gov/technologies/carbon_seq/refshelf/refshelf.html

Assessing the Benefits of DOE R&D

Assessing Energy Policy Including CCS

- **DOE R&D Portfolio analysis (TRL)**
- **NETL is developing Carbon Transport and Storage (CTS) module**
  - Assess benefits of R&D
- **National Energy Modeling System (NEMS)**
  - project energy-economic-environmental impacts of policy through 2035

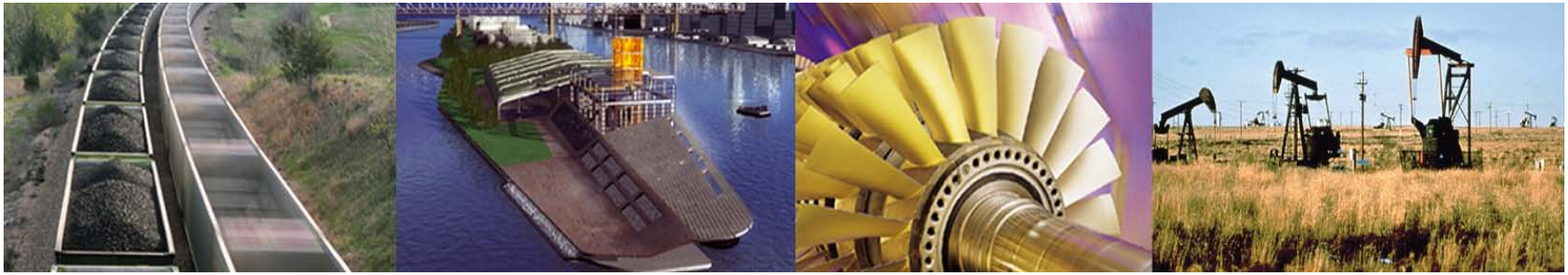


NEMS schematic (EIA)

Summary

- Carbon Storage technologies necessary for mitigating CO2 emissions globally
- There is a need to bring field projects to conclusion to address many issues R&D issues associated with storage and resource assessment
- United States well positioned to deploy and provide technology solutions for CCS

Thank you



Questions?