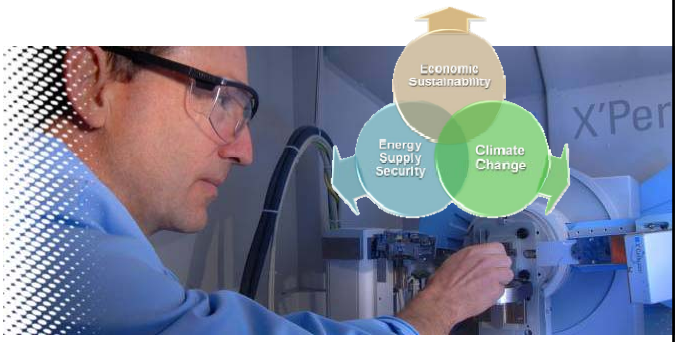
NATIONAL ENERGY TECHNOLOGY LABORATORY



DOE's Carbon Sequestration Program

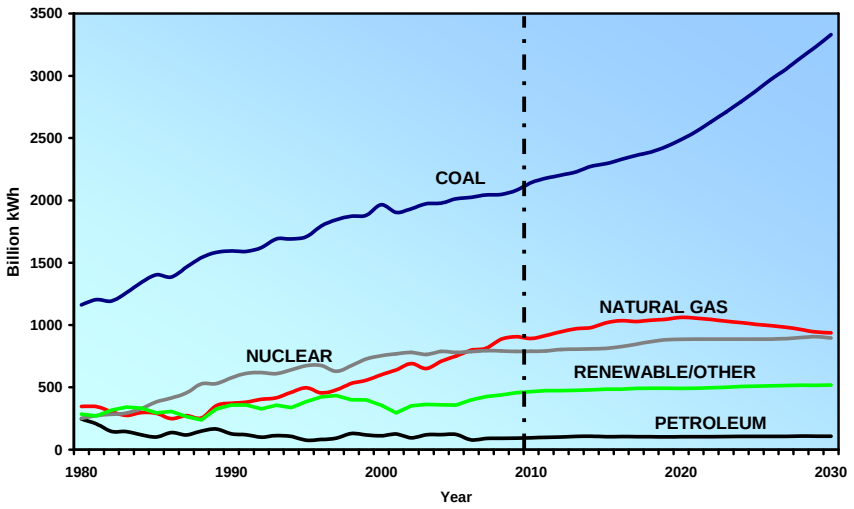
WESTCARB's Annual Business Meeting

Dawn Deel
Project Manager

Major Drivers for Sequestration

- **Global Climate Change Initiative**
- **Energy Independence and Security Act (EISA) of 2007**
- **California Global Warming Solutions Act of 2006 – AB32**
- **Northeast Regional Greenhouse Gas Initiative (RGGI)**
- **State Moratoriums on Coal Plants**
- **Senate and House Climate Bills**

Power Generation Forecast



IEA, Annual Energy Outlook 2007

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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

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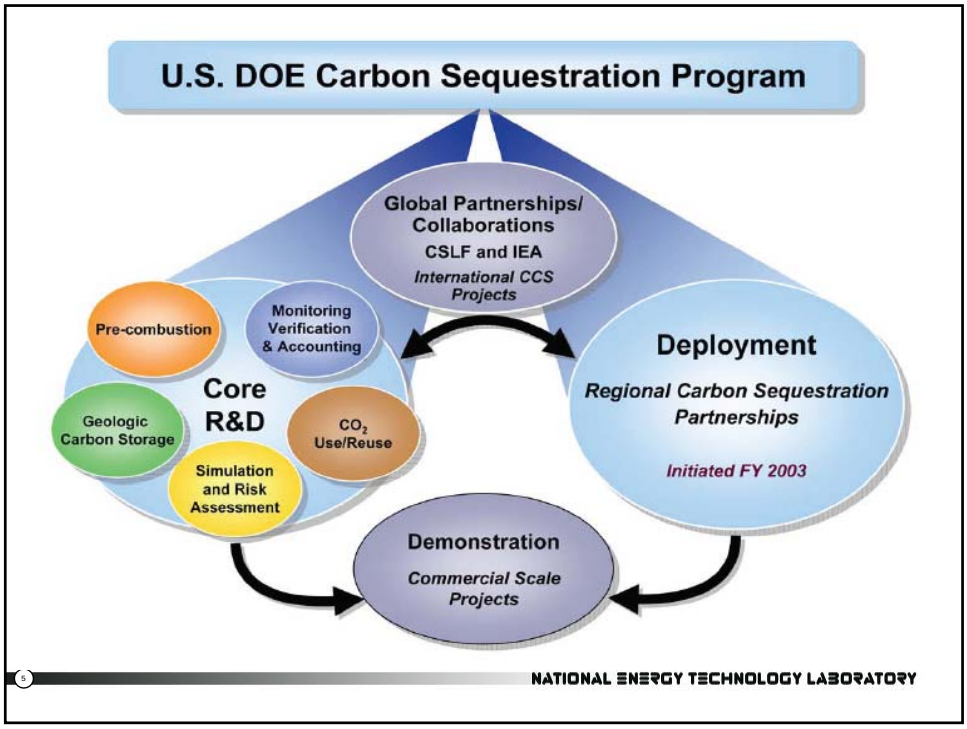
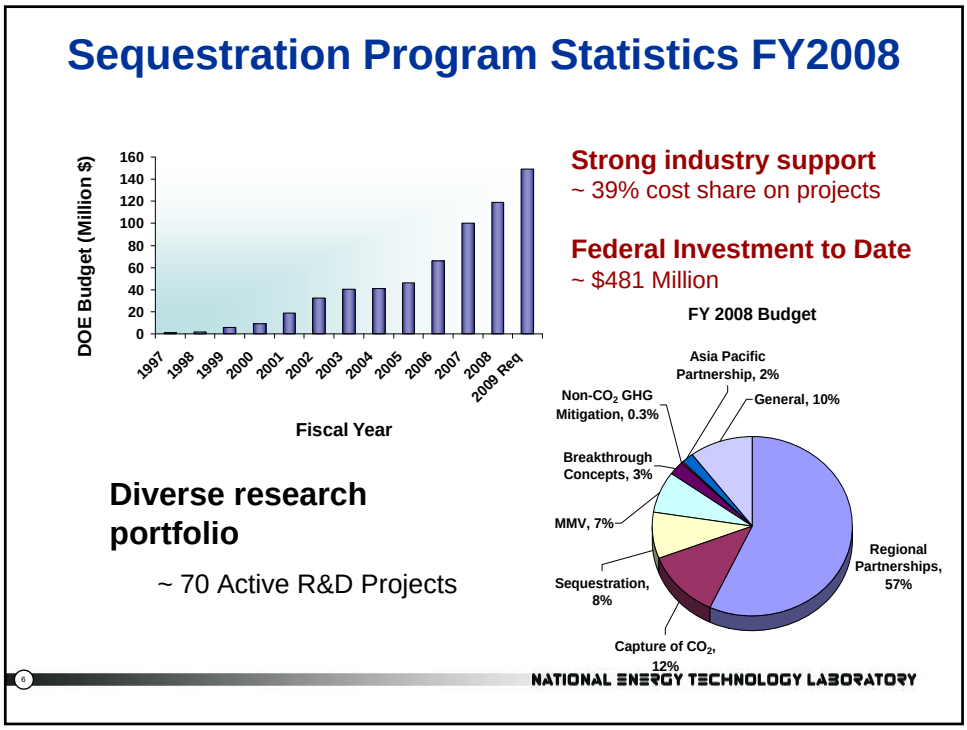

U.S. DOE Carbon Sequestration Program
Global Partnerships/ Collaborations
CSLF and IEA
International CCS Projects
Pre-combustion
Monitoring Verification & Accounting
Core R&D
Geologic Carbon Storage
CO_2 Use/Reuse
Simulation and Risk Assessment
Deployment
Regional Carbon Sequestration Partnerships
Initiated FY 2003
Demonstration
Commercial Scale Projects
5
NATIONAL ENERGY TECHNOLOGY LABORATORY


Sequestration Program Statistics FY2008
DOE Budget (Million $)
160
140
120
100
80
60
40
20
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009 Req
Fiscal Year
Strong industry support
~ 39% cost share on projects
Federal Investment to Date
~ $481 Million
FY 2008 Budget
Asia Pacific Partnership, 2%
General, 10%
Non-CO_2 GHG Mitigation, 0.3%
Breakthrough Concepts, 3%
MMV, 7%
Sequestration, 8%
Capture of CO_2, 12%
Regional Partnerships, 57%
Diverse research portfolio
~ 70 Active R&D Projects
6
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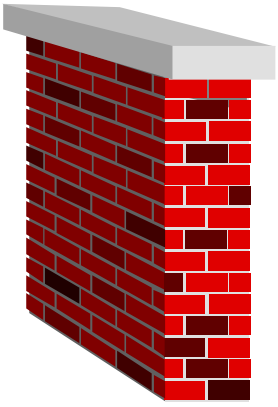
Key Challenges to CCS

- **Sufficient Storage Potential ?** **Turning resource into reserve**
- **Cost of CCS ?** **Capture and Compression**
- **Permanence ?** **Prove it!**
- **Infrastructure ?** **Time and Money**
  - Transport Lines
  - Permitting
  - Regulatory framework
  - Public Acceptance (NIMBY → NUMBY)
  - Liability
  - Best Practices
  - Human Capital Resources



Program helping to address challenges – either specific project, participation in working groups, or through Regional Partnerships

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Carbon Sequestration Program Goals

- **Deliver technologies & best practices that validate:**
  - 90% CO_2 capture
  - 99% storage permanence
  - <10% increase in COE (pre-combustion capture)
  - <30% increase in COE (post- and oxy-combustion)
  - +/-30% storage capacity

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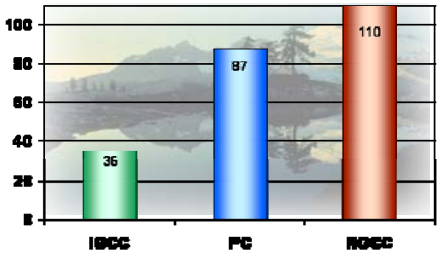
CO_2 Capture Is Expensive!

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

Currently refining cost target for PC plants considering potential improvements in:

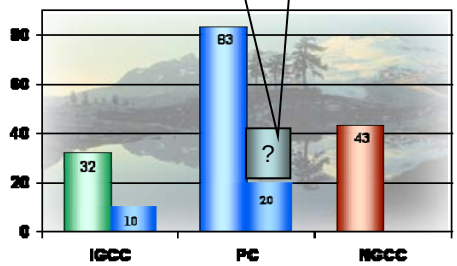
- Capital cost
- Fixed operating cost
- Variable operating cost
- Energy cost
- Transport, storage & monitoring costs

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



Note: CO_2 capture costs based on use of Selexol process for IGCC and MEA for PC and NGCC.

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; NETL, May 2007.*

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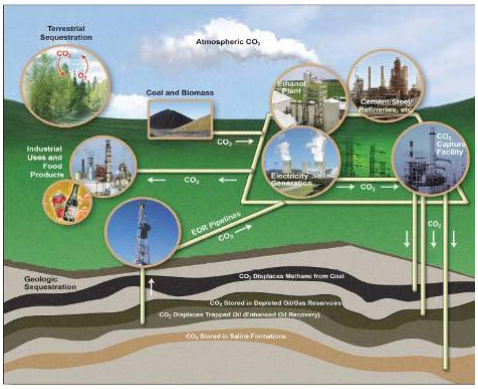
Summary of Storage R&D Activities

The goal of DOE research in this focus area is to develop technologies to safely, permanently, and cost effectively store CO_2 in geologic formations and monitor its movement and behavior.

Critical Challenges

- Well design and management
- Maintaining & verifying well integrity
- Improved well materials
- Maximizing CO_2 injectivity & storage capacity
- Long-term storage security
- Management of produced water
- Increased mineralization of CO_2
- Scale-up to commercial size projects
- Development of balance regulatory framework



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Monitoring, Verification, and Accounting (MV&A)

Research Areas

- **Atmospheric and Remote Sensing**
- **Near-Surface Monitoring**
- **Well-Bore Monitoring**
- **Deep Subsurface Monitoring**
- **Accounting Protocols**

Critical Challenges

- **Quantification of stored carbon**
- **Verification of stored CO_2**
- **Development of robust, flexible accounting protocols**
- **Reducing cost of near-term and long-term monitoring**
- **Distinguishing leaks from natural CO_2 fluxes**
- **Design of monitoring network**
- **Improved instrumentation**

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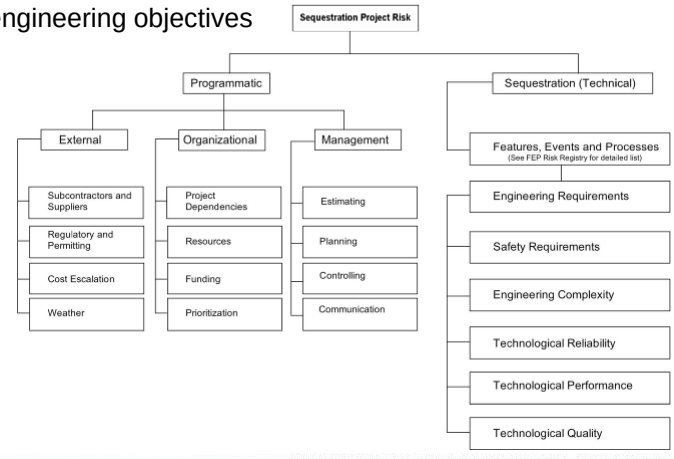
Different Kinds of Risks Are Important

- Each project required to conduct comprehensive risk analysis
- Programmatic risks that impede project progress/cost
- Technical risks inherent to the scientific and engineering objectives of a project



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Prioritization and Mitigation Strategies

- **Risks must be prioritized based on impact and probability**
- **Continuously monitor risks during project lifecycle**
- **Develop mitigation strategies for major risks**
  - Leakage
  - Well bore leakage
  - Drill rig availability
  - Materials

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Regional Carbon Sequestration Partnerships

"Developing the Infrastructure for Wide-Scale Deployment"

14 LABORATORY

Regional Carbon Sequestration Partnerships

westcarb.org	**California Energy Commission** http://www.westcarb.org/
Southwest Regional Partnership on Carbon Sequestration	**New Mexico Institute of Mining and Technology** http://www.southwestcarbonpartnership.org/
BIGSKYCARBON SEQUESTRATION PARTNERSHIP	**Montana State University** http://www.bigskyco2.org/
The Plains CO2 Reduction Partnership PCOR	**University of North Dakota, Energy & Environmental Research Center** http://www.undeerc.org/pcor/
MGSC	**University of Illinois, Illinois State Geological Survey** http://www.sequestration.org/
MRCSP	**Battelle Memorial Institute** http://www.mrcsp.org/
Southeast Regional Carbon Sequestration Partnership	**Southern States Energy Board** http://www.secarbon.org/

Characterization Phase
- 24 months (2003-2005)
- 7 Partnerships (40 states)
- $16M DOE funds

Validation Phase
- 4 years (2005-2009)
- Field validation tests
  - Over 20 Geologic
  - 11 Terrestrial
- $112M DOE funds
- $43M cost share

Deployment Phase
- 10 years (2008-2017)
- Seven large volume injection tests
- ~ $700M DOE and cost share

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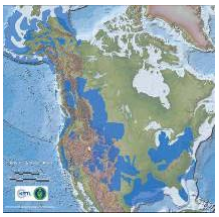
National Atlas Highlights

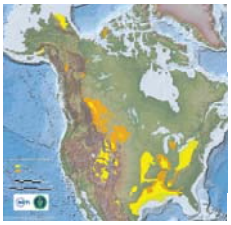
Adequate Storage Projected

Regional Stationary Emissions ~3,276 million metric tons

Oil and Gas Fields



Saline Formations



Unmineable Coal Seams

Regional CO_2 Storage Potential (Million Metric Tons)

Sink Type	Low	High
Saline Formations	3,284	12,210
Unmineable Coal Seams	171	197
Oil and Gas Fields	130	130

Conservative Resource Assessment

Hundreds of Years of Storage Potential

Available in November 2008

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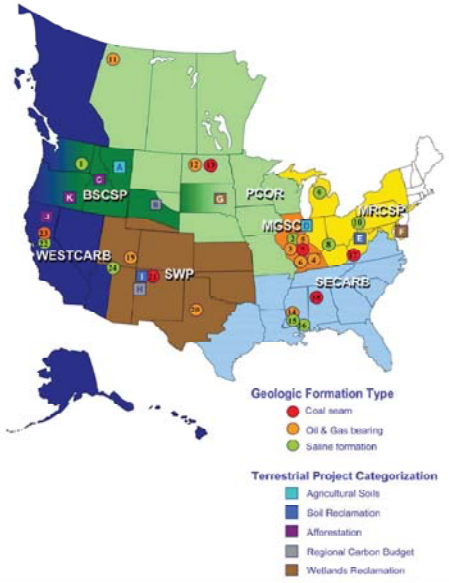
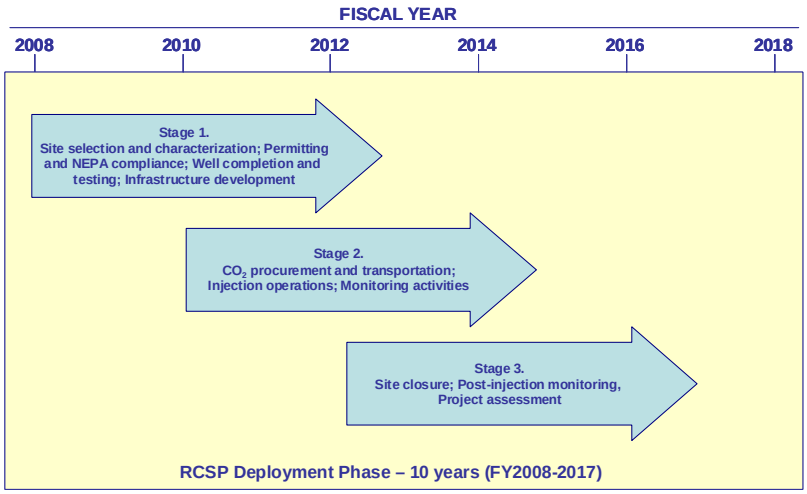
Validation Phase CO_2 Storage Projects



	Partnersh	Geologic Provinc Project Location	Geologic: Total CO Iniection (tons CO	Geologic: Approximate Depth (feet)	Terrestrial: Estimated CO Capacity
		Columbia Basin	3,000-5,000	2,500-4,000	
A		North Central MT			60 Mt over 20 years
B		Eastern WY			30 MT over 10 years
C		Regionwide			640-1,040 Mt over 80 rs
	MGSC	Illinois Basin	10,000	7,000-8,600	
		Illinois Basin	300	1,550	
		Illinois Basin	300	1,549	
		Illinois Basin	300	1,548	
		Illinois Basin	300	1,551	
		Illinois Bin	750	1,000	
		Cincinnati Arch	1,000-3,000	3,200-3,500	
	MRCSP	Michigan Basin	3,000-20,000	3,200-3,500	
		Appalachian Basin	1,000-3,000	5,900-8,300	
D		Regionwide			25 Mt over 20 years
E		Regionwide			100 Mt over 20 years
F		Cambridge MD			TBD
		Keg River Formatior	250,000 tons CO w/90,000 tons SH	5,000	
		Duperow Formation	<1,000	10,000-10,500	
		Williston Basin	<1,000	1,600-1,800	
G		Great Plains wetlands complex (PI			14.4 Mt
		Gulf Coas (stacked test	500,000	10,066	
		Gulf Coas	30,000	10,300	
		Mississippi Salt Basi	3,000	8,600	
		Central Appalachian	1,000	1,600-2,300	
		Black Warrior Basin	1,000	1,500-2,500	
		Paradox Basin, Aneth	450,000-750,000	5,600-5,800	
	SWP	Permian Basin	900,000	5,800	
		San Juan Basin	75,000	3,000	
H		Regionwide			TBD
I		San Juan Basin Coa Fairway (Navajo City,			TBD
		Sacramento Basin	2,000	8,000	
		Colorado Plateau	2,000	4,000	
J		Shasta County, CA			4,600 Mover 80 years (CA)
K		Lake County, OR			900 Mt over 80 years (OR)

Deployment Phase

Scaling Up Towards Commercialization



$470M DOE - over $200M cost share

Project Goals

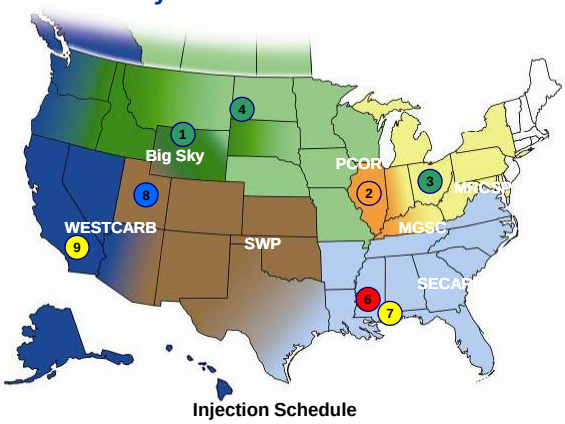
- **GOAL 1** - Demonstrate that storage capacity and injectivity are present in the formation that will permit storage for long duration commercial projects
- **GOAL 2** – Demonstrate permanence of CO_2 such that the CO_2 will be contained in the target formations and not impact Underground Sources of Drinking Water and/or release to the atmosphere
- **GOAL 3** - Determine the areal extent of the plume and effects of pressure influence on the plume
- **GOAL 4** - Assess the potential hazards and develop mitigation strategies
- **GOAL 5** - Develop Best Practice Manuals for site selection, characterization, operational, and closure practices
- **GOAL 6** - Engage the public and support the development of future regulations for CCS

Deployment Phase
Summary of Large Scale Projects

- **6 awarded projects with the Regional Partnerships**
- **Sources**
  - Natural gas processing facilities, including H_2S ~15%
  - 2 Ethanol plants
  - At least 2 post-combustion capture technologies
  - Oxyfuel combustion pilot power plant
  - Up to 1MT of CO_2 per year provided from each source
- **Geology**
  - 6 deep Saline formations, carbonates and sandstones 3,000 to 13,000 feet deep throughout the United States
  - 1 depleted oil fields (10,000 ft deep)
- **Comprehensive site characterization, modeling, monitoring, and risk assessment**

Deployment Phase

5 *Injection Schedule*



Injection Schedule

- 2008 Injection Scheduled
- 2009 Injection Scheduled
- 2010 Injection Scheduled
- 2011 Injection Scheduled

	Partnership	Geologic Province	Formation Type
1	Big Sky Carbon	Triassic Nugget Sandstone/ Moxa Arch	Saline
2	MGSC	Mt. Simon Sandstone	Saline
3	MRCSP	Mt. Simon Sandstone	Saline
4	PCOR	Williston Basin	Oil Bearing
5	PCOR	Devonian Age Carbonate Rock	Saline
6		Lower Tuscaloosa Formation Massive Sand Unit	Saline
7			
8	SWP	Regional Jurassic and Older Formations	Saline
9		San Joaquin Basin	Saline

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Working Groups

- **Geologic and Infrastructure**
- **Monitoring**
- **Simulation**
- **Capture and Transportation**
- **GIS and Database**
- **Public Outreach**
- **Regulatory Working Group**
  - IOGCC
- **Economics and Markets**

- **Benefits:**
  - Standard approaches (Best Practices)
  - Technology transfer between Partnerships and partners

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Satisfying CCS Injection Regulations

- **NEPA Compliance**
  - Each project undergoing NEPA review
  - Environmental Assessments planned for all sites
- **UIC Permitting**
  - Saline project to be permitted as Class V or Class I "non-hazardous"
  - EOR project – Class II
- **Acid Gas Disposal – Canada's jurisdiction under existing acid gas disposal well regulations**

Public Outreach and Education

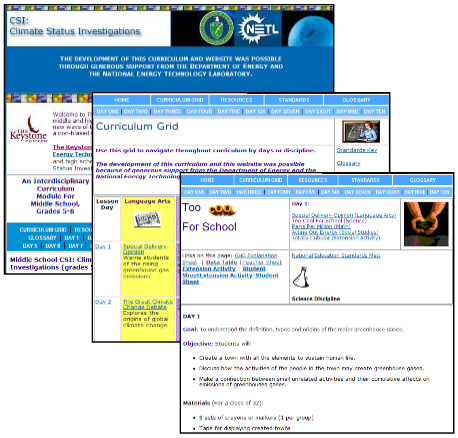
- **Public outreach and education is essential**
- **Each RCSP has developed a team approach consisting of technology and communications experts**
- **Phase I and II provided significant "learning by doing" in approaches and materials**
- **Lessons for Phase III:**
  - Learn about stakeholders' concerns and perceptions
  - Develop materials that speak to the stakeholders (not just to the research team)
  - Trust – gained through openness and transparency key
- **Research and Coordination:**
  - Focus groups and interviews with stakeholders and partners
  - Mediated modeling
  - Outreach Working Group (OWG) calls

Websites

Information Materials

Posters, Fact Sheets, Video

Educational Materials

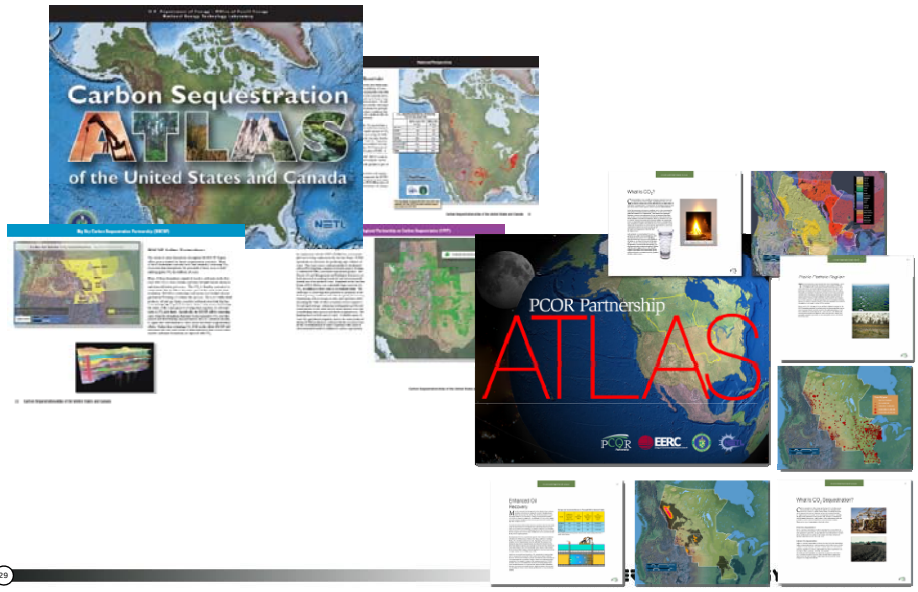


The Keystone Science School Curriculum trains teachers and gives detailed lesson plans and information:
http://www.keystonecurriculum.org/

From the PCOR site, several links for educators including The Wisconsin materials
http://www.uwsp.edu/cnr/wcee/keep/

CCS Models

Carbon Atlases



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Public Information Meetings

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Growing Membership

"Join your local Partnership"

160 organizations in Phase I

349 organizations in Phases II and III

Organizations Involved	Number		Organizations Involved	Number
Chemical Companies	5		Land Management/Development Company	2
CO_2 Trading Organizations	3		Law Firm	2
Coal Companies	8		Local Agencies	4
Electric Utilities	1		Media/Outreach	6
Electric Utilities	52		National Laboratories	10
Engineering and Research Firms	44		Oil & Gas Companies	36
Environmental NGOs	11		Other State Agencies	51
Foreign Government Agencies	10		Pipeline Company	1
Forest Products Companies	4		State Geologic Surveys	18
Governmental Advisory Groups	2		U.S. Federal Agencies	6
Indian Nations	4		University and Academic Institutions	47
Industry Trade Groups	22		**Total**	**349**

Moving Towards Commercialization