



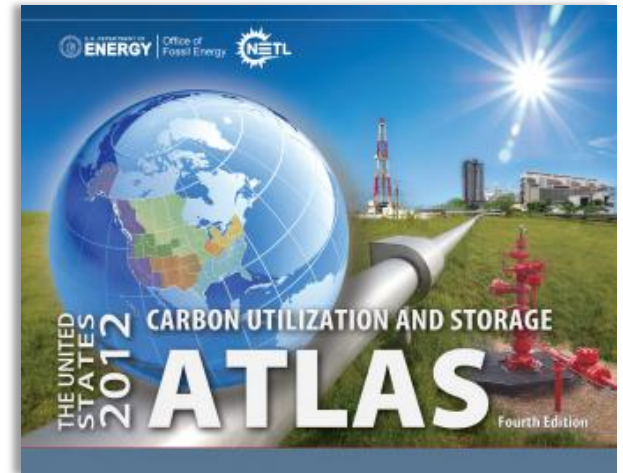
United States Energy Association (USEA):
*Briefing on the U.S. 2012 Carbon Storage
and Utilization Atlas and Partnerships*

Traci D. Rodosta, Carbon Storage Technology Manager
February 21, 2013

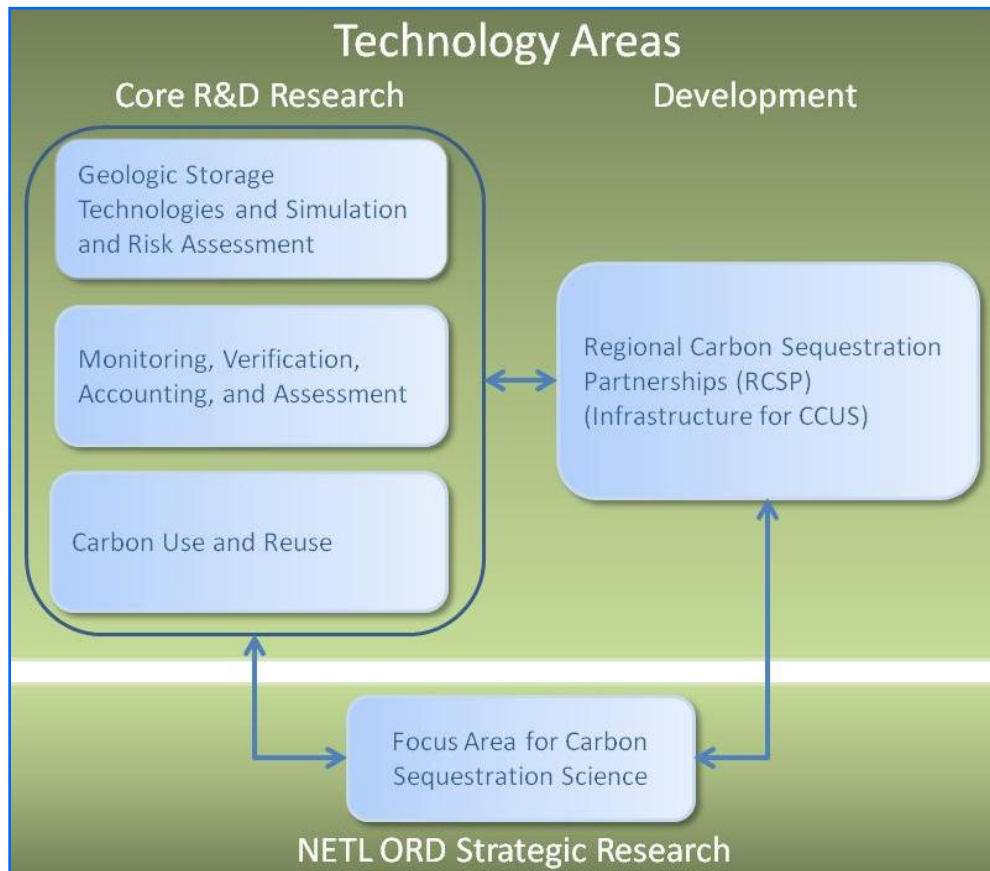


The U.S. 2012 Carbon Utilization and Storage Atlas (Atlas IV)

- **Released in December 2012**
- Updated CO₂ stationary source emission estimates and storage potential of various geologic storage types:
 - at least 2,400 billion metric tons total storage resource
 - 3.3 billion metric tons annual CO₂ emissions
- Outlines DOE's Carbon Storage Program
- Showcases updated info about Regional Carbon Sequestration Partnership (RCSP) CO₂ storage activities
- New information from the ARRA Site Characterization projects
- Highlights CCS collaborations and worldwide CCS projects



U.S. DOE's Office of Fossil Energy Carbon Storage Program



Program Goals

- Account for 99% CO₂
- Improve Storage Efficiency
- Estimate Capacity +/- 30%
- Best Practices Manuals

Benefits

- Mitigate GHG Emissions
- Credits for CO₂ Storage
- Increased Oil/NG Recovery
- Reduce Capital and O&M Costs
- Reduce Environmental Footprint

U.S. 2012 Carbon Utilization and Storage Atlas

Regional Carbon Sequestration Partnership (RCSP) Updates

- RCSP Sections include 10 pages
- First 6 pages: Overview; Sources; Oil and Gas Reservoirs; Saline Formations; Unmineable Coal; Phase III Field Project
- Remaining 4 pages optional content such as: Additional Phase III page; Commercialization potential in the region; Outreach; Well Drilling; Permitting/Regulation; MVA; Risk Analysis; Modeling; Basalt; Shale



Denbury's Citronelle Oil Field



SECARB Early Test

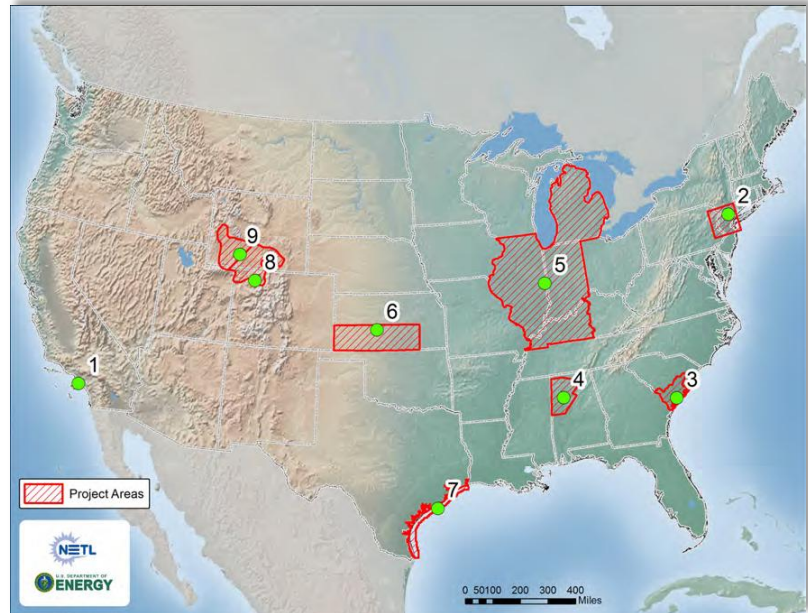


Illinois Basin-Decatur Project

U.S. 2012 Carbon Utilization and Storage Atlas

ARRA Site Characterization Project Updates

- Characterizing promising geologic formations:
 - Saline Formations
 - Oil and Natural Gas Reservoirs
 - Unmineable Coal Seams
- Projects provide insight into potential for geologic reservoirs across U.S. to safely and permanently store CO₂
- Critical projects because they advance DOE's efforts to develop national assessment of CO₂ storage resource estimates

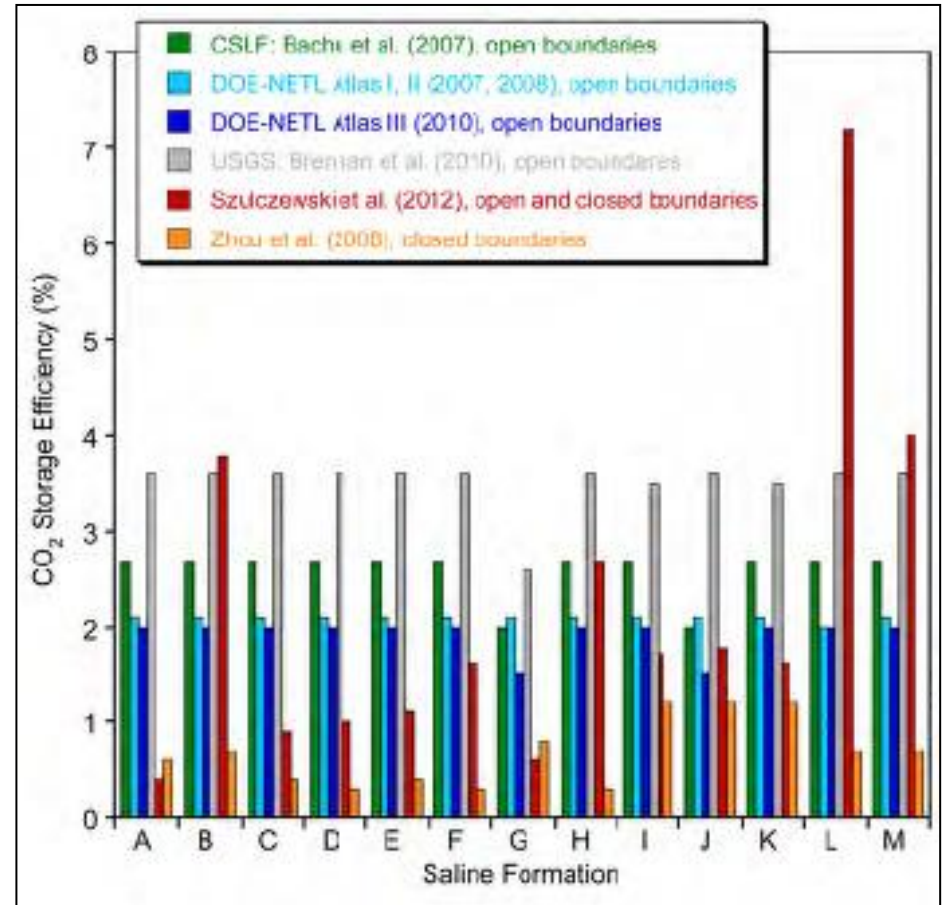


1	GeoMechanics Technologies
2	Sandia Technologies
3	South Carolina Research Foundation
4	University of Alabama
5	University of Illinois
6	University of Kansas Center for Research
7	University of Texas at Austin
8	University of Utah
9	University of Wyoming

U.S. 2012 Carbon Utilization and Storage Atlas

Comparison of Publicly Available Methodologies

- **Comparison of 13 Saline Formation data sets**
 - Szulczewski et al./ 2012
- **6 Methodologies**
- **Assumptions**
 - Pressure and Temperature were adequate for CO₂ to be supercritical
 - Suitable Seal to limit vertical flow
 - Combination of hydrogeologic conditions isolates the CO₂ within the saline formation
 - Open and closed systems
- **Results included in the Atlas IV**



U.S. 2012 Carbon Utilization and Storage Atlas

Systems Analysis Saline and EOR Cost Models

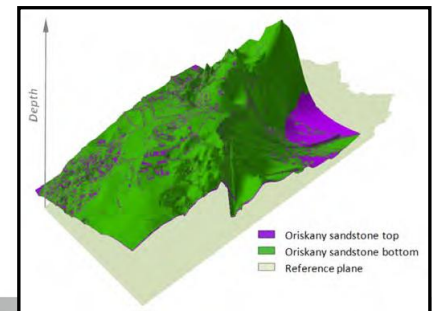
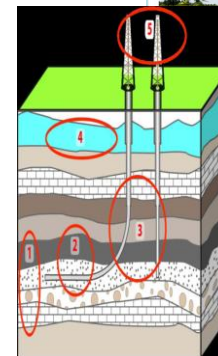
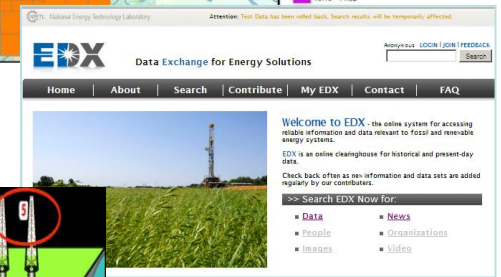
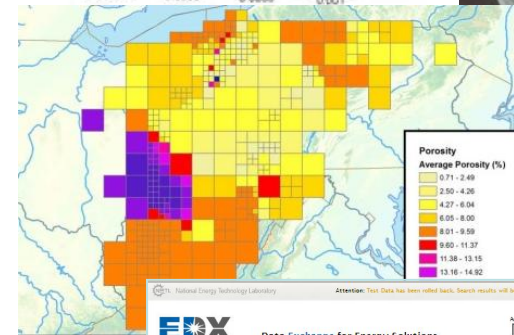
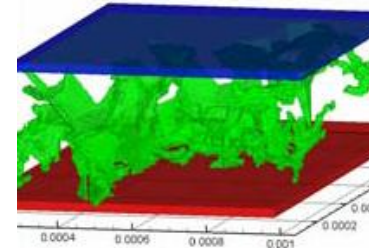
CO₂ Transport and Storage (CTS) Cost Models being developed that estimates revenues and capital, operating, and financial costs for a CO₂ storage project (Beta-testing, 2013/2014 release)

- **CTS—Saline Cost Model**
 - Costs occur in one or more of the five storage project stages
 - Simplified reservoir engineering linked with database (saline fm)
 - Estimate costs for a single project or cycle through database to generate a breakeven CO₂ price and capacity
- **CTS—EOR Cost Model**
 - Simulates (CO₂ Prophet) inputs and outputs incorporating oil reservoir database (EIA) for single pattern CO₂-EOR facility
 - Model includes costs for complying with EPA Subpart UU and Subpart RR
 - Estimate costs for single project or cycle through database to generate a break-even oil price and oil output

U.S. 2012 Carbon Utilization and Storage Atlas

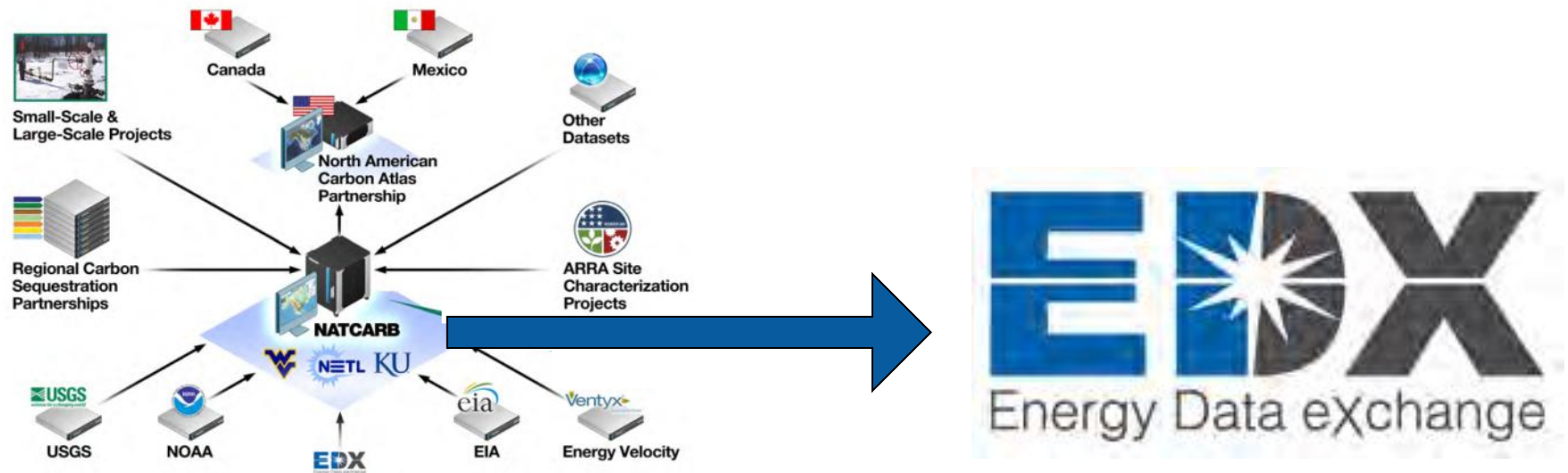
Focus Area for Carbon Sequestration Science (R&D)

- **Flow Properties of Reservoirs and Seals** – *assessing the impact of chemical reactions and geomechanics on injectivity and storage permanence*
- **Fundamental Processes and Properties** – *improving our ability to predict capacity, injectivity, and storage permanence by better understanding reaction kinetics and fluid properties*
- **Estimates of Storage Potential** – *methodologies for predicting storage capacity to improve accuracy and allow for use in alternative reservoirs and comparison studies of existing methodologies*
- **Verifying Storage Performance** – *subsurface and near-surface monitoring technologies to verify storage permanence and track plume movement*
- **Geospatial Data Resources** – *improve access to geospatial data both for public use (NATCARB) as well as for researchers (EDX)*



U.S. 2012 Carbon Utilization and Storage Atlas

NATCARB and EDX



National Carbon Sequestration Database and Geographic Information System (NATCARB)

- Data Downloads
- Custom Map Requests
- The NATCARB Viewer is available at: <http://www.natcarbviewer.com>

Energy Data eXchange (EDX)

- Developed by NETL's Office of Research and Development
- Online research collaboration and coordination effort providing access to a variety of research datasets
- EDX is available at <http://edx.netl.doe.gov>

U.S. 2012 Carbon Utilization and Storage Atlas

North American Carbon Atlas Partnership (NACAP)

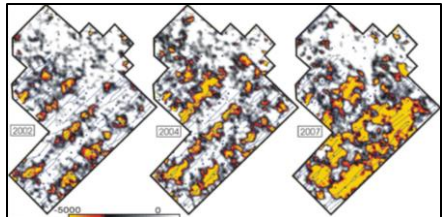
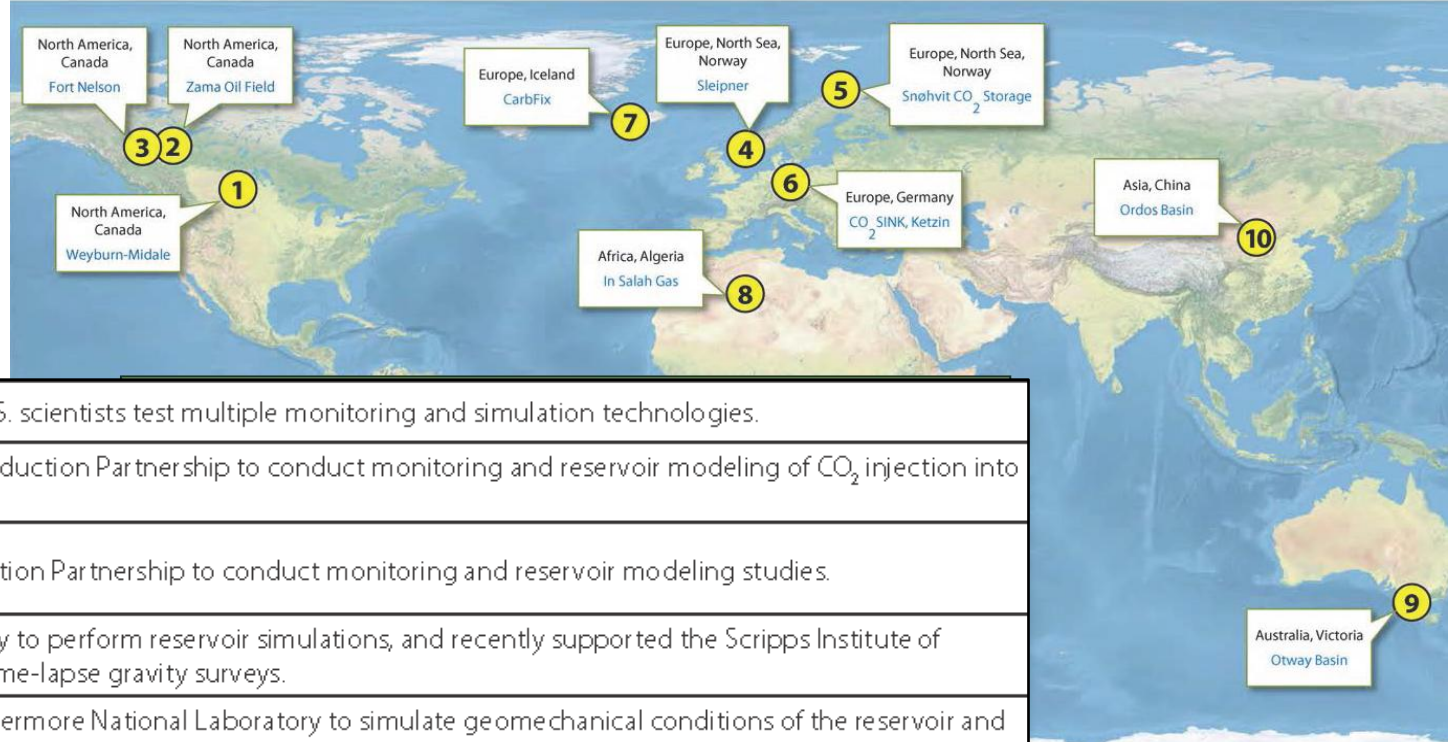
Joint effort between Canada, Mexico, and the United States to publish a resource of data on CCS technologies, issues, and progress toward solutions

- **NACAP's Objective:**
 - Identify, gather, and **share** data of CO₂ sources and geologic storage potential
- **Development of GIS-based CO₂ sources and storage database**
- **3 North American Products**
 - North American Carbon Storage Atlas (NASCA)
 - NASCA Website www.nacsap.org
 - NASCA Viewer



World-wide CCS Collaborations

Leveraging International Geologic Storage R&D Projects



1	DOE is a lead sponsor and U.S. scientists test multiple monitoring and simulation technologies.
2	Supporting the Plains CO ₂ Reduction Partnership to conduct monitoring and reservoir modeling of CO ₂ injection into pinnacle reefs.
3	Supporting Plains CO ₂ Reduction Partnership to conduct monitoring and reservoir modeling studies.
4	Supporting Indiana University to perform reservoir simulations, and recently supported the Scripps Institute of Oceanography to conduct time-lapse gravity surveys.
5	Supporting the Lawrence Livermore National Laboratory to simulate geomechanical conditions of the reservoir and caprock.
6	Supported Lawrence Berkeley National Laboratory to deploy downhole monitoring technology based on thermal perturbation sensors.
7	Supporting Columbia University Lamont-Doherty Earth Observatory to test tracer methods to assess trapping mechanisms in basalt formations.
8	Supporting the Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory to test field and remote sensing monitoring technologies and modeling geomechanical and geochemical reservoir processes.
9	Supporting scientists at Lawrence Berkeley National Laboratory to test multiple monitoring technologies at depleted gas field and saline formations.
10	Supporting West Virginia University and Lawrence Livermore National Laboratory to assess capacity for storage, and simulating hydrogeologic and geochemical reservoir conditions.



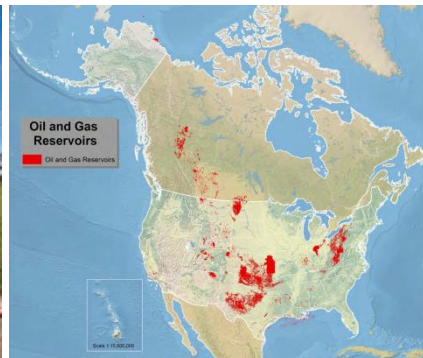
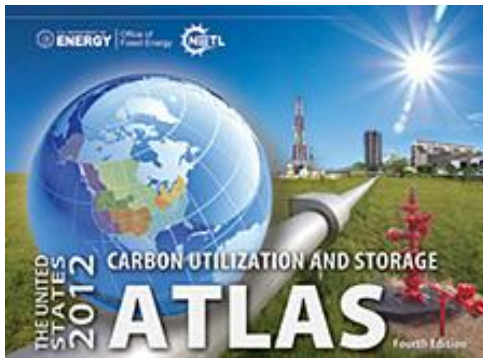
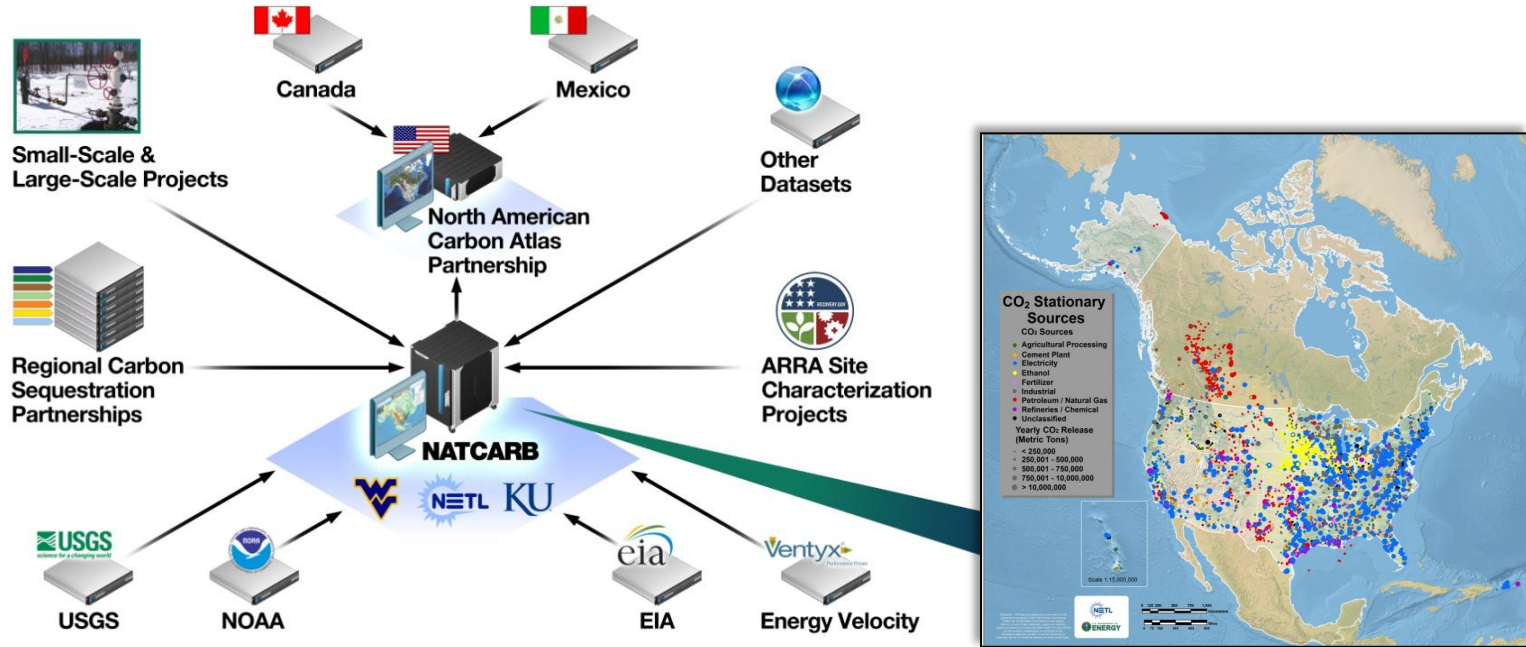
U.S. 2012 Carbon Utilization and Storage Atlas

Updates Every Two Years

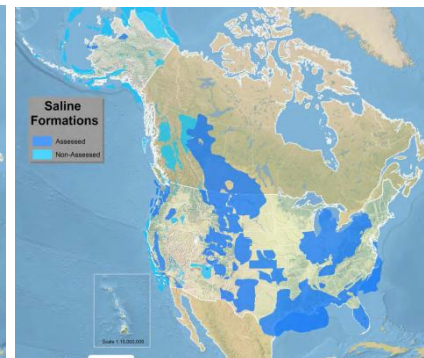
- NATCARB collects quarterly updates from research projects (RCSPs, ARRA Site Characterization and other Small-Scale Field Projects) that is uploaded into NATCARB and EDX
- Large-scale Field Projects (through 2018+) and even the Carbon Storage Program itself continually evolve
- Improving understanding of CO₂ storage resulting in improvements to methodologies for CO₂ storage resource and refined estimates for all storage types
- Update information on location and emissions data from CO₂ stationary sources and field validation of CCS technologies
- Provide updates to world-wide CCS projects

U.S. 2012 Carbon Utilization and Storage Atlas

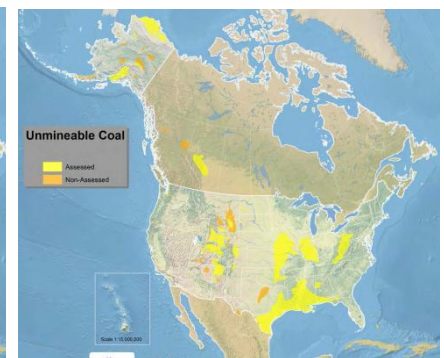
National Carbon Sequestration Database and Geographic Information System (NATCARB)



Oil and Gas Reservoirs
226 BMT CO₂
Storage Resource



Saline Formations
2,102 - 20,043 BMT CO₂
Storage Resource

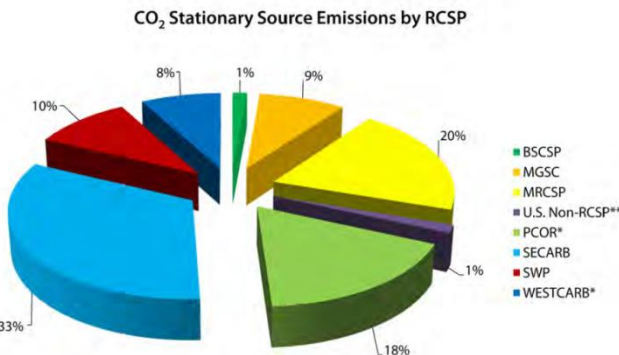
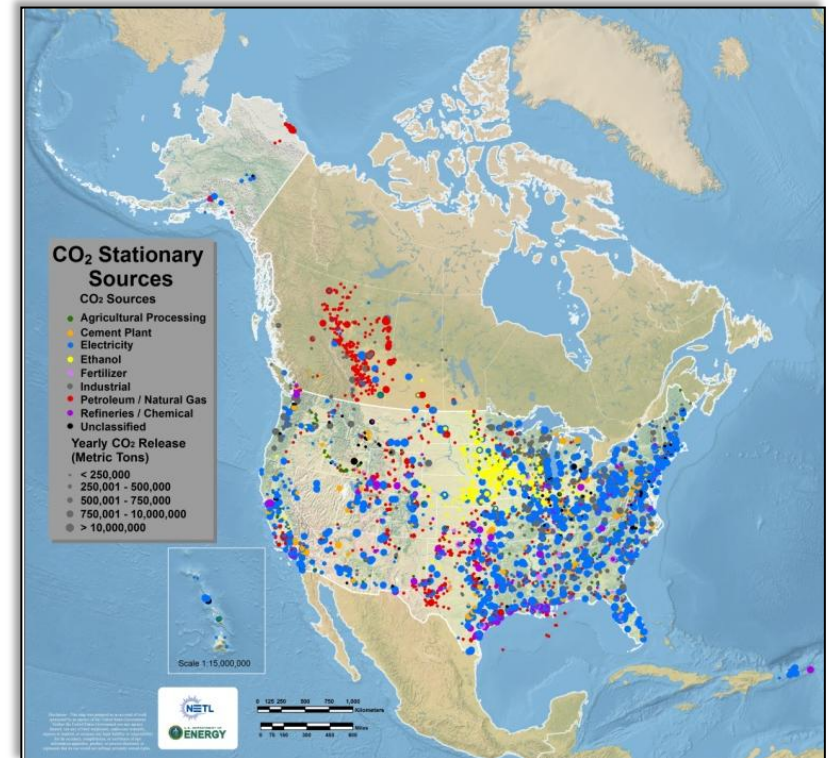


Unmineable Coal Seams
56 - 114 BMT CO₂
Storage Resource

U.S. 2012 Carbon Utilization and Storage Atlas

Comparison of CO₂ Emission Estimates – Atlas III & IV

- 2012 Atlas CO₂ Emission estimate includes stationary sources confirmed and documented in the RCSPs with cut-off of 100,000 tons of CO₂ emitted per year
- Differences Atlas III versus Atlas IV:
 - Incorporation of EPA’s GHG Reporting Program Data for Calendar Year 2010
 - Removal of Canadian sources in areas of Canada not included in RCSP regions
 - Updated RCSPs values from ongoing research activities



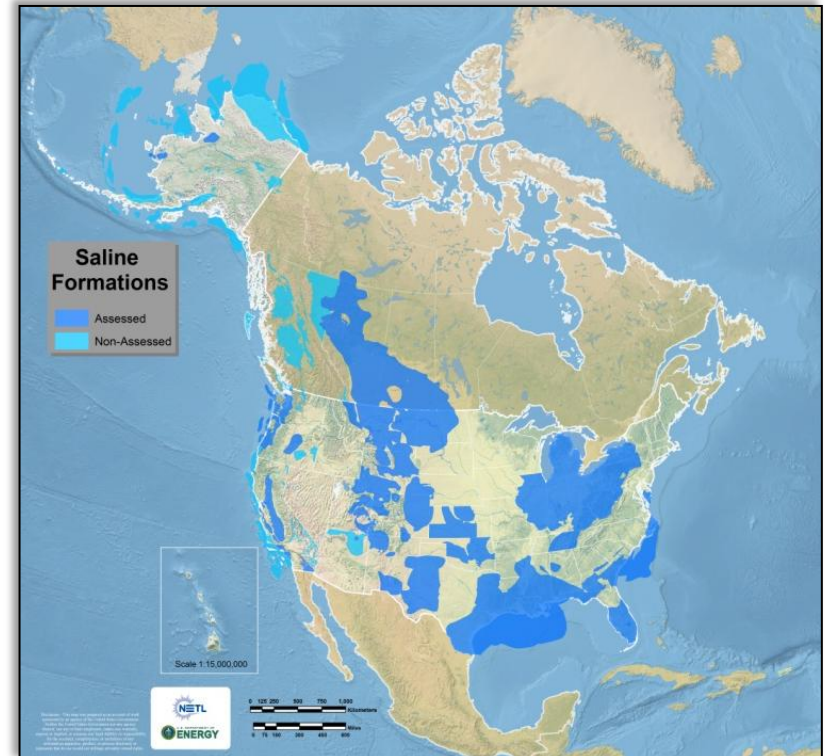
Version	Estimate (BMT)	Sources (#)
Atlas III	3.47	4,507
Atlas IV	3.28	4,245

* Includes only Canadian Sources Identified by RCSP
 ** As of November 2012 ** U.S. Non-RCSP** includes Connecticut, Delaware, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and District of Columbia

U.S. 2012 Carbon Utilization and Storage Atlas

Comparison of Saline Formations Storage – Atlas III & IV

- **Saline formations are porous rock saturated with brine (salty water)**
- **Enormous potential and more extensive than coal or oil/gas bearing rock (less well control)**
- **Differences Atlas III versus Atlas IV:**
 - Continuous refinement of the storage assessments including ARRA Site Characterization Projects
 - Inclusion of State Waters
 - Better constraint on individual formation boundaries and control data overlaps



Saline Storage Resource Estimate

$$G_{CO_2} = A_t h_g f_{tot} \rho E_{saline}$$

- Presence of seal and supercritical conditions
- TDS 10,000 ppm and >800 meter depth
- E_{saline} factors for P10, P50, and P90 are 0.5%, 2.0%, and 5.5%

Storage Estimates (BMT)

	Low	High
Atlas III	1,653	20,213
Atlas IV	2,102	20,043

U.S. 2012 Carbon Utilization and Storage Atlas

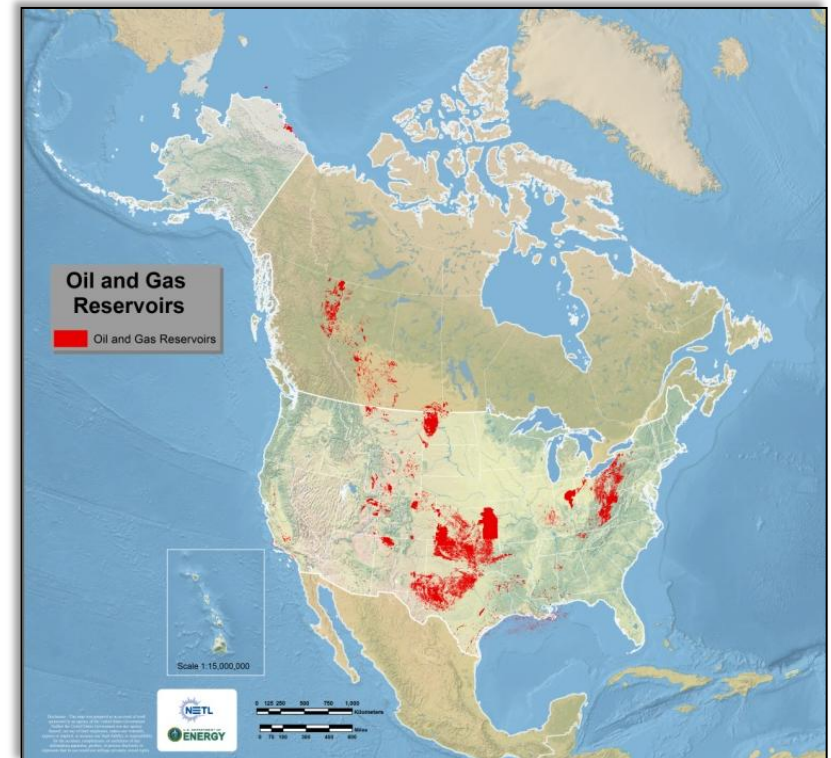
Comparison of Oil and Gas Reservoir Storage— Atlas III & IV

- **Sedimentary rocks containing oil and gas with an impermeable seal**
- **Added benefit of enhanced recovery (EOR and EGR)**
- **Differences Atlas III versus Atlas IV:**
 - Continuous refinement of the storage assessments
 - Inclusion of State Waters
 - Better control of RCSP data overlaps

Oil and Gas Storage Resource Estimate

$$G_{CO_2} = A h_n f_e (1-S_w) B \rho E_{oil/gas}$$

- Volumetric Based Equation
- TDS 10,000 ppm
- No minimum or maximum depth criteria
- $E_{oil/gas}$ derived from local experience



Storage Estimates (BMT)

Atlas III	143
Atlas IV	226

U.S. 2012 Carbon Utilization and Storage Atlas

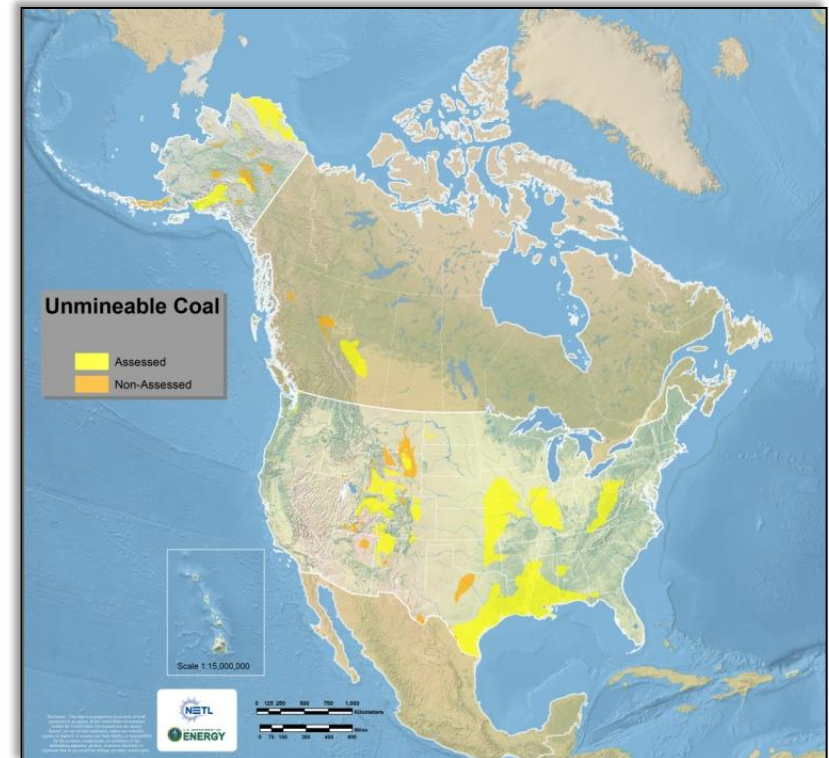
Comparison of Unmineable Coal Storage— Atlas III & IV

- Organic sedimentary rocks
- “Unmineable” is defined as coal that is too deep or too thin to be economically mined based on today’s standards
- Differences Atlas III versus Atlas IV:
 - Continuous refinement of the storage assessments
 - Better control of RCSP data overlaps

Unmineable Coal Storage Resource Estimate

$$G_{CO_2} = A h_g C_s r_{s,max} E_{coal}$$

- Maximum depth based on sorption in coal and cleat closure (below ~5,000 feet)
- TDS 10,000 ppm
- E_{coal} factors for P10, P50, and P90 are 21%, 37%, and 48%

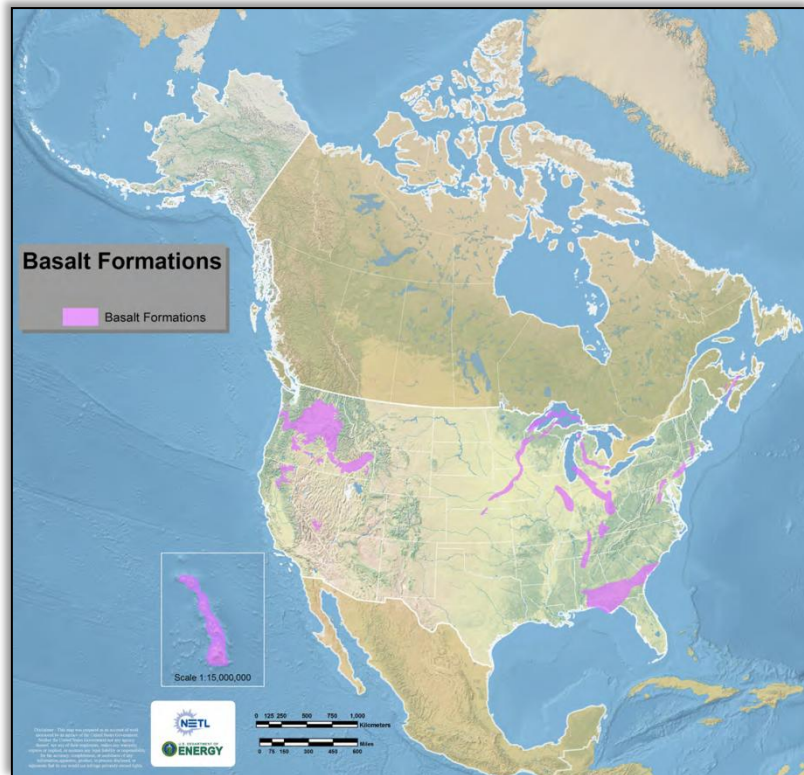


Storage Estimates (BMT)

	Low	High
Atlas III	60	117
Atlas IV	56	114

U.S. 2012 Carbon Utilization and Storage Atlas

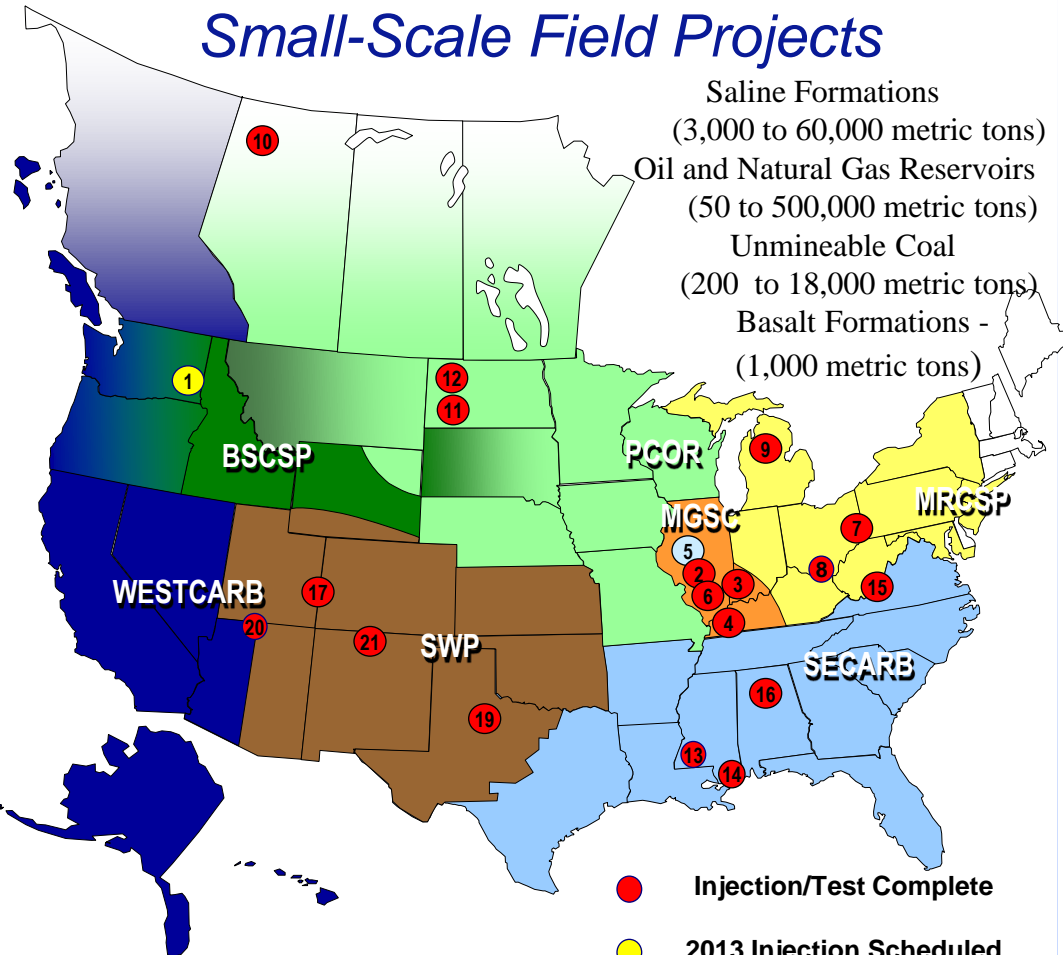
Unconventional Storage Potential Basalts and Organic-Rich Shale



Areas of current research being investigated to understand geology, CO₂ trapping mechanisms, and monitoring and modeling tools needed

U.S. 2012 Carbon Utilization and Storage Atlas

Small-Scale Field Projects



Completed 18 Injections

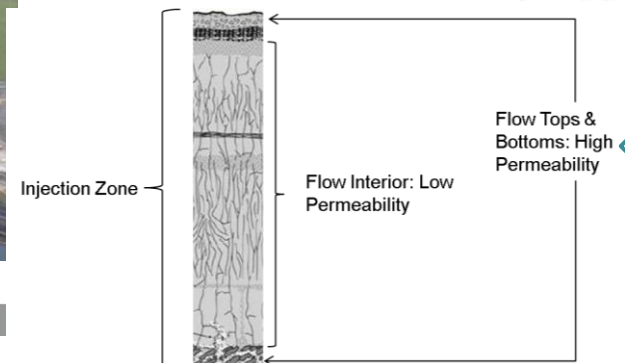
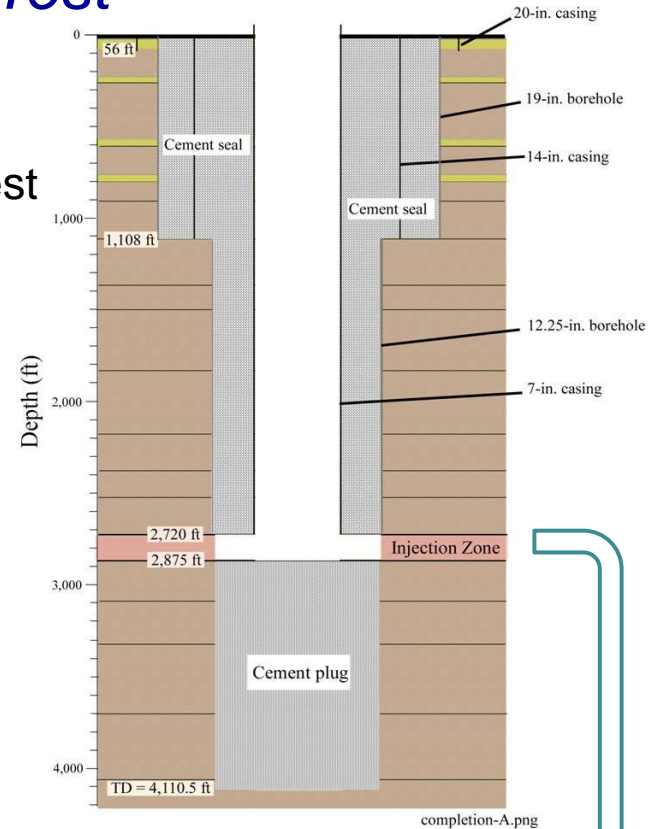
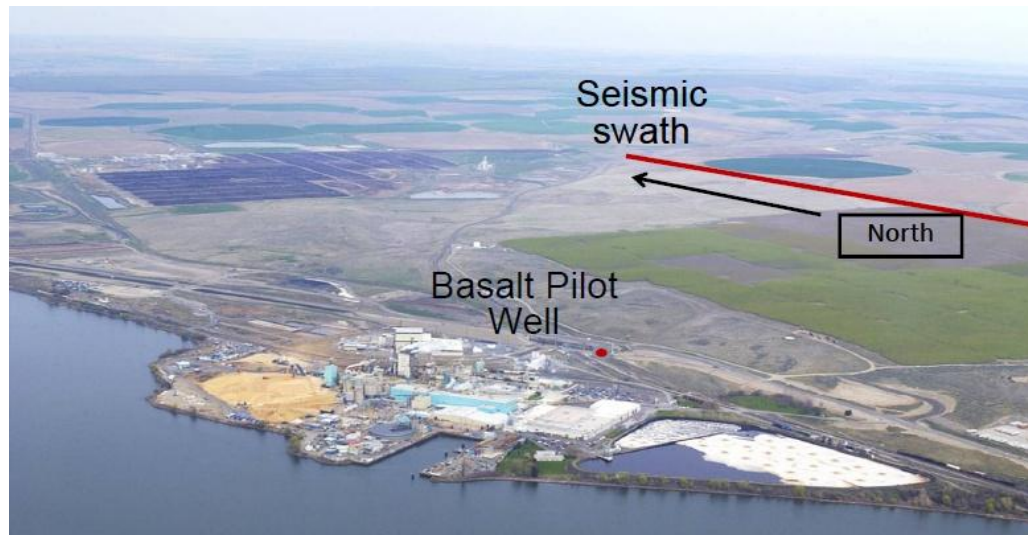
Over 1.2 MMT Injected

RCSPP	Formation Type	Geologic Province
BIG SKY Big Sky Carbon Sequestration Partnership	Basalt ①	Columbia Basin
MGSC Midwest Geological Sequestration Consortium	Oil-bearing ② ③ ④ Saline ⑤ Coal seam ⑥	Illinois Basin
MRCSP Midwest Regional Carbon Sequestration Partnership	Saline ⑦ ⑧ ⑨	Cincinnati Arch, Michigan Basin, Appalachian Basin
PCOR The Plains CO ₂ Reduction Partnership	Oil-bearing ⑩ ⑪ Coal seam ⑫	Keg River, Duperow, Williston Basin
SECARB Southeast Regional Carbon Sequestration Partnership	Oil-bearing ⑬ Saline ⑭ Coal seam ⑮ ⑯	Gulf Coast, Mississippi Salt Basin, Central Appalachian, Black Warrior Basin
SWP Southwest Regional Partnership on Carbon Sequestration	Oil-bearing ⑰ ⑱ Coal seam ⑲	Paradox Basin, Aneth Field, Permian Basin, San Juan Basin
WESTCARB West Coast Regional Carbon Sequestration Partnership	Saline ⑳	Colorado Plateau

Big Sky Carbon Sequestration Partnership

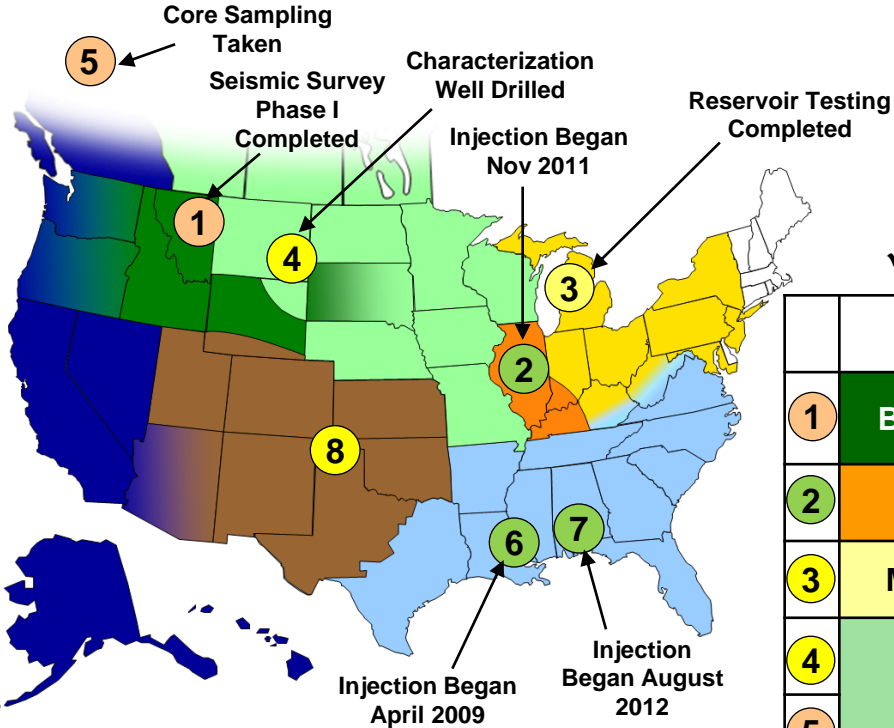
Phase II – Basalt Pilot Test

- Only basalt storage test in continental U.S.
- Advantages of Basalt for CO₂ storage
 - Extensive Basalt Formations in Pacific Northwest
 - Layered storage above and below basalt flows
 - Significant potential for CO₂ mineralization
- Host Site: Boise White Paper LLC - Wallula, WA
- CO₂ Injection Permit (WA Dept. of Ecology)
 - 1000 metric tons max.
- Target Injection Date: April 2013



U.S. 2012 Carbon Utilization and Storage Atlas

Regional Carbon Sequestration Partnership Large-Scale Projects



- ✓ Three projects currently injecting CO₂
- ✓ Three Additional Scheduled for 2013
- ✓ Remaining injections scheduled 2014-2015

- Injection Ongoing
- 2013 Injection Scheduled
- Injection Scheduled 2014-2015

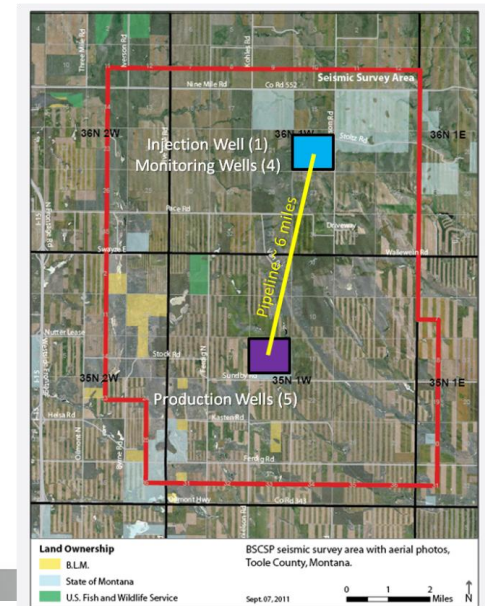
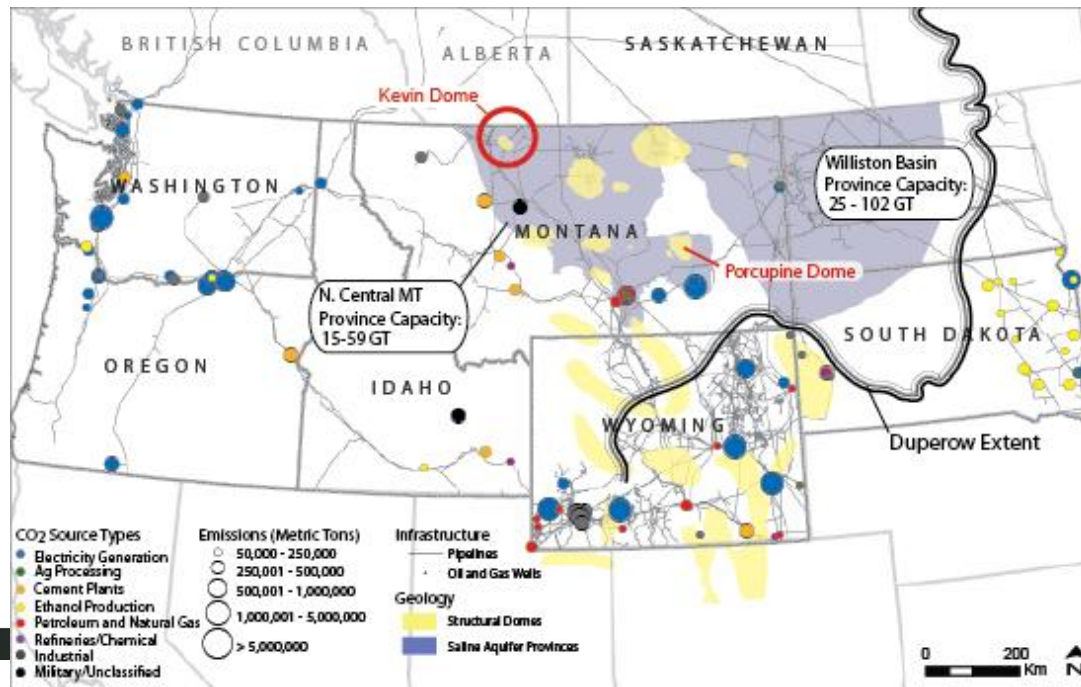
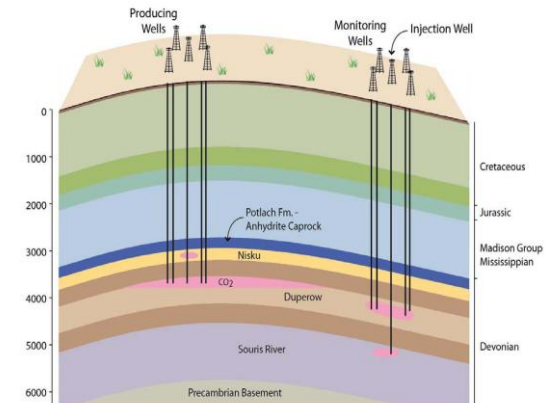
Note: Some locations presented on map may differ from final injection location

	RCSP	Geologic Province	Injection Volumes 02/2012 (MT)
1	BIG SKY	Kevin Dome-Duperow Formation	TBD
2	MGSC	Illinois Basin-Mt. Simon Sandstone	>380,000
3	MRCSP	Michigan Basin-Niagaran Reef	March 2013
4	PCOR	Powder River Basin-Muddy Sandstone	April 2013
5		Horn River Basin-Carbonates	TBD
6	SECARB	Gulf Coast - Tuscaloosa Formation	>3,000,000
7		Gulf Coast - Paluxy Formation	>30,000
8	SWP	Anadarko Basin-Morrow Sandstone	Sept 2013
	WESTCARB	Regional Characterization	

Big Sky Carbon Sequestration Partnership

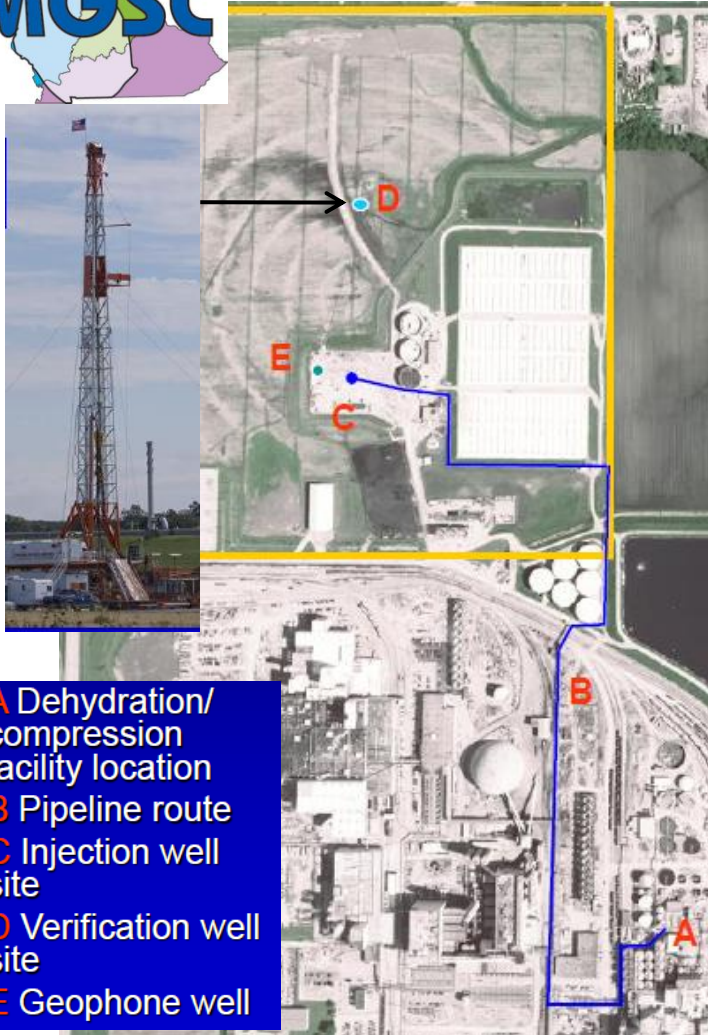
Kevin Dome Field Project

- **Injection of CO₂ into the Duperow Formation in NW Montana into the Kevin Dome**
- **1MMT over a four year period starting 2013/2014**
- **R&D to understand injection and monitoring of CO₂ in a dome as a Regional Storage Hub**
- **Completed first phase of seismic acquisition**
- **Conducting NEPA activities and preparing permit applications**



Midwest Geological Sequestration Consortium

Illinois Basin – Decatur Field Project



- A** Dehydration/compression facility location
- B** Pipeline route
- C** Injection well site
- D** Verification well site
- E** Geophone well

- **First large scale (1MMT) saline test on land**
- **1MMT from Archer Daniels Midland ethanol fermentation facility**
- **Dehydrated and compressed to 1500 PSI**
- **Injecting 1,000 MT per day since Nov 2011**
- **Over 390,000 MT injected to date**
- **Geology**
 - **Storage Formation: Mount Simon Sandstone**
 - **Seal: 500ft of Eau Claire Shale**
- **Designed to meet UIC Class VI requirements**



CO₂ Pipe to Injection Well



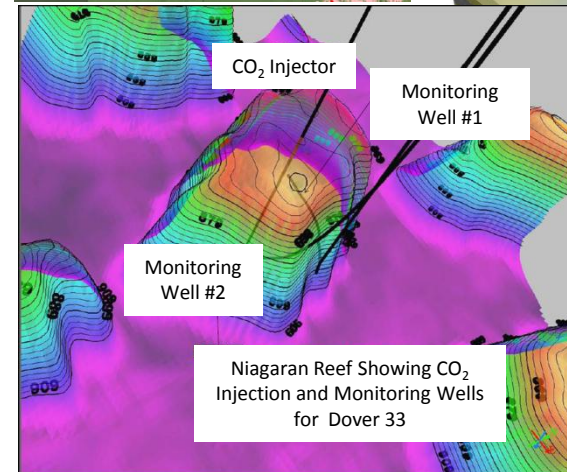
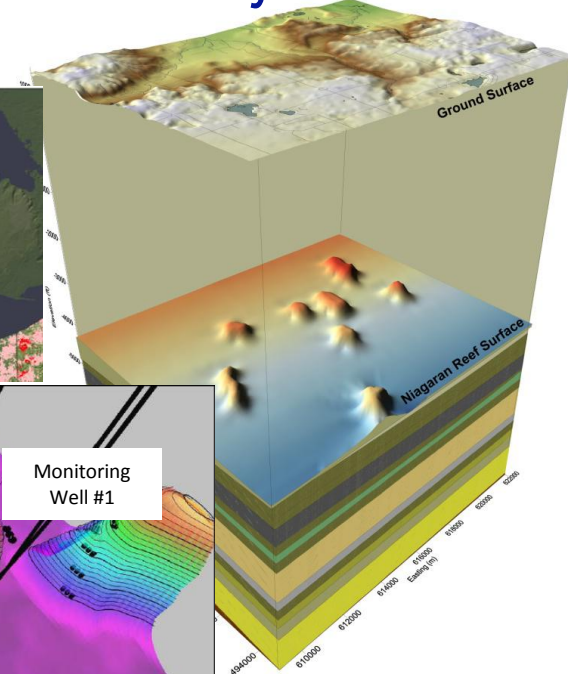
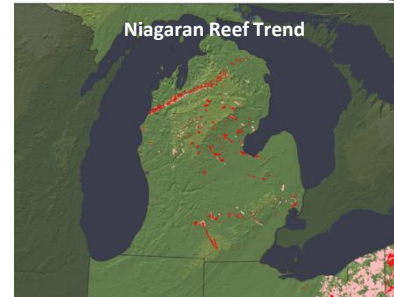
Compression Facility

Midwest Regional Carbon Sequestration Partnership



Michigan Basin Niagaran Reef Trend Field Project

- **Niagaran Reefs (Northern Michigan) closely-spaced, highly compartmentalized**
- **Core Energy – NG Processing Plant**
 - Antrim Shale Gas ~ 15% CO₂
- **CO₂ Injection 1 MMT over 4 years, categories of reefs**
 - Active Reefs – February 2013
 - Depleted Reef (Dover 33) – Spring 2013
 - New Production Reefs – Fall 2014
- **Dover 33 – Reservoir testing completed with brine injections; preliminary reservoir characterization completed; 3D (9c) seismic completed; field preparations and permitting being completed for InSAR monitoring and VSP**
- **Active Reefs – data on temperature, pressure, and flow rate being collected and analyzed**



Gas Processing Plant

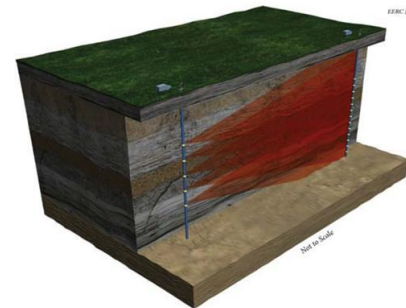
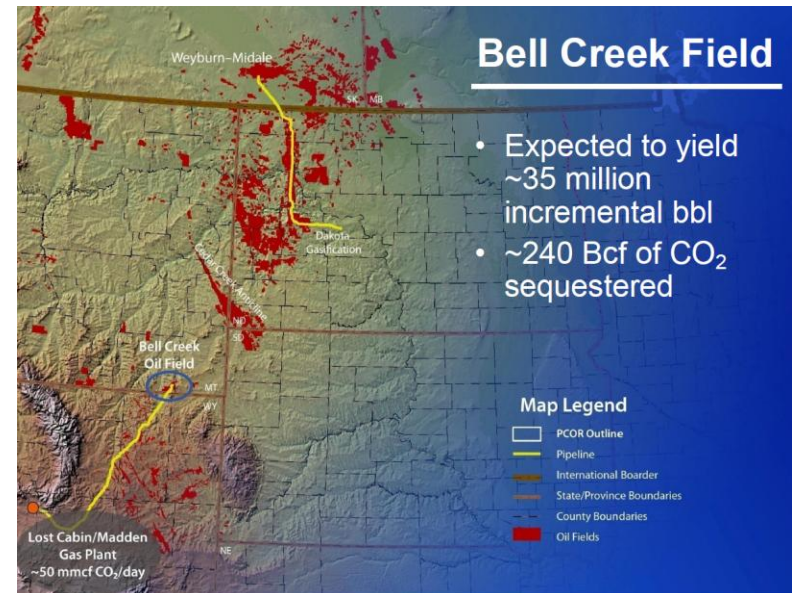


Plains CO₂ Reduction Partnership

Bell Creek Field Project



- **Collaboration with Denbury Resources**
- **Injection of 1 MMT of CO₂ to commence in early 2013**
- **Extensive MVA plan to account for stored CO₂ in the injection zone:**
 - **Based in Site Characterization, Modeling, and Risk Assessment**
 - **Surface, near-surface and subsurface monitoring**
- **Goals of Extensive MVA program:**
 - **Verify site security and identify any potential fluid migration pathways**
 - **Track CO₂ plume movement to determine ultimate fate of CO₂**
 - **Evaluate efficiency of CO₂ Storage in an active EOR field.**

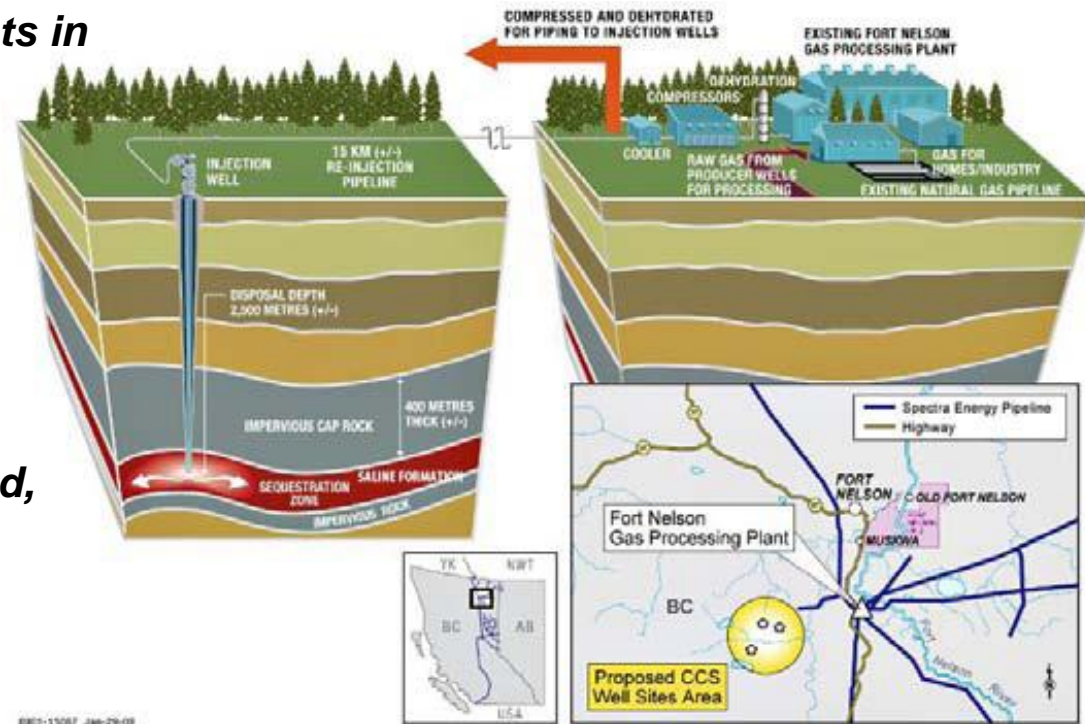


Plains CO₂ Reduction Partnership

Fort Nelson Field Project

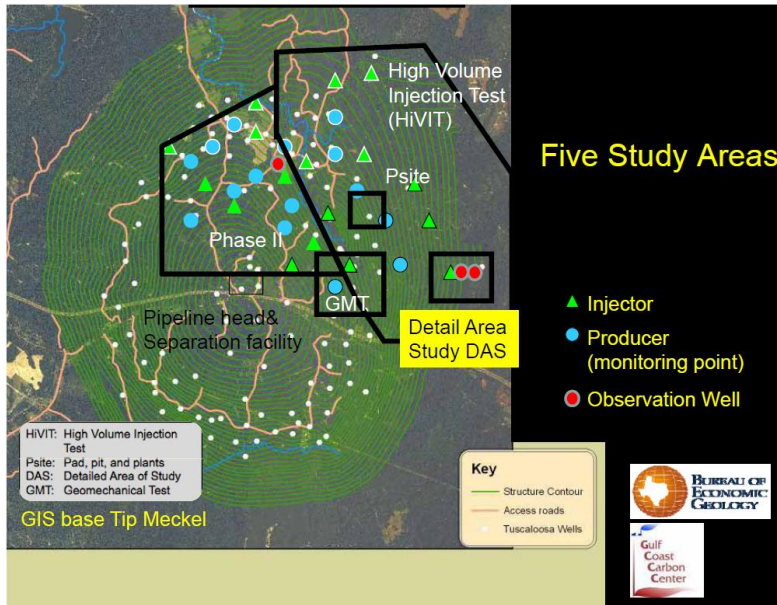


- **Spectra Energy's Fort Nelson Natural Gas Processing Plant is one of the largest sour gas-processing plants in North America**
- **Project anticipates up to 2 MMT of mixed CO₂/H₂S injected into Elk Point Group/Sulphur Point Formation**
- **Drilling of exploration well completed, as well as "side-track" to acquire additional reservoir data**
- **Project is developing integrated Risk Management Plan, Modeling and MVA Program**

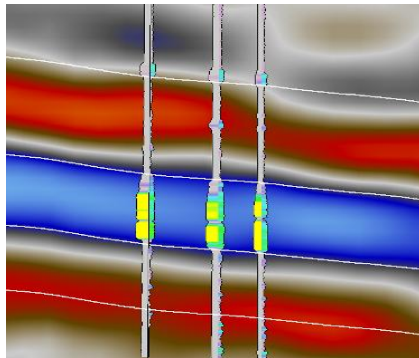


Southeast Regional Carbon Sequestration Partnership

Cranfield Field Project



- **First large scale storage project**
- **In collaboration with Denbury Resources**
- **Injection rate was 432 MT/day, now <100 MT/day**
- **Over 3.4 MMT injected for storage**
- **Extensive MVA plan to account for stored CO₂ in the injection zone:**
 - **4-D geophysics (ERT, VSP)**
 - **Geochemical (U-tube technology)**
 - **Field pressure monitoring**
 - **Distributed temperature**
 - **Wireline logging**



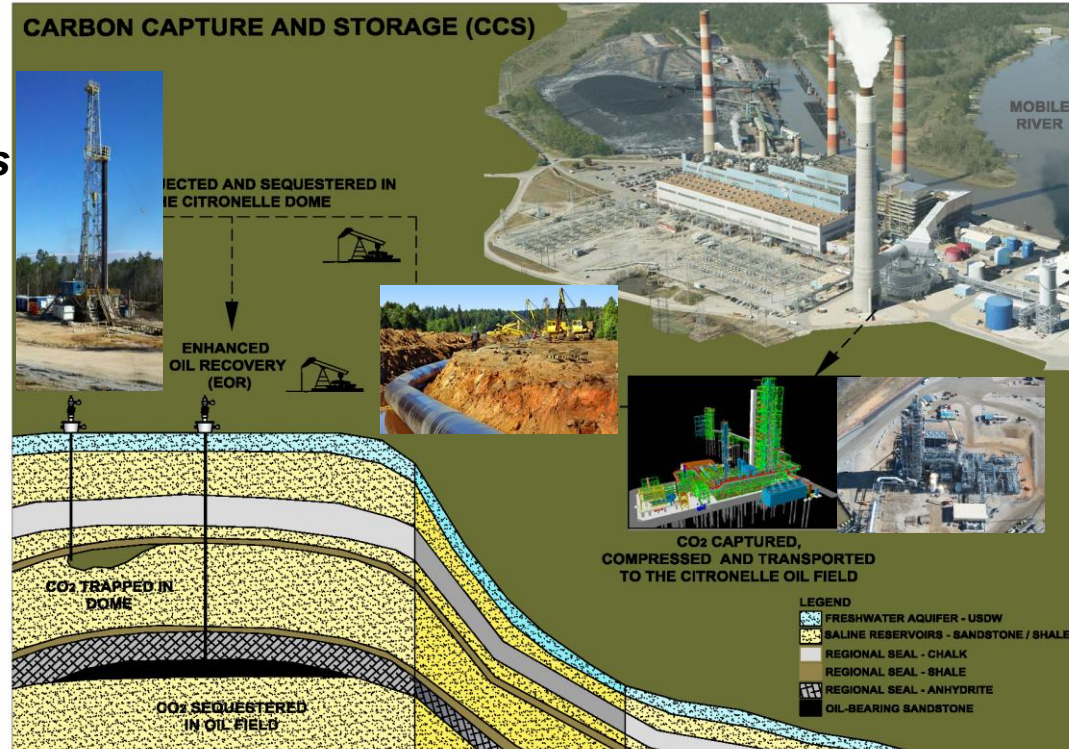
Southeast Regional Carbon Sequestration Partnership



Citronelle-Plant Barry Field Project

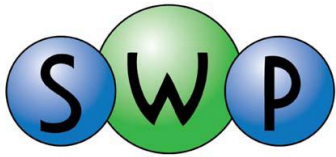


- **Largest fully integrated capture (25MW) and saline storage project in the U.S.—MHI KS1 amine process**
- **Southern Company's Plant Barry Power Station**
- **UIC Class V permit with Class VI requirements**
- **Projected CO₂ Injection Amount~250,000 MT over 2 years**
- **CO₂ injection started August 20, 2012. >30,000 MT injected to date**



Southwest Regional Partnership on Carbon Sequestration

Farnsworth Unit Field Project



- ***Project is being conducted in conjunction with an active EOR field that began in 2010 and will expand until 2015***
- ***Two anthropogenic sources will be used- Agrium (Fertilizer Plant-Borger, TX) and Arkalon (Ethanol Plant-Liberal, KS)***
- ***Extensive monitoring of injected 1 MMT into the Morrow Sandstone over five years will begin in 2013***
- ***Project completed initial 3D seismic survey in early February 2013***



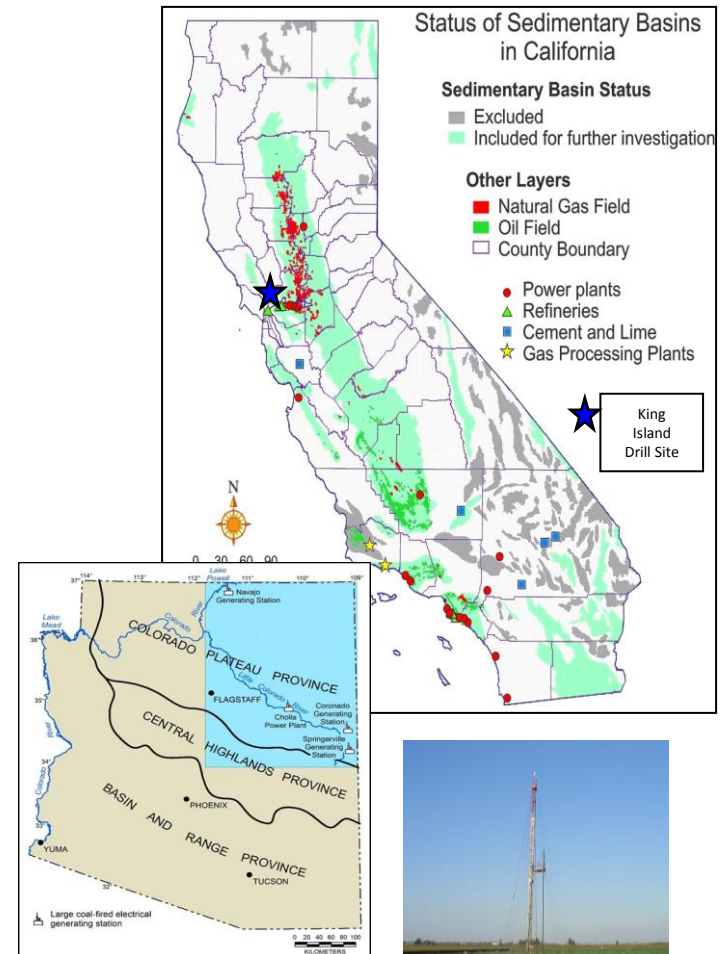
West Coast Regional Carbon Sequestration Partnership

Regional Characterization Efforts

Colorado Plateau and Sacramento Basin



- **Drilled a stratigraphic test well in the southern Sacramento Basin (King Island Site) to characterize CO₂ storage targets in a depleted natural gas reservoir**
- **Completing a California state-wide Natural Gas Combined Cycle study reviewing individual power plants, and identifying potential geologic storage**
- **Collecting existing Arizona characterization data to identify potential CO₂ storage formations and help down select a drilling location for a future Phase III characterization well**



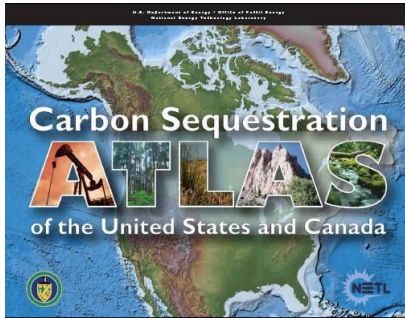
U.S. 2012 Carbon Utilization and Storage Atlas

What to Expect in Future Versions of Atlas

- Atlas V in 2014 with updated:
 - Estimates of annual CO₂ emissions
 - Refinements of storage resources based on continued regional characterization activities
 - Programmatic and project specific details (RCSPs and other small-scale field projects)
 - US and International Collaborations
 - New research results
- Future versions of the Atlas are expected to contain updated resource estimation methodologies (Oil and Natural Gas Reservoirs, Saline Formations and Unmineable Coal)
- Focus Area for Sequestration Science developing methodology for organic shale and basalt storage resource estimates

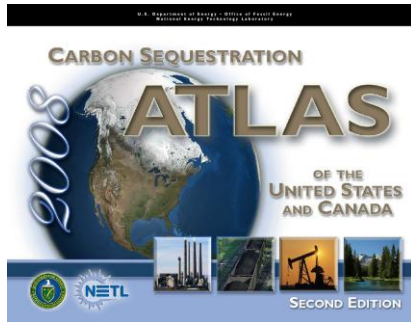
Atlas Background and Statistics

Atlas I - March 2007



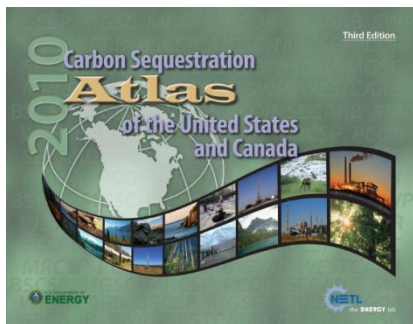
- First coordinated assessment of CCS in the United States and Canada
- Maps showing number, location and magnitude of CO₂ sources
- Maps showing areal extent of geologic storage sites
- Storage potential by Partnership
- More than 3,000 hardcopies released: 1,000 CDs mailed

Atlas II - November 2008



- Updated the CO₂ storage portfolio
- Documented differences in CO₂ resource and CO₂ capacity
- Provided CO₂ emission estimation for stationary sources
- Provided state CO₂ geologic storage potential
- More than 1,500 hardcopies released: 500 CDs mailed

Atlas III - November 2010



- Featuring updates on: DOE's Carbon Storage Program, DOE's International Collaborations, Regional Carbon Sequestration Partnership Activities, Updated CO₂ Stationary Source Estimates, Refined Methodology for Calculating Geologic Storage Potential, Updated CO₂ Storage Resource Potential, Worldwide CCS Projects, and ARRA Activities
- Daily downloads from NETL website