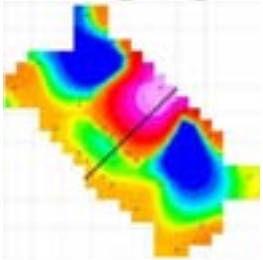
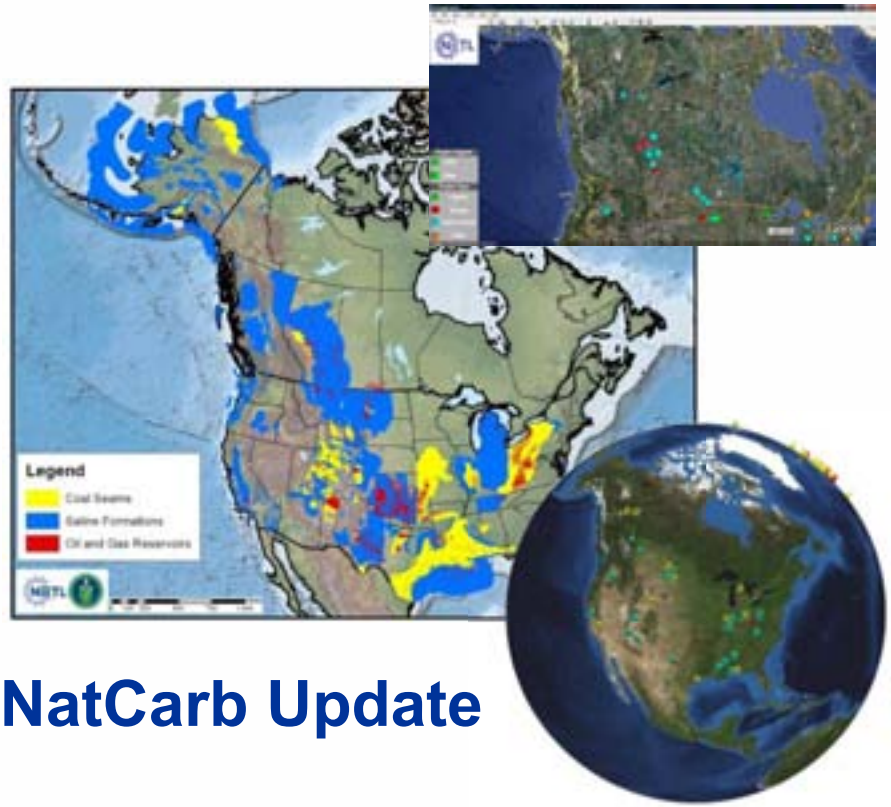
NATIONAL ENERGY TECHNOLOGY LABORATORY



NETL Office of Research and Development: Geologic Storage Collaborations

George Guthrie

Focus Area Lead, Geological and Environmental Systems, NETL Office of Research and Development



NatCarb Update

J. Alexandra Hakala

Geosciences Division, NETL Office of Research and Development

Regional Carbon Sequestration Partnerships Annual Review Meeting

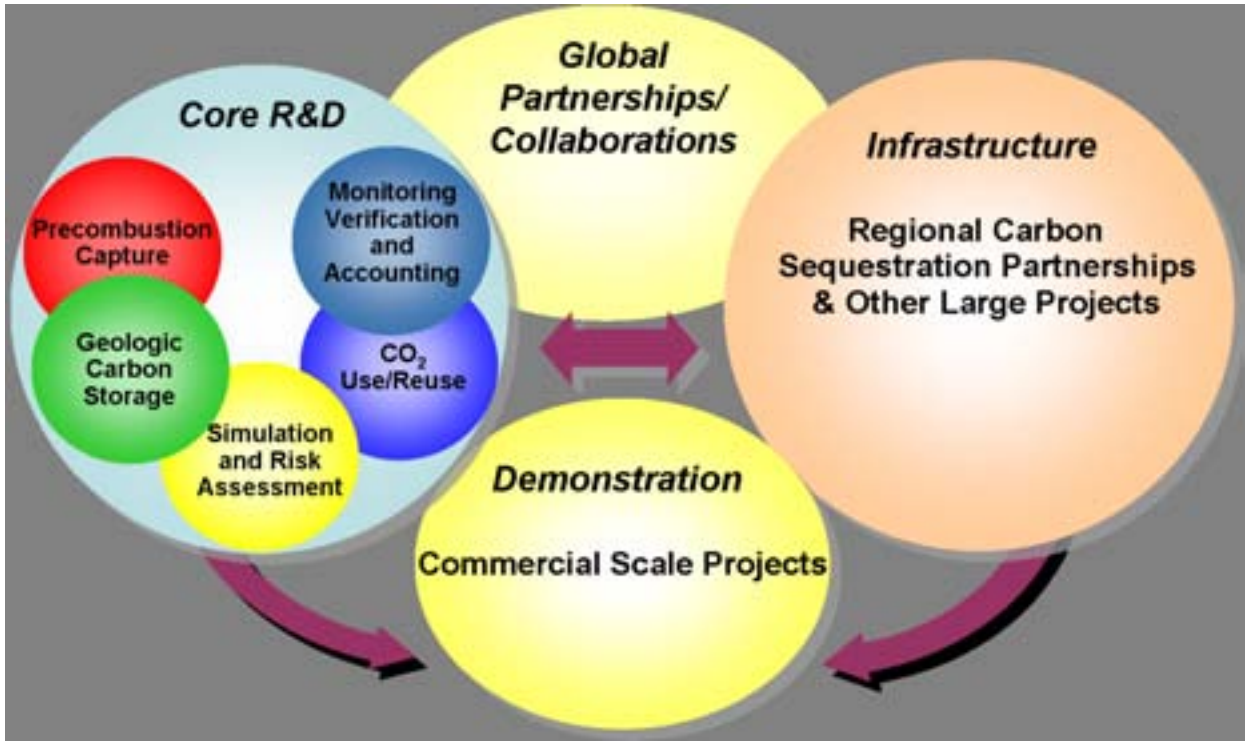
Pittsburgh, PA, 16–19 November 2009

U.S. DEPARTMENT OF ENERGY

NETL Office of Research and Development: Geologic Storage Collaborations

George Guthrie
Focus Area Lead, Geological and Environmental Systems, NETL Office of Research and Development

US-DOE Sequestration Program Structure
Office of Fossil Energy



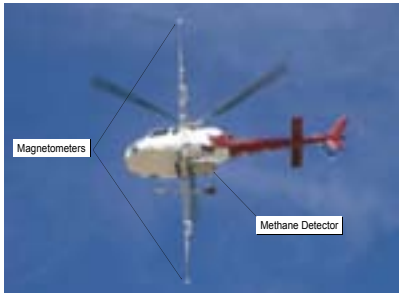
- **Opportunities to collaborate on US-DOE Sequestration Program Core R&D**
- **Leverage expertise, modeling and experimental capabilities**

Geological/Environmental Research

Science/engineering research of natural systems to enable the clean production & utilization of fossil energy

Main Research Competencies

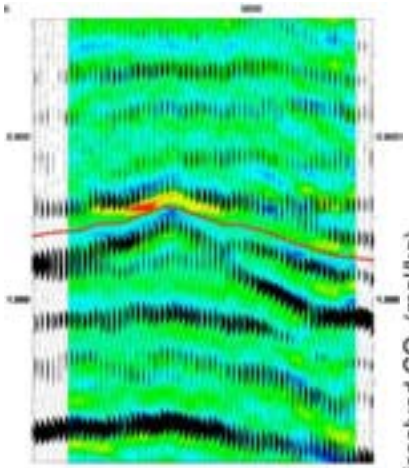
- ***Multiscale/multiphase fluid flow (including fractured media)***
- ***Geomaterials science***
- ***Field-based monitoring***
- ***Geospatial data management/assessment***
- ***Drilling under extreme conditions***

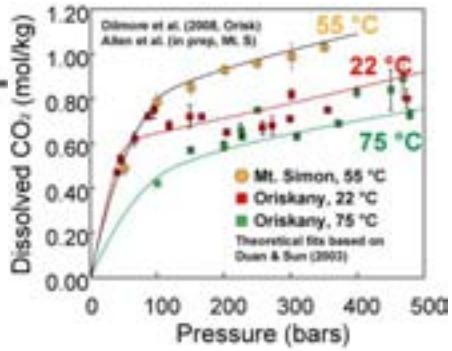


Main Research Areas

CO_2 Storage

- ***Capacity, injectivity, long-term fate***
- ***Seal integrity (cement durability)***
- ***Long-term impacts (fluid-rock interactions)***
- ***Monitoring & assessment (including GIS, risk assessment)***





Oil, gas, unconventional fossil fuels

- ***Extreme drilling (deep & ultradeep)***
- ***Environmental impacts***
- ***Unconventional oil & gas (including EOR)***
- ***Resource assessment (geospatial data)***
- ***Methane hydrates***

Multiscale, Multiphase Flow

Goal

- To improve accuracy & reliability of predictions of fluid flow and fate from pore to system

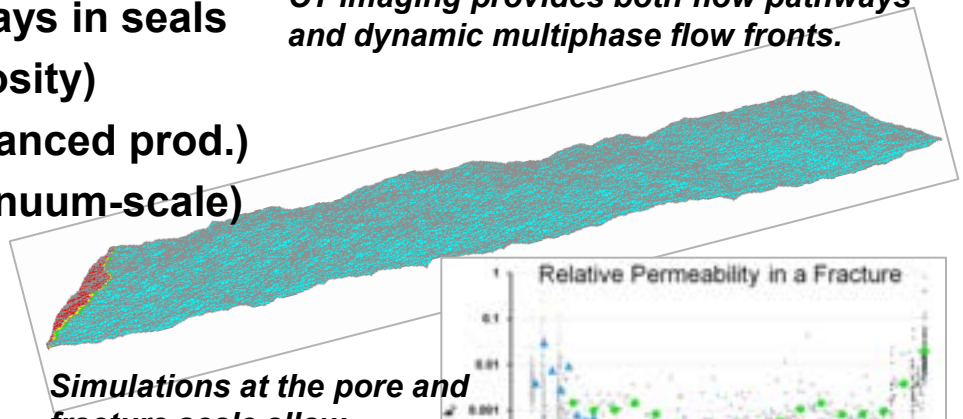
NETL Research

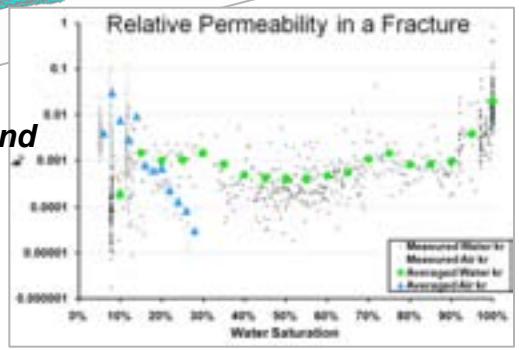
- CT imaging of cores at PT with fluid-flow
- Multiple-scale simulations (including discrete fractures)

Principal Efforts

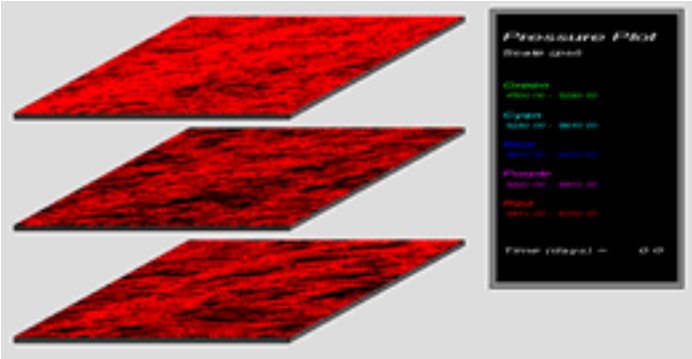
- CO_2 Risk Assessment (lead for multi-national-lab effort)
- CO_2 storage: coal (including enhanced CH_4 prod.); characterization of potential flow pathways in seals
- CO_2-EOR (including control of CO_2 viscosity)
- Shale-oil production (including CO_2 enhanced prod.)
- Geothermal (discrete fractures vs. continuum-scale)

CT imaging provides both flow pathways and dynamic multiphase flow fronts.





Simulations at the pore and fracture scale allow determination of flow dynamics and scaling relations.



Simulation of flow on discrete fractures at reservoir scale.

Geomaterials Science

High Pressure–Temperature Fluid–Rock Interactions

Goal

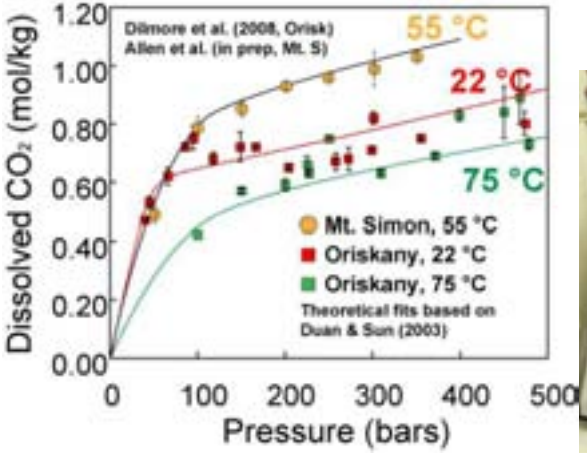
- To improve accuracy & reliability of predictions of fluid–rock systems

NETL Research

- Static, stirred, rocked, and flowing
- Characterization of reactions
- Field data and site-specific samples

Principal Efforts

- CO_2+brine system: Validity of EOS for specific RCSP sites
- CO_2+brine+rock: Seals, reservoirs, cements; water-chemistry and mineralogy impacts
- Core flow experiments: Will channels open/close?



Rocking autoclaves for exploring high PT reactions, such as CO_2 dissolution in brine.

Core-flow facilities for investigating multiphase fluid flow dynamics (including reactive flow).

Stirred and static reactors for determining long-term fluid-solid reactions at elevated PT.

Geomaterials Science

Quantitative Geophysical Properties

Goal

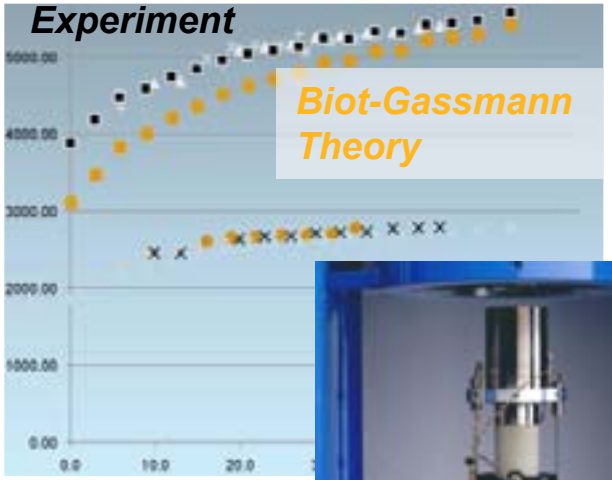
- To develop quantitative descriptions of site-specific geomaterials for prediction & monitoring

NETL Research

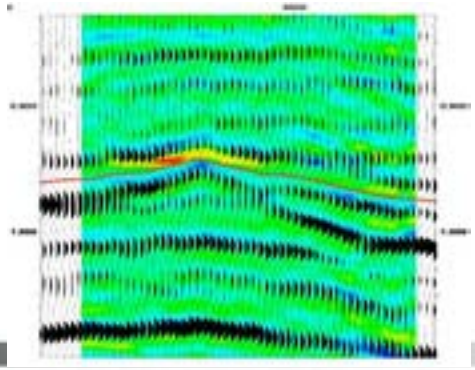
- Site-specific physical properties at elevated *PT*, fluid saturation, etc.
  - Sorption isotherms (for capacity)
  - Acoustic velocities (for quantitation)
  - Permeabilities at reservoir conditions
  - Novel imaging processing methods that enhance signals associated with CO_2

Principal Efforts

- CO_2 storage: geomaterials characterization from RCSP sites; exploration of novel imaging methods for CO_2 plumes



Site-specific physical properties (including acoustic velocities, permeabilities, Young's modulus, etc.) at P, T, fluid saturation can enable more accurate quantitative assessments of seismic data.



Novel processing of seismic data enables CO_2 plume imaging at CO_2-EOR site.

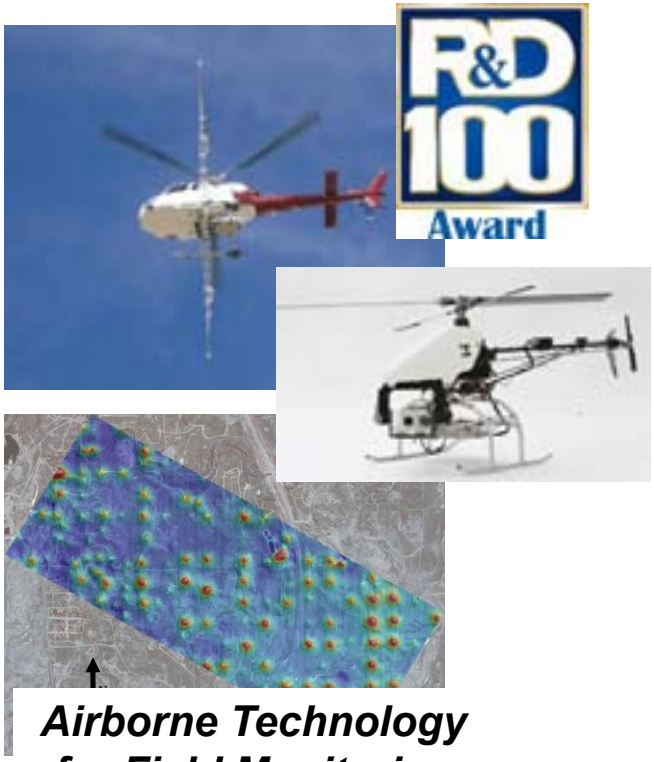
Field-Based Monitoring and Geospatial Data

Goals

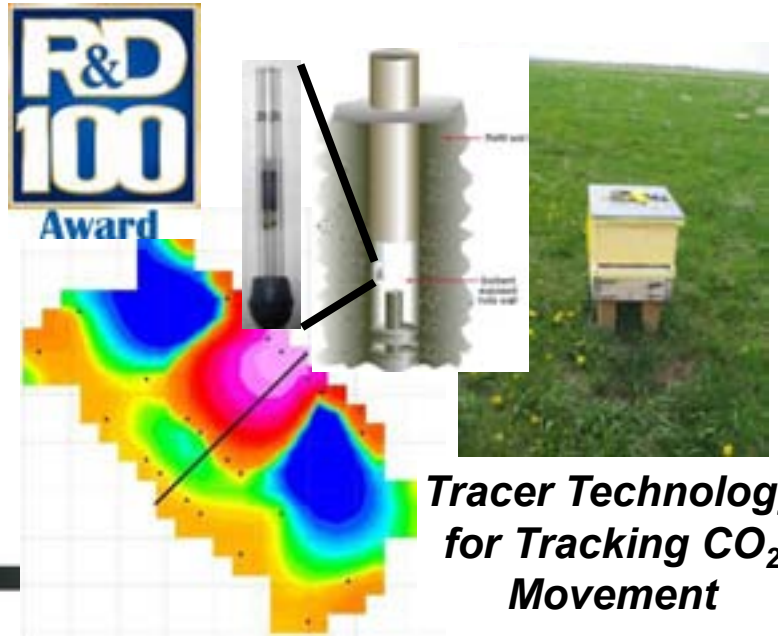
- To improve assessments and to verify the behavior of natural systems via integration of geospatial data
- To develop new monitoring and assessment tools

NETL Research

- Novel geochemical tracers for tracking CO_2 fate
  - Synthetic and natural; inorganic and organic
- Surface assessment and localization of wellbores
- Produced water
- Air quality



Airborne Technology for Field Monitoring



Tracer Technology for Tracking CO_2 Movement

Mobile Air Research Lab

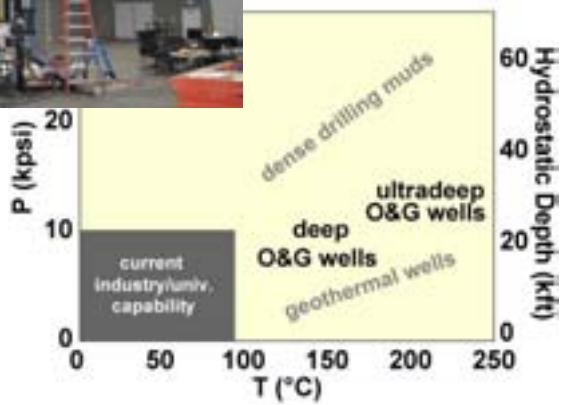
Drilling under Extreme Conditions

Goal

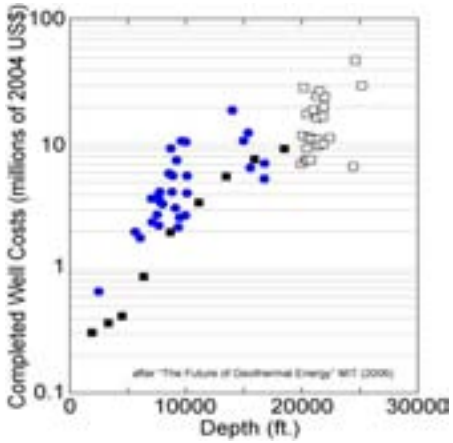
- To improve drilling rate and costs for extreme environments

NETL Research

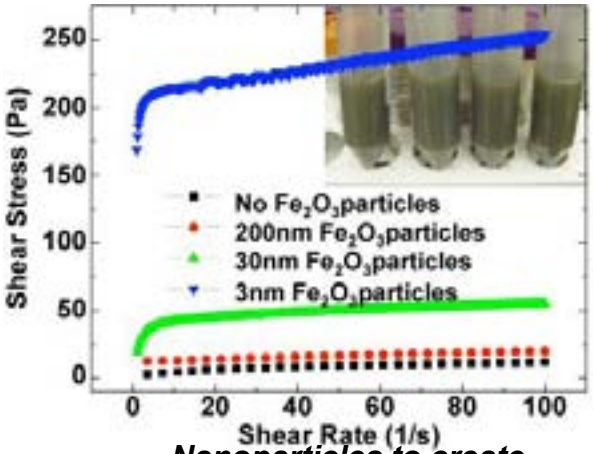
- Unique experimental facility (to 30kpsi, 250°C)
  - X-ray imaging unit to penetrate real drilling fluids
- Simulation/validation of drilling dynamics
  - Continuum and discrete-element
- Development of new materials for high PT
  - improved properties (e.g., viscosity)



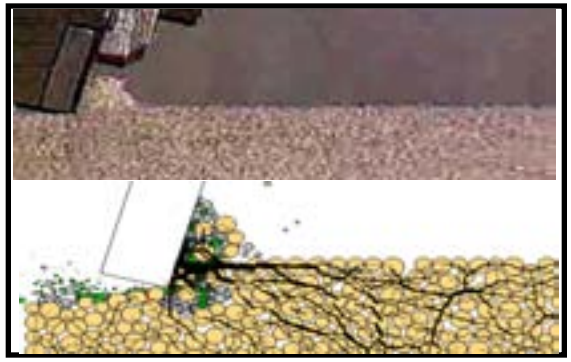
Ultra-deep Drilling Simulator



Drilling costs increase exponentially with depth.

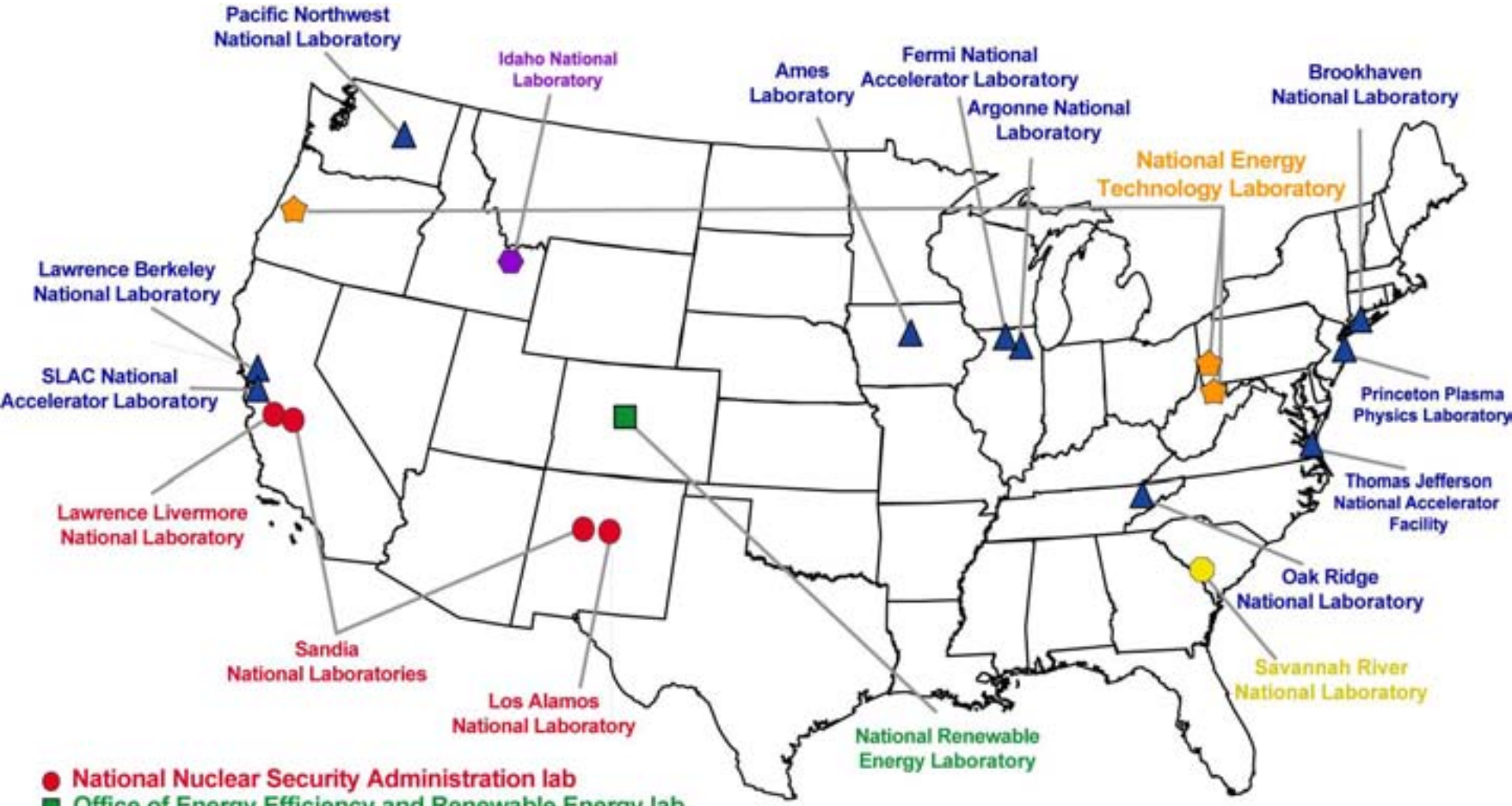


Nanoparticles to create "smart" drilling fluids



Advanced computational simulations to elucidate factors that control rate of penetration based on UDS data.

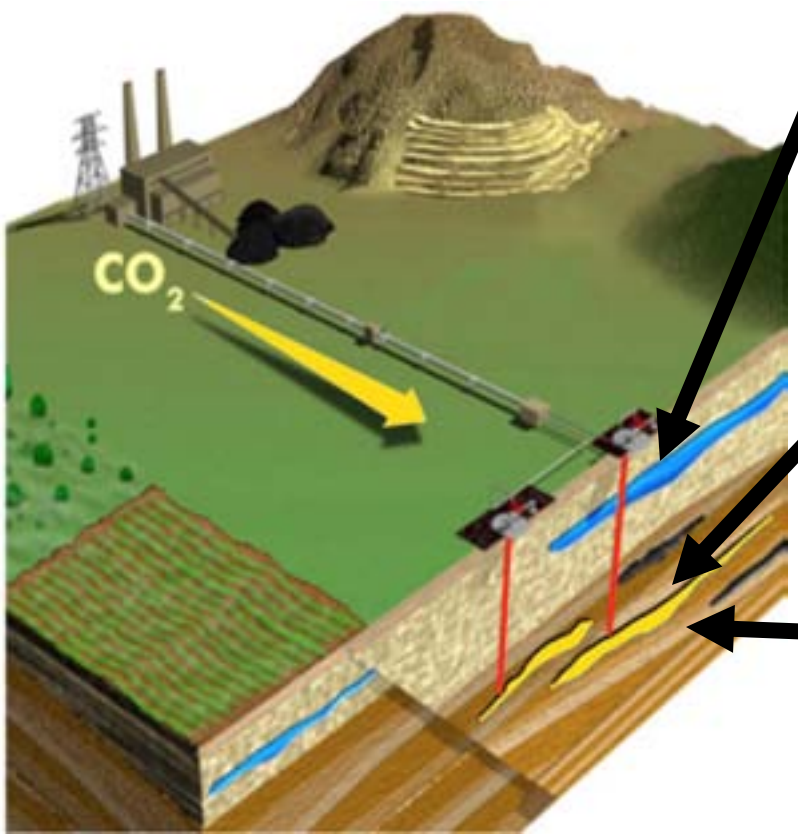
U.S. Department of Energy National Labs



- National Nuclear Security Administration lab
- Office of Energy Efficiency and Renewable Energy lab
- Office of Environmental Management lab
- Office of Fossil Energy lab
- Office of Nuclear Energy, Science and Technology lab
- Office of Science lab

U.S. DEPARTMENT OF ENERGY

Risk assessment underpins a number of factors that must be addressed for a successful CO_2 storage project.



Outside of the Reservoir

- **Strategic monitoring for the site (during injection and post closure)**
- **Potential impacts of CO_2 release**
- **Protection of subsurface resources (groundwater, minerals, etc.)**

Seal

- **Seal integrity over time**
- **Wellbore integrity over time**

Reservoir

- **Capacity & injectivity over time**
- **Strategic site characterization**
- **Impacts from introducing CO_2 into the reservoir**
- **Plume movement in reservoir (CO_2, brine, pressure front)**

Regional Carbon Seq. Partnerships

- Application of existing tools for Phase III assessments
- Generation of Phase II/III field data
- Coordination via DOE Working Groups

Core R&D

- Base program research
- Other research programs (e.g., EFRCs;)
- New FOA from DOE-FE
- Other research efforts (e.g., ZERT; CCP-II)

National Risk Assessment Program (NRAP)

(part of the US-DOE Carbon Sequestration Program)

National Goals

- Assurance of Permanence, Capacity, etc.
- Best Practice Manual
- Common Assessment Framework

Site-Specific Goals

- prediction of site performance
- site-specific risk assessment
- strategic monitoring (MVA)
- mitigation strategies

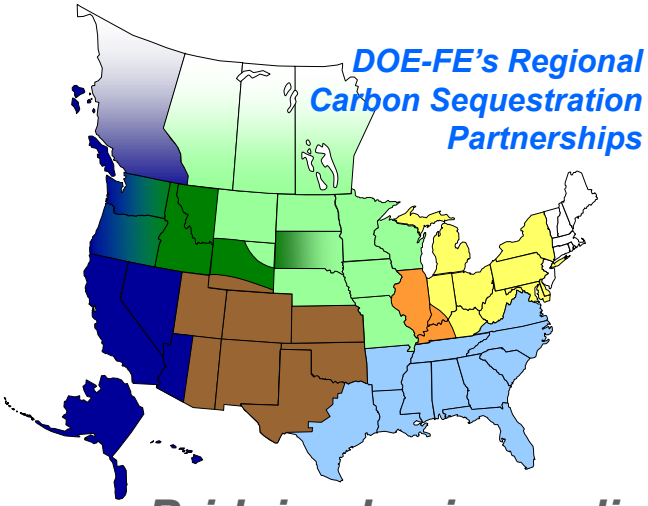
National Labs Working Group

LANL
LBNL
LLNL
NETL (lead)
PNNL

Other Risk Activities

- EPA
- IEA-GHG
- CSLF
- etc.

NRAP Guiding principles…

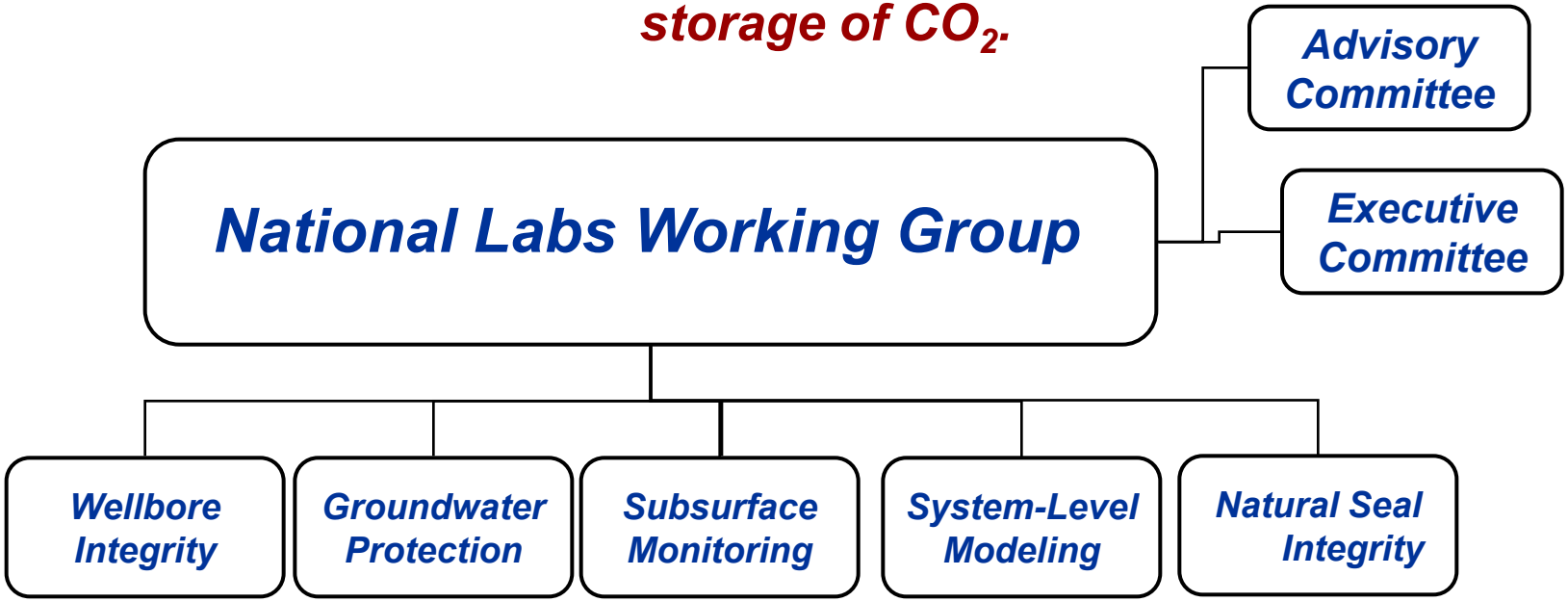


Bridging basic–applied gap to ensure the strong science base for successful large-scale demonstration of geologic storage of CO_2.

DOE-SC BRN Roadmap on Geosciences

- **Leverage the collective resources of national labs**
  - **collaborate & coordinate**
  - **integration (across labs; across scientific community)**
- **Ensure key science base (including tools) for assessment, prediction, and monitoring**
- **Produce key findings that inform stakeholders and decision makers**

Bridging the basic and applied gap to develop the strong science base that ensures successful large-scale field projects for geologic storage of CO_2.



Annual Workshop (June/July)

- **Technical presentations of previous year's work/results**
- **Re-Assessment of key science gaps**
  - **Integration includes new results from various risk-related activities**
- **Development of workplan for following year**
  - **Coordination/collaboration**

NRAP Laboratories and Primary Coordinators

Lawrence Berkeley National Laboratory
Curt Oldenburg

Lawrence Livermore National Laboratory
Susan Carroll

Los Alamos National Laboratory
Rajesh Pawar

National Energy Technology Laboratory
Grant Bromhal

Pacific Northwest National Laboratory
Pete McGrail

Topical Working Groups

Monitoring for Risk Assessment
Tom Daley

Natural Seal Integrity
Joe Morris

Systems Modeling for Risk Assessment

Wellbore Integrity
Brian Strazisar

Groundwater Impacts
Christopher Brown

NETL Office of Research and Development Geologic Storage Collaborations

George Guthrie
Focus Area Lead, Geological and Environmental Systems, NETL Office of Research and Development

- **Opportunities to collaborate on US-DOE Sequestration Program Core R&D**
- **Leverage expertise, modeling and experimental capabilities**
- **National Risk Assessment Program**
  - Multi-laboratory working group
  - Can help address cross-cutting needs for the Regional Partnerships
  - Available as a resource to the Regional Partnerships, and to strengthen DOE's ability for site-specific risk assessment
- **NatCarb and CO_2 Atlas**

NatCarb Update

J. Alexandra Hakala

Geosciences Division, NETL Office of Research and Development

Dawn Deel

Sequestration Division, NETL Strategic Center for Natural Gas and Oil

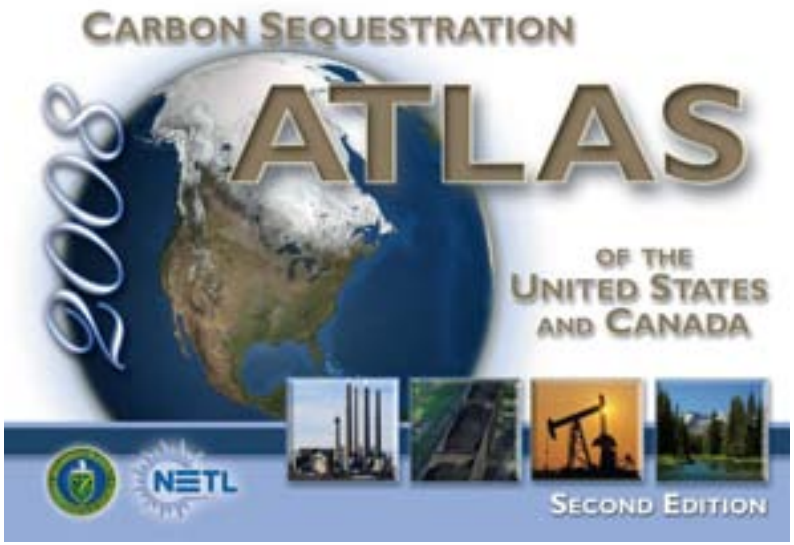
Tim Carr

Department of Geology and Geography, West Virginia University

Cast of Thousands

NatCarb and the Atlas

- **NatCarb: National Carbon Sequestration Database and Geographic Information System**
- **Atlas: Carbon Sequestration Atlas of the United States and Canada**
- **Data collected and managed by Regional Partnerships and provided through NatCarb is used for the Atlas**
  - CO_2 source and storage maps; CO_2 source emission and storage resource estimates



Overview

- **Transfer of NatCarb project management to NETL Office of Research and Development**
- **NETL-based NatCarb webpage**
  - Links to “click-and-point” Google Maps-based maps, external interactive ArcIMS server
  - Map making requests, data download
- **GIS Users Group: NatCarb and Atlas development activities**
- **Timeline for Atlas 2010 (Atlas III)**
- **New activities – start coordinating the development of research activities and NatCarb**

Site Map GO>

the ENERGY lab

Where energy challenges converge and energy solutions emerge

www.netl.doe.gov/natcarb

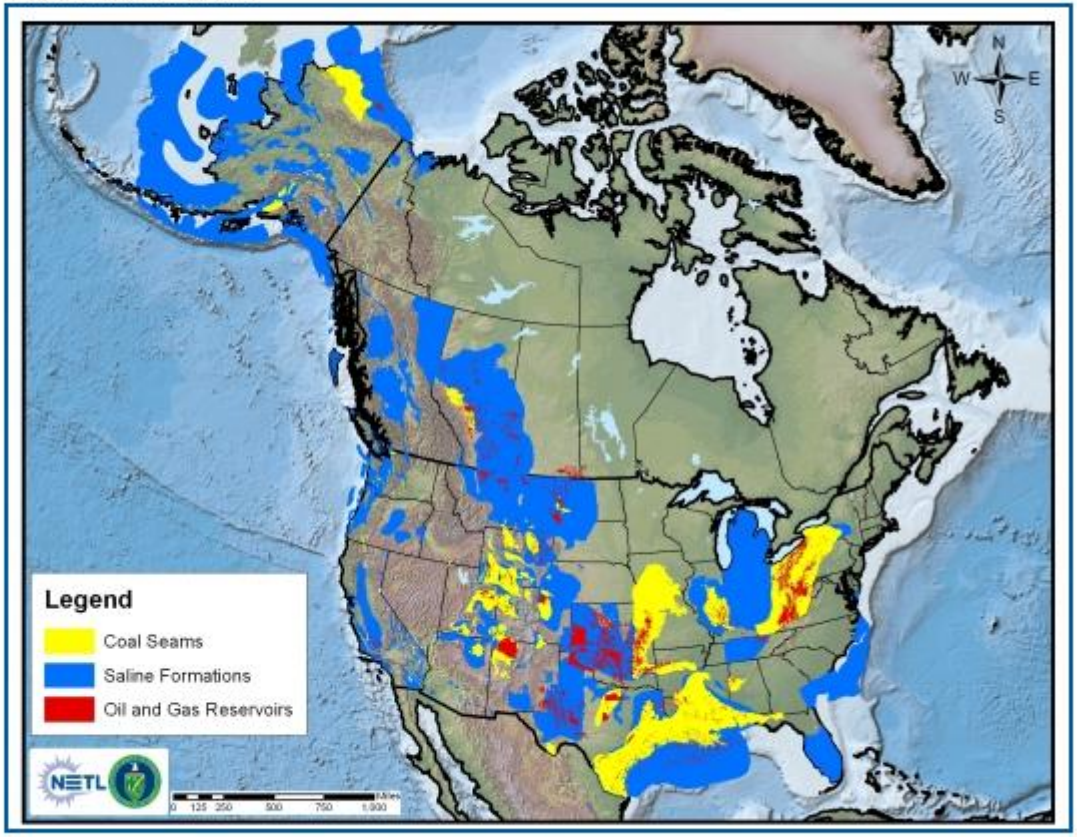
In the process of going live, will be available soon!

- ABOUT NETL
- KEY ISSUES & MANDATES
- RESEARCH
- TECHNOLOGIES
  - Oil & Natural Gas Supply
  - Coal & Power Systems
  - Carbon Sequestration
  - NatCarb
    - Background
    - CO_2 Sources
    - CO_2 Storage
    - Partnership Activities
    - Methodologies
    - Maps
    - Downloads
    - Contacts
  - Hydrogen & Clean Fuels
  - Technology Transfer
- ENERGY ANALYSIS
- SOLICITATIONS & BUSINESS
- EDUCATION
- NEWSROOM
- CONTACT NETL

Home > Technologies > *NatCarb*

Technologies
NatCarb

The National Carbon Sequestration Database and Geographic Infor
information system (GIS)-based tool developed to provide a nation
potential in the United States and Canada, and to provide all stakeh
and analysis of CCS data.



LOGY LABORATORY

NatCarb will provide CCS data both through user-friendly web tools such as Google Earth™ and Google Maps™,

Features of NatCarb Webpage

- Text primarily derived from Atlas II
- Links to NETL Partnership Activities page, which contains direct links to Partnership Webpages
- Links to NatCarb server, "point-and-click" GIS maps of CO_2 sources and storage reservoirs, worldwide CCS projects
- Map repository, map-making requests, and data downloads for advanced GIS users

NatCarb will provide CCS data both through user-friendly web tools such as Google Earth™ and Google Maps™, and through high-end GIS and database query tools. Maps and background information from the 2008 Carbon Sequestration Atlas of the United States and Canada are available as links in the navigation menu to the left, or as Adobe PDF files below. Interactive CO_2 sources and storage maps are provided below, along with a link to the experimental viewer.

- 2008 Carbon Sequestration Atlas II of the United States and Canada – Version 2
- Interactive CO_2 Sources Map
- Interactive CO_2 Storage Locations Map
- Experimental NatCarb Viewer

Announcements and Updates

- August 27, 2009 – Department of Energy Announces More than $8.4 Million for Regional Sequestration Technology Training Projects

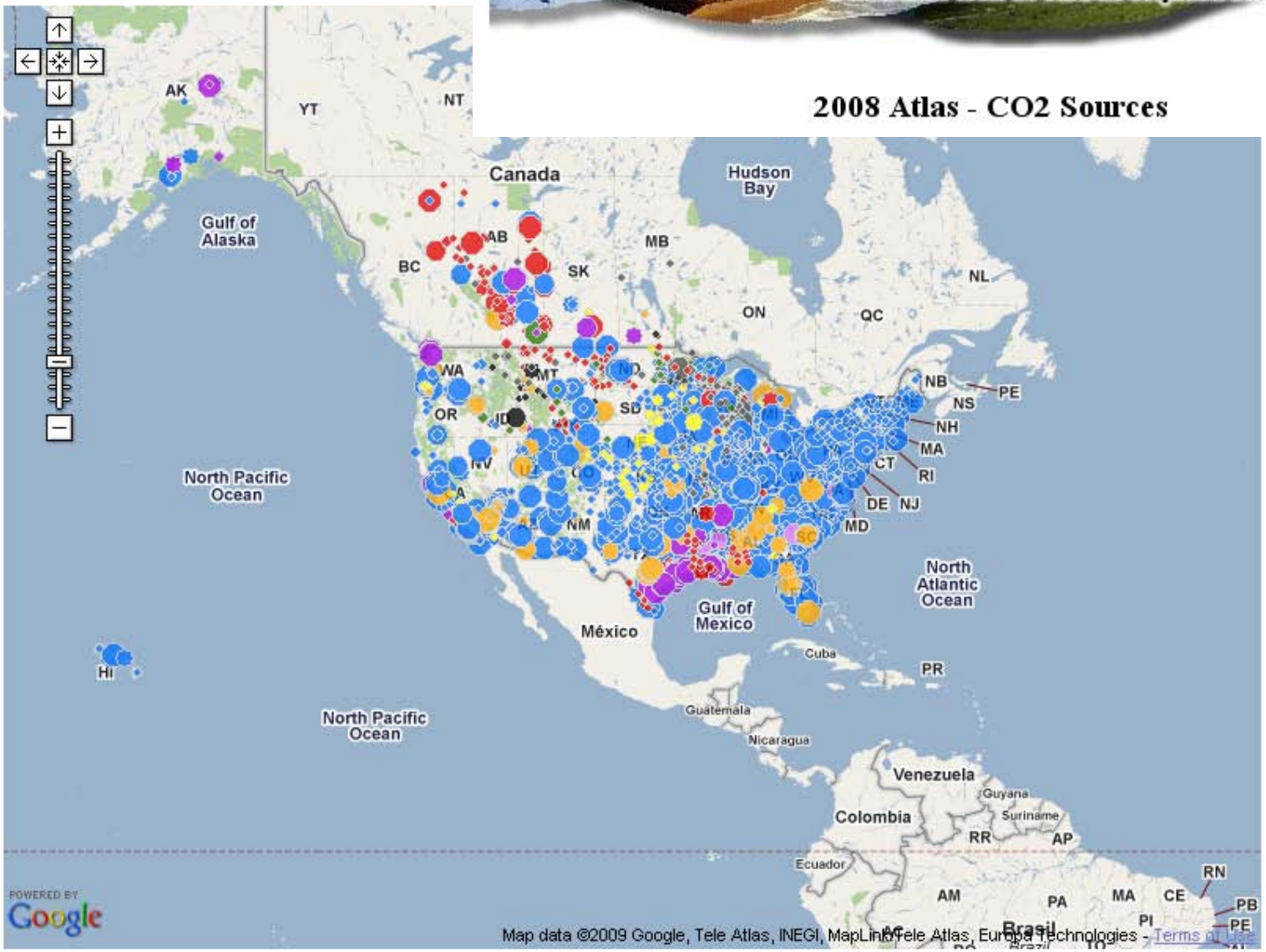
USA.GOV | U.S. DEPARTMENT OF ENERGY | DOE OFFICE OF FOSSIL ENERGY

- **Links to maps and interactive tools on Main Page**
- **Announcements and Updates**

Zoom To Alabama Go

Download Summary Data

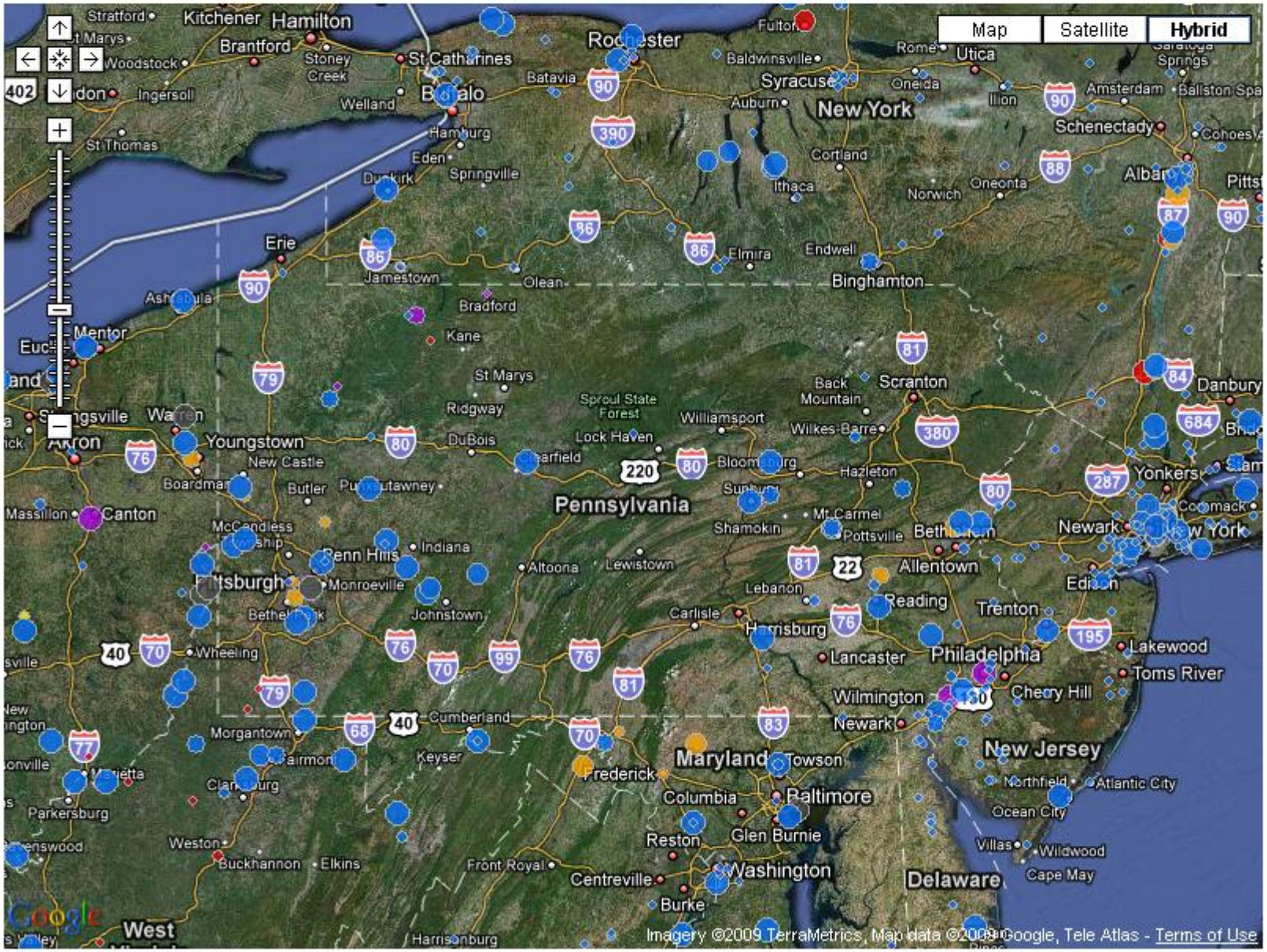
2008 Atlas - CO2 Sources



CO2 Sources
- Ag Processing
- Electricity Generation
- Fertilizer
- Industrial
- Petroleum & Natural Gas
- Refineries/Chemical
- Unclassified

Zoom To Pennsylvania Go

[Download Summary Data]



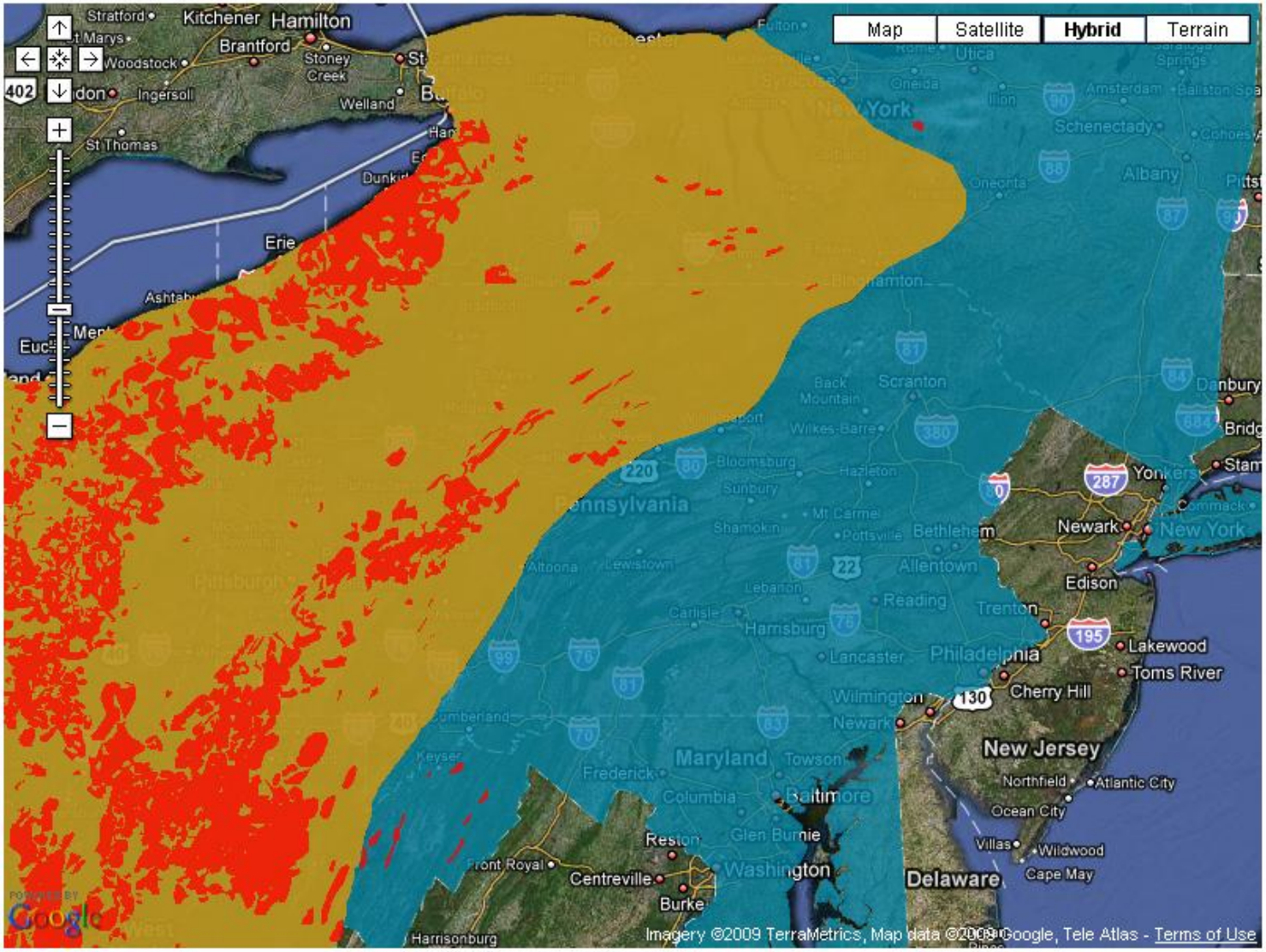
CO2 Sources

- Ag Processing
- Electricity Gen
- Fertilizer
- Industrial
- Petroleum & Na
- Refineries/Che
- Unclassified

Zoom To Pennsylvania Go

☑ **Unmineable Coal Seams** ☑ **Deep Saline Formations** ☑ **Oil and Gas Reservoirs**

Download Summary Data

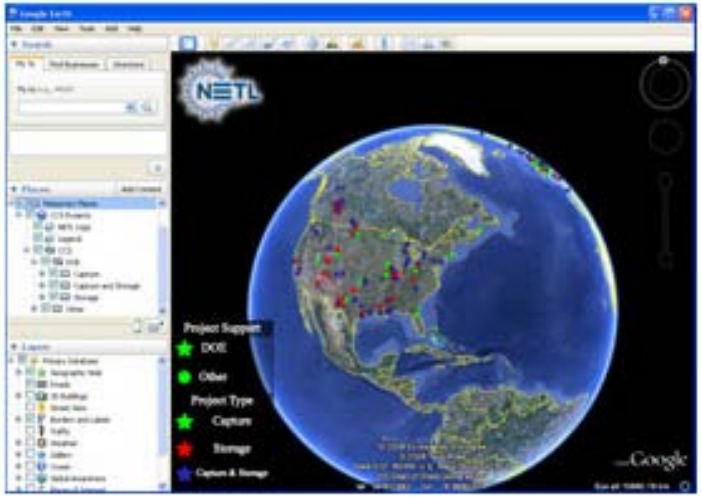


CO2 Sinks

- Unmineable Coal Seams
- Deep Saline Formations
- Oil and Gas Reservoirs

Carbon Sequestration
NETL Carbon Capture and Storage Database

Welcome to the Carbon Capture and Storage database assembled by NETL. The database includes both active and proposed Carbon Capture and Storage (CCS) projects world-wide. Information in the database regarding technologies being developed for capture, evaluation of sites for sequestration of carbon dioxide (CO2), estimation of project costs and anticipated dates of completion for projects are sourced from publically available information. This database provides the public with information regarding efforts by various industries, public groups, and governments towards development and eventual deployment of CCS technology. This is an active database that will be updated as information regarding these or new projects are released to the public.



Access to the database requires use of Google Earth. The NETL CCS database is a layer in Google Earth. Free downloadable software for Google Earth is available at http://earth.google.com/

Refer to our directions [PDF-1.2MB] for step-by-step instructions.

Download the CCS Database Google Earth Layer (Need link to DL file)

- Click here to download the database Google Earth Layer to your hard drive.
- In Google Earth, go to "File," Open," and find the downloaded CCS Database file and open.
- Double-clicking the CCS Database file once saved to your computer will also work.

Please provide feedback here: netl.ccsprojectlist@netl.doe.gov.

Features of NatCarb Webpage

- Text primarily derived from Atlas II
- Links to NETL Partnership Activities page, which contains direct links to Partnership Webpages
- Map repository, map-making requests, and data downloads for advanced GIS users
- Links to NatCarb server, "point-and-click" GIS maps of CO_2 sources and storage reservoirs

NatCarb
Maps

In addition to contributing national maps to the 2008 Carbon Sequestration Atlas II of the United States and Canada – Version 2, the NatCarb project offers different resources for those individuals needing maps:

- 2008 Atlas – 2008 Carbon Sequestration Atlas II of the United States and Canada – Version 2.
- CO_2 Sources Map – Map displaying the location and relative magnitude of a variety of CO_2 stationary sources.
- CO_2 Storage Locations Map – Map displaying CO_2 storage locations.
- Experimental NatCarb Viewer – Interactive map displaying the location and relative magnitude of a variety of CO_2 stationary sources and storage locations.
- Map Library – Archive of NatCarb maps presenting carbon capture and storage data
- Custom request – Template for submitting requests for maps not available in the Map Library.
- Data downloads – Links to the GIS data files used in creating the 2008 Carbon Sequestration Atlas of the United States and Canada.

Map Resources

- 2008 Atlas
- CO_2 Sources Map
- CO_2 Storage Locations Map
- Experimental NatCarb Viewer
- Map Library
- Custom request
- Data downloads

Saline Formations and CO2 Sources

NatCarb
Maps – Custom Request

This page provides a template for public mapping requests for presentation-quality maps that have not been previously published in the Map Library. New map requests can be directed to NatCarb.Maps@netl.doe.gov with the information requested below:

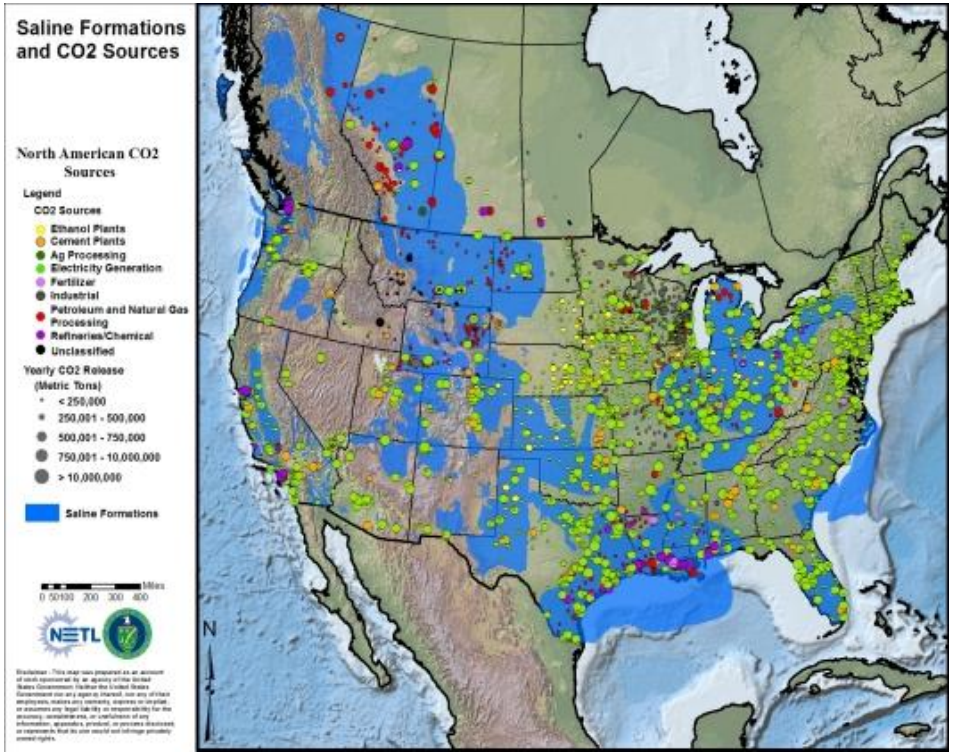
- Requestor Agency/Company
- Name
- Title
- Address
- Phone Number
- Purpose for Map (please specify)
- Map Image Quality (choose one of the following):
  - Medium resolution (for PowerPoint or 8.5×11 page)
  - High resolution (300 dpi for posters)
- File type (choose one of the following):
  - jpg
  - tiff
  - png
  - geo-pdf
- Map Elements (choose all that apply):
  - Scale bar (km)
  - Scale bar (mi)
  - Graticules

Map Resources

- 2008 Atlas
- CO_2 Sources Map
- CO_2 Storage Locations Map
- Experimental NatCarb Viewer
- Map Library
- Custom request
- Data downloads

NatCarb.Maps@netl.doe.gov

- Map Extent (choose one of the following):
  - North America
  - Lower 48 States
  - Basin (specify name)
  - State (specify name)
- Map Layers (choose all that apply):
  - CO_2 Sources
  - Oil and Gas Reservoirs
  - Coal Seams
  - Saline Formations
  - State/Province Boundaries
  - County Boundaries
  - Major Water Bodies
- Special Instructions (e.g., filters to be applied to the data):



By default maps will be created using Albers Equal Area projection. A draft map will be delivered in electronic form. Please send comments on the draft version, and a final electronic version will be delivered.

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NatCarb.Maps@netl.doe.gov

Home > Technologies > NatCarb > Maps > *Data Downloads*

NatCarb
Maps – Data Downloads

Below please find links to the GIS data files used in creating the 2008 Carbon Sequestration Atlas of the United States and Canada.

- CO_2 Sources
- Oil and Gas Reservoirs
- Coal Seams
- Saline Formations
- 2008 Carbon Sequestration Atlas II of the United States and Canada – Version 2

Please note NETL does not provide technical support for GIS software.

Map Resources

- 2008 Atlas
- CO_2 Sources Map
- CO_2 Storage Locations Map
- Experimental NatCarb Viewer
- Map Library
- Custom request
- Data downloads

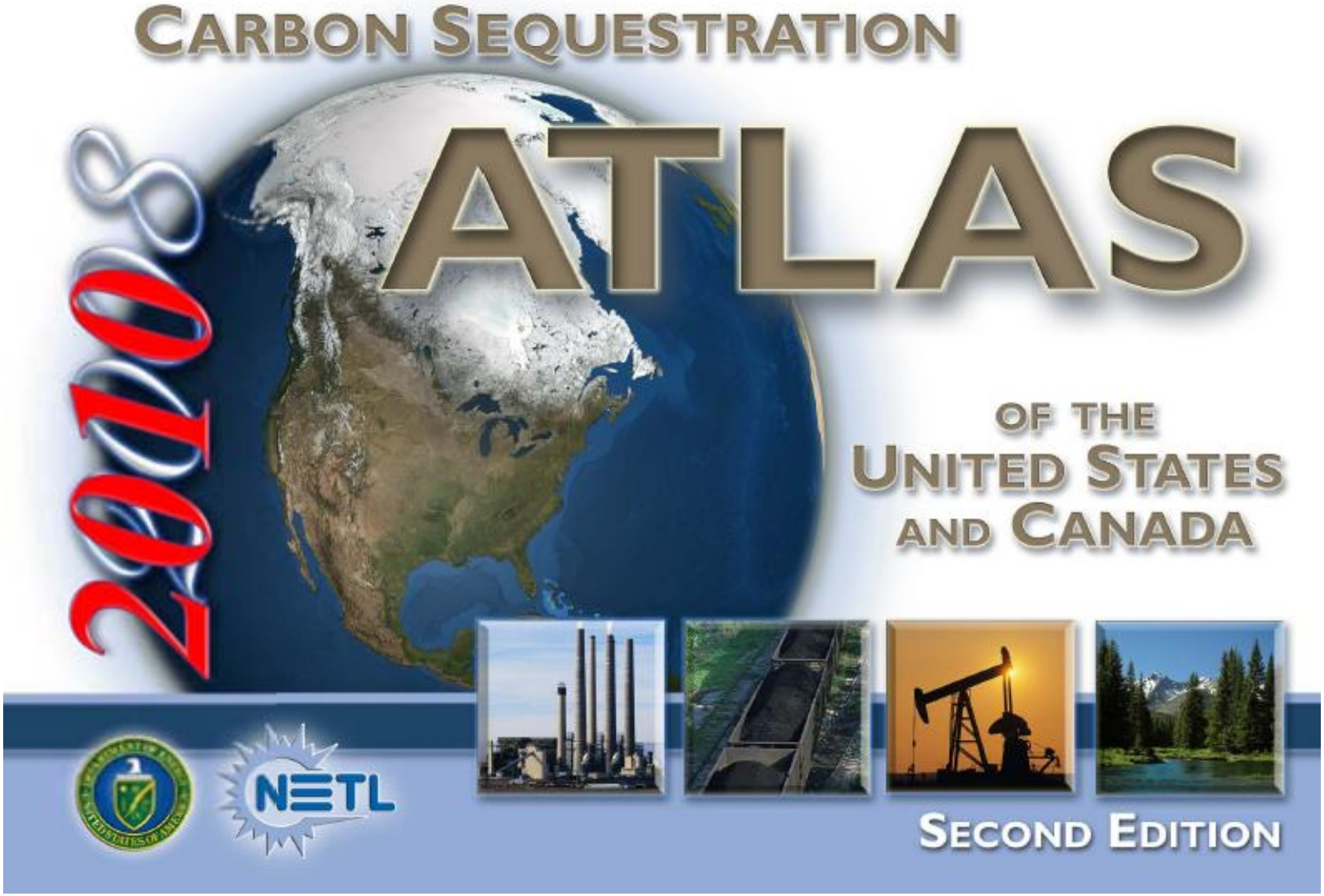
- **Still maintains link to experimental NatCarb viewer**

GIS Users Workshop July 2009

Goals:

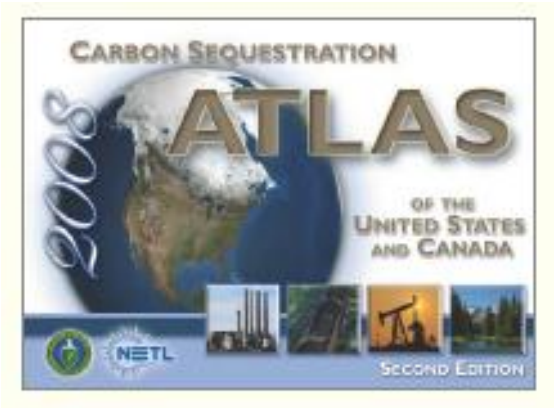
- Initiate cooperation and standardization amongst RCSPs for Atlas III
- Focus on geotechnical, GIS/IT technical aspects
  - To improve exchange and quality of CCS data for the RCSPs and NatCarb
- Defined responsibilities and general timeline for path forward

Action Items
Connect to server with periodic updates
Develop a community sharing site
Inventory of map layers from RCSPs
Migration to new platform
Pre-Atlas Gap Analysis
Create documentation website with available white papers
Tool building


CARBON SEQUESTRATION
ATLAS
2008
OF THE
UNITED STATES
AND CANADA
NETL
SECOND EDITION

Exploring Potential to Incorporate New Features into NatCarb

Coal Seam $G_{CO_2} = AhC\rho E$ Saline Formation $G_{CO_2} = Ah\phi\rho E$



2008 CO_2 Capacity Estimates by Partnership				
	Unmineable Coal Seams		Saline Formations	
	Low	High	Low	High
	Billion Metric Tons of CO_2	Billion Metric Tons of CO_2	Billion Metric Tons of CO_2	Billion Metric Tons of CO_2
Big Sky	12.1	12.1	460.9	1,831.5
MGSC	1.7	2.4	29.2	116.6
MRCSP	0.8	0.8	49.6	199.1
PCOR	10.7	10.7	185.6	185.6
SECARB	43.8	63.0	2,274.6	9,098.4
SWP	0.7	1.8	92.4	368.9
WESTCARB	86.8	86.8	204.5	818.2
Total	157.0	178.0	3,297.0	12,618.0

Intergovernmental Panel on Climate Change, 2005

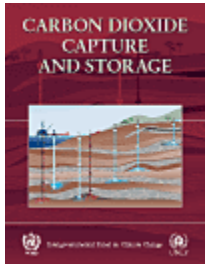
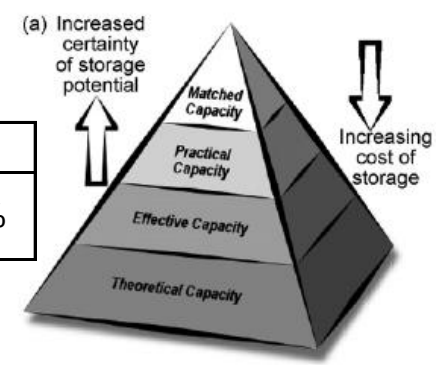


Table 5.2 Storage capacity for several geological storage options. The storage capacity includes storage options that are not economical.

Reservoir type	Lower estimate of storage capacity ($GtCO_2$)	Upper estimate of storage capacity ($GtCO_2$)
Oil and gas fields	675[a]	900[a]
Unminable coal seams (ECBM)	3-15	200
Deep saline formations	1000	Uncertain, but possibly 10[4]

[a] These numbers would increase by 25% if "undiscovered" oil and gas fields were included in this assessment.



Uncertainty in Parameters

	A	h	ρ	C or ϕ	E	G_{CO2}	Goal
Unminable Coal Seams and Deep Saline Formations	?	?	?	?	?	?	+/- 30%

Site Map GO>

the ENERGY lab

Where energy challenges converge and energy solutions emerge

www.netl.doe.gov/natcarb

In the process of going live, will be available soon!

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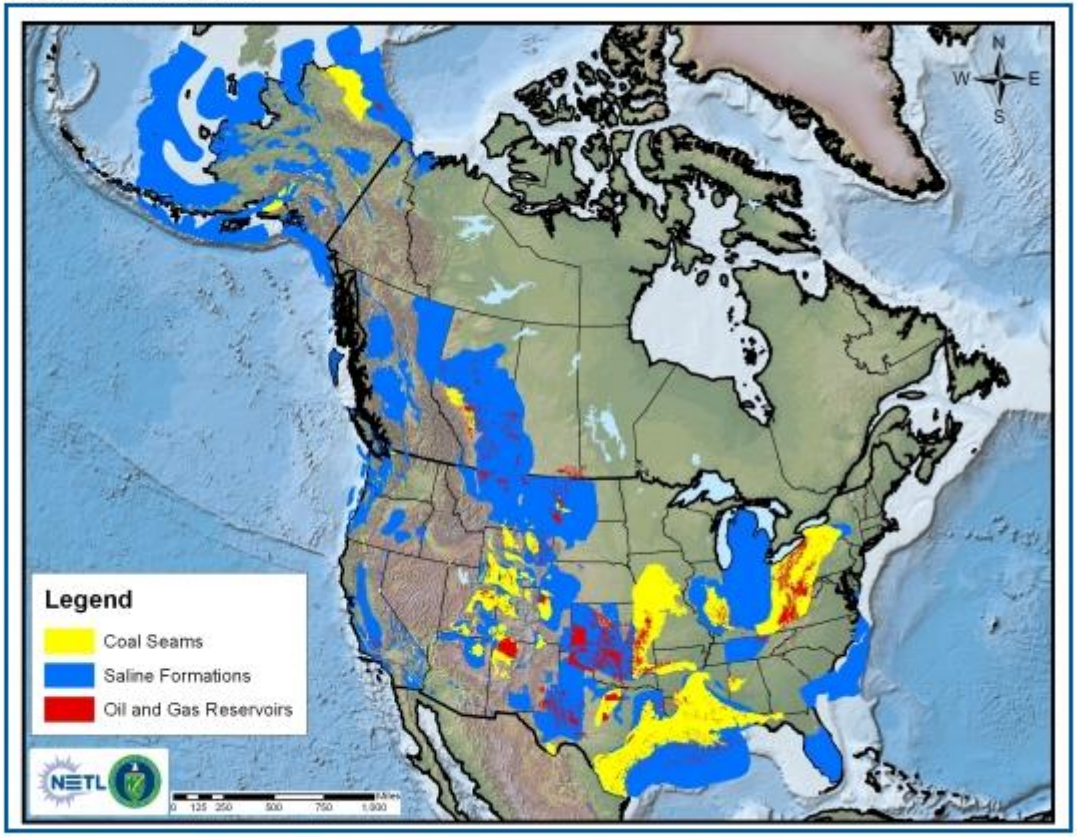
Technologies
NatCarb

The National Carbon Sequestration Database and Geographic Infor
information system (GIS)-based tool developed to provide a nation
potential in the United States and Canada, and to provide all stakeh
and analysis of CCS data.



LOGY LABORATORY

NatCarb will provide CCS data both through user-friendly web tools such as Google Earth™ and Google Maps™,