

An Initial Set of Working Hypotheses Concerning Some Chemical and Physical Phenomena That Occur When CO₂ Is Injected Into a Coal Bed

Curt M. White, National Energy Technology Laboratory

The presentation will describe some of the technological impediments to performing sequestration of CO₂ in deep unmineable coalbeds with concomitant enhanced coalbed methane recovery on a wide scale. The impediments include: 1) developing techniques to handle millions of gallons of produced water; 2) a lack of knowledge concerning the methane content of deep unmineable coal seams; and 3) a lack of understanding of some of the chemical and physical phenomena that occur when CO₂ is injected into a coalbed. This includes a lack of knowledge concerning the flow of CO₂ in coal, the uncertain effects upon permeability, and a lack of criteria to identify favorable coal formations. In any new area of science and technology it is often beneficial to formulate hypotheses and then work toward proving, disproving and refining them. Toward that end an initial set of seven working hypotheses concerning the effects of supercritical CO₂ injection on both the organic and mineral matter in coal will be presented. This will include a description of the depression of the glass-to-rubber transition temperature and the plasticization of the coal by imbibition of supercritical CO₂. Plasticization is expected to result in relaxation of the macromolecular network, swelling of the coal, decreased softening temperature, and increased diffusivity of guest molecules in the coal. Further, a discussion of the displacement of CH₄, the adsorption and imbibition of CO₂ into the coal, coal swelling, coal plasticization, extraction of small organic molecules trapped in the coal macromolecular network, the migration of the extracted molecules through the coal and their effect on permeability, and the concept of threshold pressure will be discussed.

The presence of high pressure CO₂ and water can also have a profound effect on the mineral matter present in coal. Many minerals present in coal are soluble in acidic aqueous solutions. The solubility of CO₂ in water at various temperatures as a function of pressure and the reaction of CO₂ with water to form carbonic acid will be described. Many of the minerals present in coal are soluble in acidic solutions. The alkaline earth metals are removed from coal by treating coal with acidic aqueous solutions. We expect calcite, dolomite, and other carbonate minerals to be removed from coal when it is in contact with acidic aqueous solutions of carbonic acid. Other minerals and clays may also be removed. The solubility trends of a number of minerals common to coal will be described.

NETL Sequestration Workshop

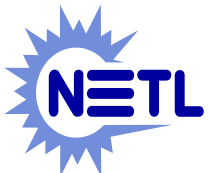
“Establishing the scientific basis for safe, cost-effective, and verifiable carbon sequestration”

- Performing sound science
- Achieving excellence
- Meeting goals

Curt White

Carbon Sequestration Science Focus Area Leader

February 16, 2003



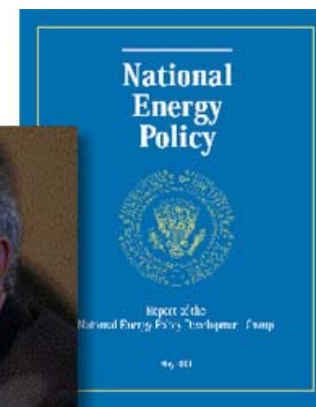
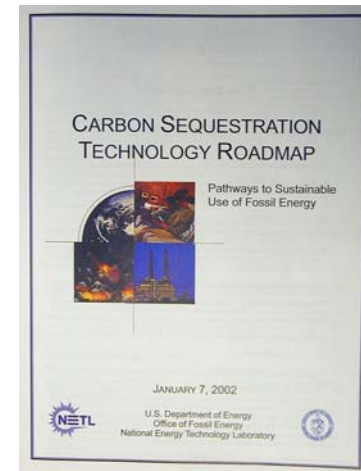
Carbon Sequestration Science Focus Area

Goals

- Develop underpinning science and technology to ensure safe, essentially permanent carbon sequestration
- Significantly (90%) reduce the costs of sequestration, especially separation and capture of CO₂, from fossil energy production and utilization systems
- Develop reliable carbon sequestration monitoring, verification, and validation protocols

Focus Area Research Thrusts

- CO₂ Separation and Capture
- Coal Seam Sequestration
- Advanced Monitoring, Verification, and Validation Systems
- Brine Sequestration
- Ocean Sequestration

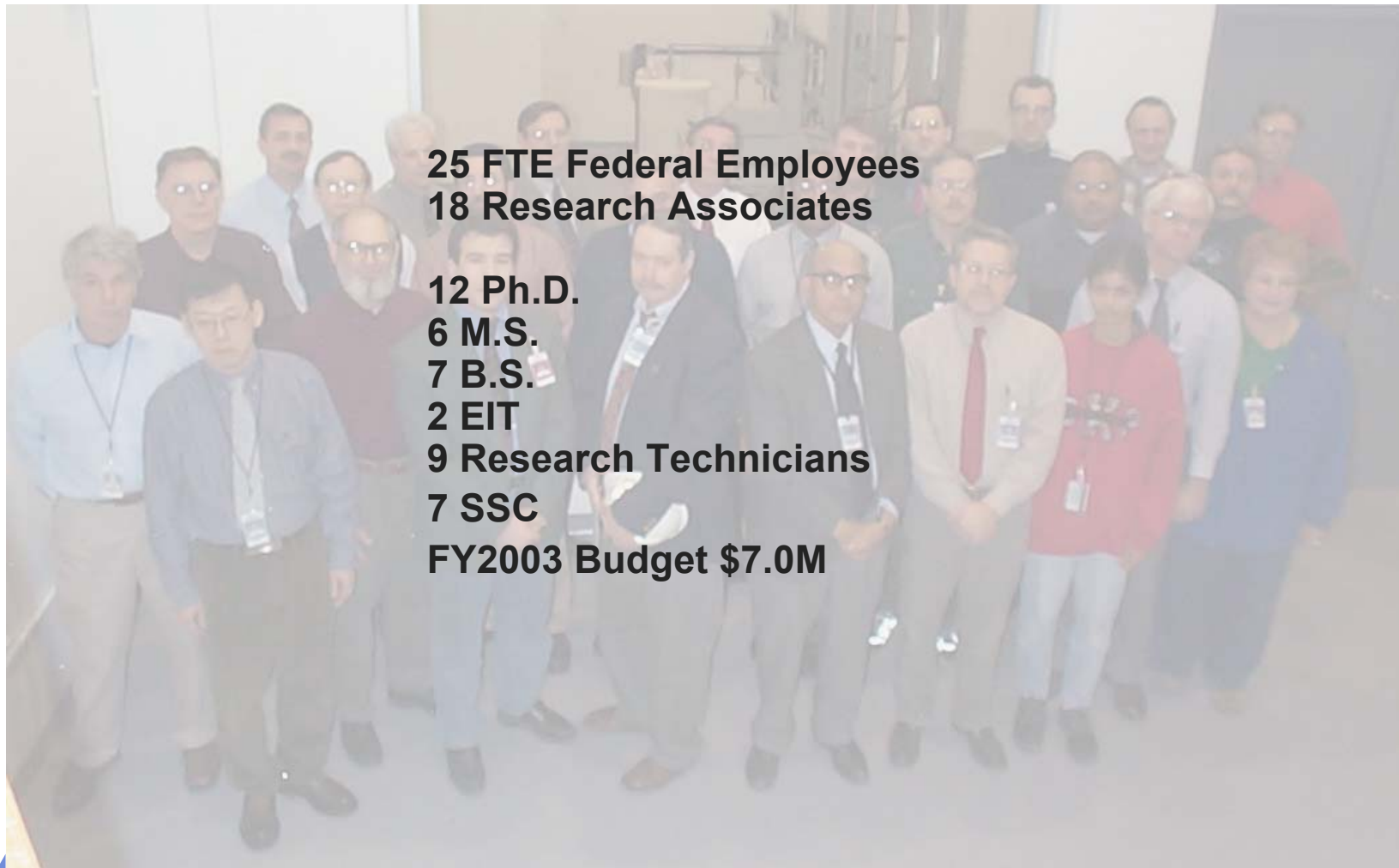


White House photo: Paul Morse



Carbon Sequestration Science Focus Area

Research Staff



25 FTE Federal Employees
18 Research Associates

12 Ph.D.

6 M.S.

7 B.S.

2 EIT

9 Research Technicians

7 SSC

FY2003 Budget \$7.0M

Program Goals

Technology Options for GHG Management

Possess scientific understanding of sequestration options and provide cost-effective, environmentally-sound technology options that lead to reduced GHG intensity and stabilization of atmospheric CO₂

Create Sequestration Options

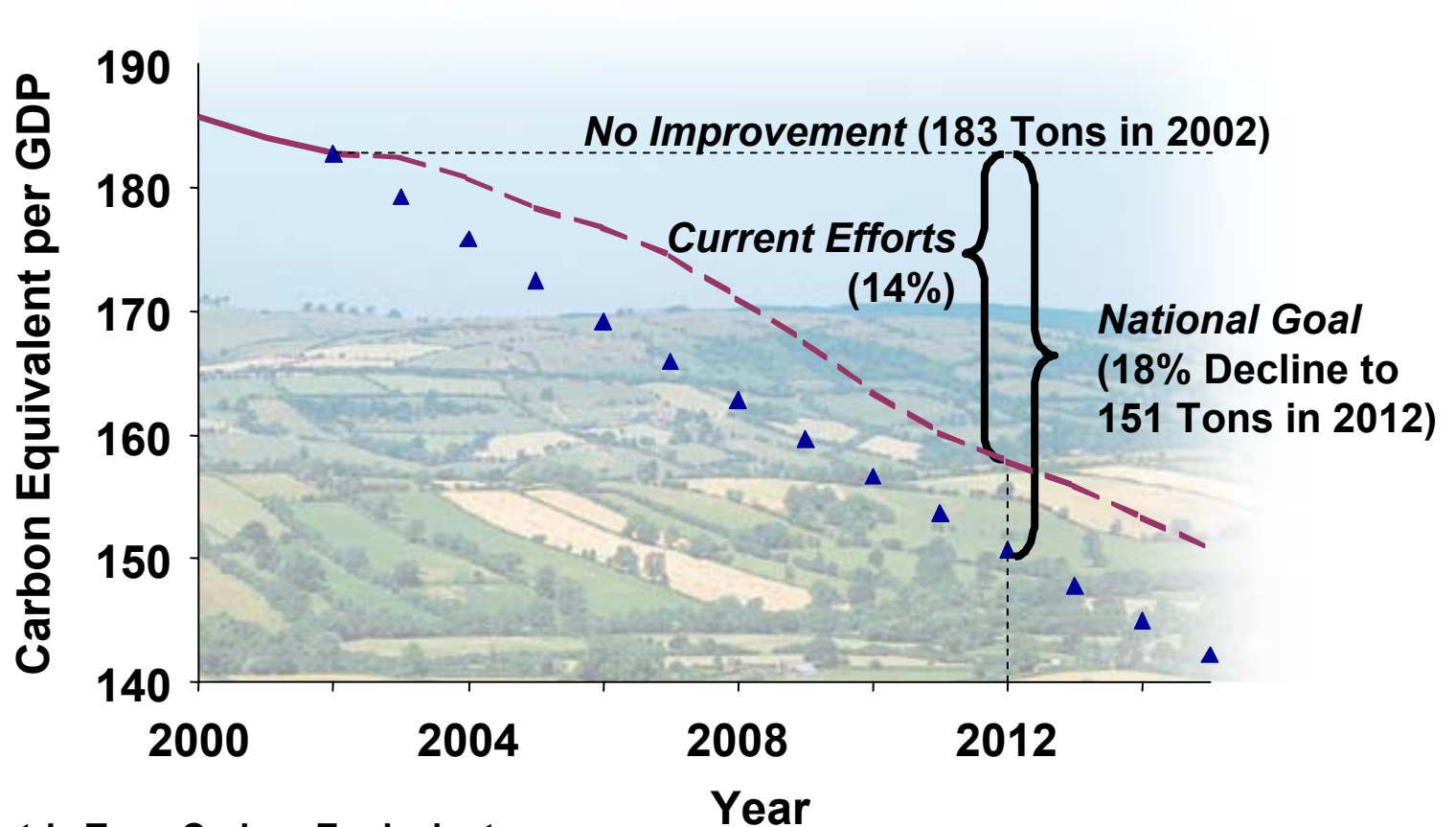
- Reduce CO₂ emissions by 90% with < 10% increase in cost of energy services for capture, transport, storage
- Establish measurement, monitoring & verification protocols for accounting and assurance of permanence

Support Global Climate Change Initiative

- Contribute to 2012 goal of reducing carbon intensity by 18%
- Provide portfolio of commercially ready technologies for 2012 assessment



Reduce Greenhouse Gas Emission Intensity by 18% Over Next Decade



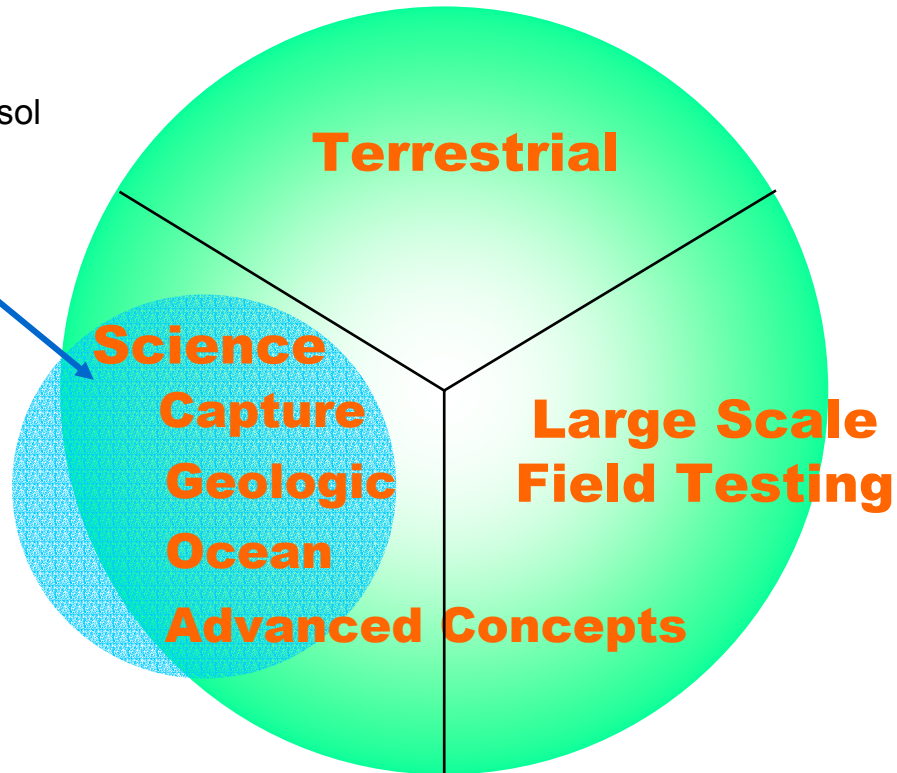
Metric Tons Carbon Equivalent per Million \$ GDP, 2001 Dollars



Relationship to Office of Fossil Energy Sequestration Program/NETL Focus Area

Focus Area

- PSA/TSA
- Physics & chemistry of coal seam sequestration
- Geological Sequestration modeling, Consol ECBM
- Multi-pollutant control
- Hydrate research, CO₂ & CH₄
- CO₂/water/rock reactions
- Geological Sequestration Core Flow Lab
- Flexible Modular CO₂ Capture Facility
- Verification and monitoring
 - geochemical methods - tracers, CO₂ /CH₄ flux, water chemistry
 - geophysical methods - remote sensing - lineaments
 - development of simulators that model subsurface CO₂ flow



Building Core Capabilities

User Facilities

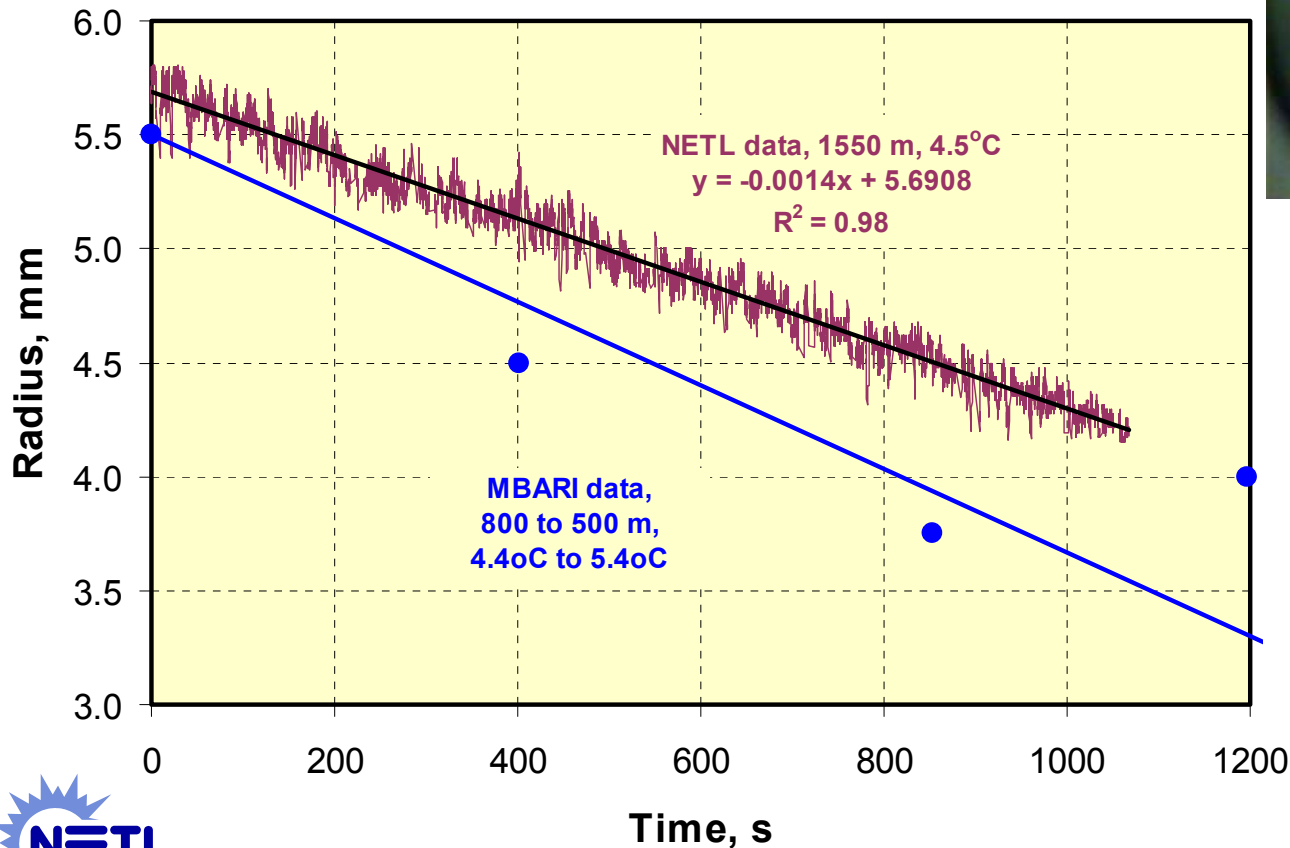
- **Unique Oceanic Sequestration Research Facility**
 - High pressure water tunnel
 - Machine vision, advanced imaging
- **Modular CO₂ Capture Facility (MCCF)**
 - Modular facility
 - Advanced instrumentation and diagnostics
 - Flue Gas 2003
 - Fuel Gas 2004
 - Allows side by side comparison of various capture technologies under identical conditions
- **Geological Sequestration Core Flow Lab**
 - Multipurpose facility for simulating various geologic formations and the effects of CO₂ and Brine
 - Highly instrumented, advanced imaging
 - Princeton, PSU



Results From The HPWT

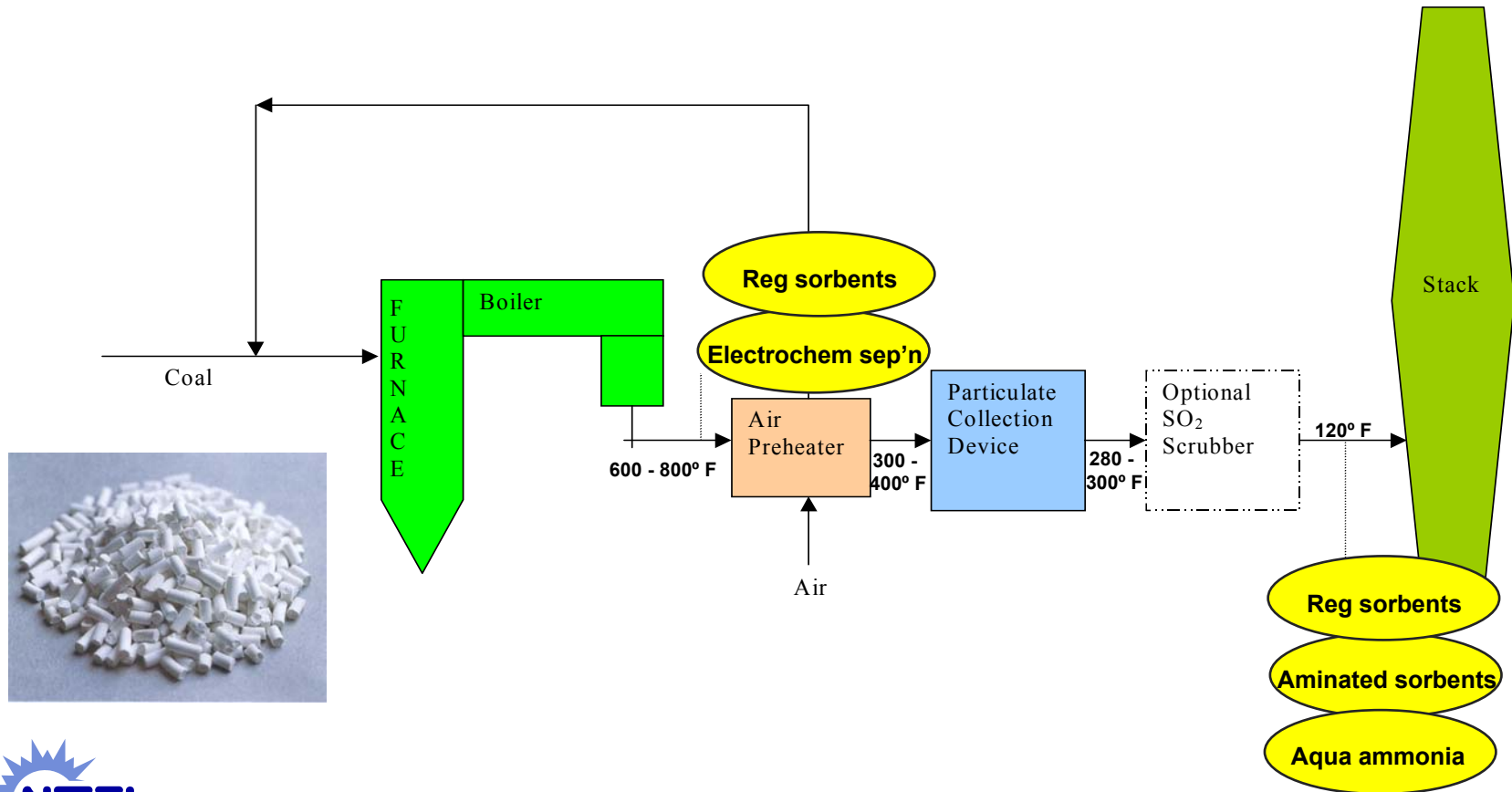
Comparison of CO₂ Drop Dissolution Data

- NETL data obtained at constant P and T in fresh water.
- MBARI data obtained from observations of two drops rising in the ocean.

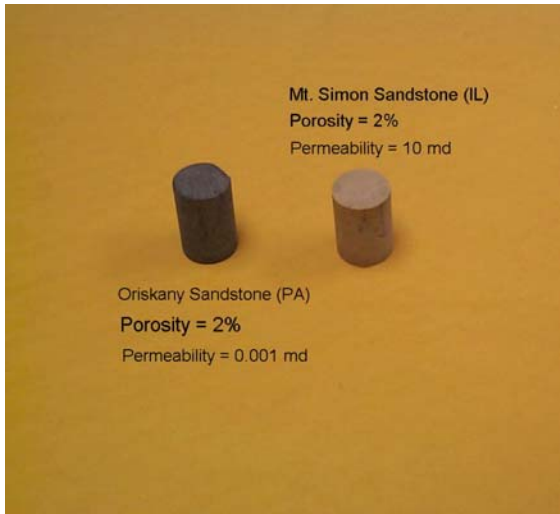


Modular CO₂ Capture Facility

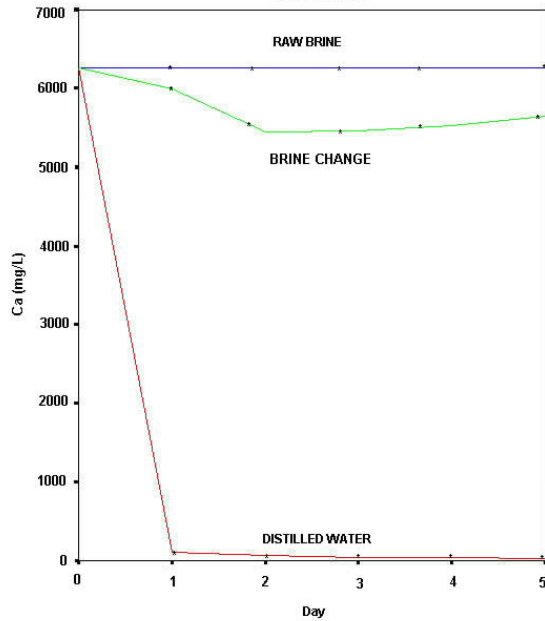
Evaluating the ability of solid regenerable sorbents and membranes to separate and capture CO₂ from flue gas. OST is holding a workshop on CO₂ capture where institutions developing CO₂ capture technologies, that may be evaluated in the MCCF, have been invited. Potential collaborators include: Toshiba, RTI, University of Cincinnati, Media & Process Technology, LANL, Ohio State University, and ORNL.



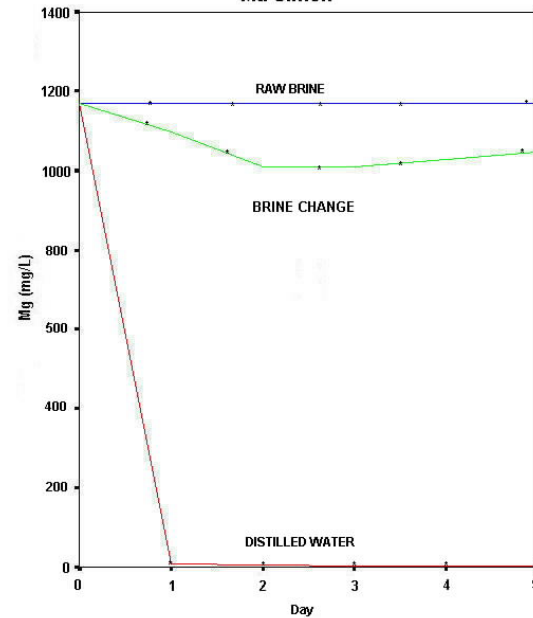
Geological Sequestration Core Flow Lab



Mt. Simon



Mt. Simon



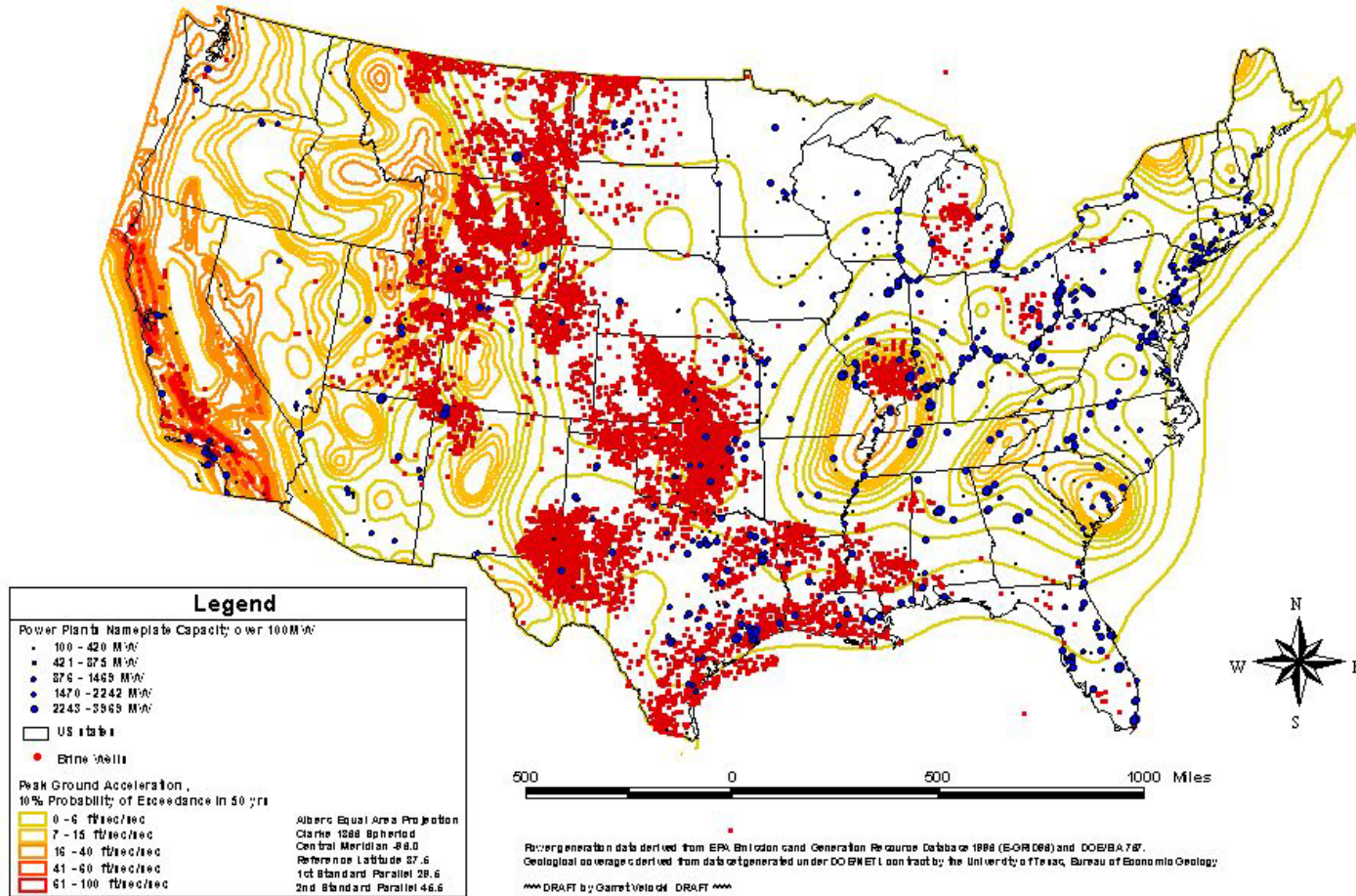


GEOLOGIC SEQUESTRATION OF CARBON DIOXIDE

Powerplant Locations

Brine Well Locations

Seismic Potential



Focus Area Planning and Stakeholder Input

Research Partnerships and collaborators

AES Corporation
Battelle Columbus
BNL
BP
Consol
CSIRO
Dravo
Fluent, Inc.
Fluor Daniels
IMC Chemicals
Los Alamos National Laboratory
Monterey Bay Aquarium Research Institute

New England Research
Ohio Geological Survey
OPHIR Corporation
ORNL
PA Bureau of Topographic and Geologic Survey
Procter & Gamble
RTI
United States Geological Survey
Sud Chemie
SNL
TNO
TICORA Geosciences
Toshiba



Focus Area Planning and Stakeholder Input

Research Partnerships and collaborations

Aachen University of Technology (RWTH)

Carnegie Mellon University

Case Western Reserve

Clarkson University

Colorado School of Mines

Duquesne University*

Oklahoma State University

Pennsylvania State University

Southern Illinois University

University of Akron

University of Pittsburgh*

University of Texas

West Virginia University

*Initiated a starter grant program where NETL provides \$30K in support and the university matches it to yield \$60K in funding. Each Proposal is developed jointly by a faculty member and a NETL scientist.



Visit the NETL Sequestration Website

www.netl.doe.gov/coalpower/sequestration/

NATIONAL ENERGY TECHNOLOGY LABORATORY
CARBON SEQUESTRATION WEBSITE

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January 13, 2003

Carbon Sequestration

*Pathways to Sustainable Use of Fossil Fuels--
enabling the removal and permanent storage
of carbon dioxide from fossil-energy systems*

Welcome to NETL's **Carbon Sequestration Product** webpage. We seek to define carbon sequestration's role in stabilizing atmospheric carbon dioxide levels by developing a scientific understanding and environmentally acceptable technologies. Our research areas include capture & storage, geologic, ocean, and terrestrial sequestration, advanced CO₂ conversion & reuse, and modeling & analysis.

Our site is designed to answer your questions about carbon sequestration—

- Regional Partnerships
- Capture & Storage
- Geologic Sequestration
- Ocean Sequestration
- Terrestrial Sequestration
- Adv. CO₂ Conversion & Reuse
- Modeling & Analysis

What's New
Events
Overview
Capture
Geologic
Ocean
Terrestrial
Conversion
Modeling
In-House R&D
Ref. Shelf
Kids Only!
Links
Contacts
GHG Facts



Carbon Sequestration E-mail Newsletter

Subscribe for The Carbon Sequestration Newsletter

Each month, NETL publishes a short newsletter describing significant events related to carbon sequestration that have taken place over the past month. This newsletter is posted here on our website's [Reference Shelf](#) and distributed by e-mail. If you'd like to join the e-mail distribution list, please refer to the [Subscription Directions](#) page for more information as to "Subscribing" and "Unsubscribing" to our mailing list.



The Carbon Sequestration Newsletter

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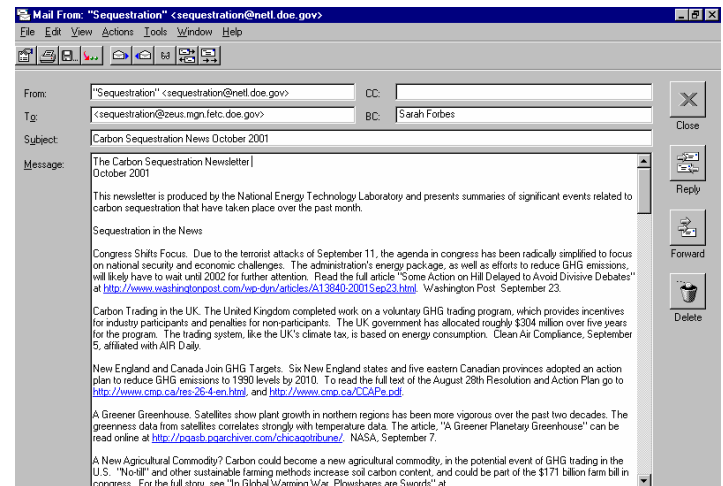
- Sequestration in the News
- Events/ Announcements from NETL's Carbon Sequestration Program
- Publications
- Legislative Activity

www.netl.doe.gov/products/sequestration/refshelf.html

Sequestration in the News

Congress Shifts Focus Due to the terrorist attacks of September 11, the agenda in congress has been radically simplified to focus on national

A Greener Greenhouse NASA Satellites show plant growth in northern regions has been more vigorous over the past two decades. The



Mail From: "Sequestration" <sequestration@netl.doe.gov>

From: "Sequestration" <sequestration@netl.doe.gov> CC: [Redacted]

To: <sequestration@zeus.mgr.fetc.doe.gov> BC: Sarah Forbes

Subject: Carbon Sequestration News October 2001

Message: [The Carbon Sequestration Newsletter] October 2001

This newsletter is produced by the National Energy Technology Laboratory and presents summaries of significant events related to carbon sequestration that have taken place over the past month.

Sequestration in the News

Congress Shifts Focus. Due to the terrorist attacks of September 11, the agenda in congress has been radically simplified to focus on national security and economic challenges. The administration's energy package, as well as efforts to reduce GHG emissions, will likely have to wait until 2002 for further attention. Read the full article "Some Action on Hill Delayed to Avoid Divisive Debates" at <http://www.washingtonpost.com/wp-dyn/articles/A13840-2001-Sep23.html>. Washington Post September 23.

Carbon Trading in the UK. The United Kingdom completed work on a voluntary GHG trading program, which provides incentives for industry participants and penalties for non-participants. The UK government has allocated roughly \$304 million over five years for the program. The trading system, like the UK's climate tax, is based on energy consumption. Clean Air Compliance, September 5, affiliated with AIR Daily.

New England and Canada Join GHG Targets. Six New England states and five eastern Canadian provinces adopted an action plan to reduce GHG emissions to 1990 levels by 2010. To read the full text of the August 28th Resolution and Action Plan go to <http://www.cmp.ca/res-26-4-en.html>, and <http://www.cmp.ca/CC&PE.pdf>.

A Greener Greenhouse. Satellites show plant growth in northern regions has been more vigorous over the past two decades. The greenness data from satellites correlates strongly with temperature data. The article, "A Greener Planetay Greenhouse" can be read online at <http://eosab.jpl.nasa.gov/cheapp/feature/>. NASA, September 7.

A New Agricultural Commodity? Carbon could become a new agricultural commodity, in the potential event of GHG trading in the U.S. "No-ill" and other sustainable farming methods increase soil carbon content, and could be part of the \$171 billion farm bill in congress. For the full story, see "In Global Warming War, Plowshares are Swords" at

