Carbon Sequestration Newsletter

June 2009

What's Inside?

Introduction

This Newsletter is created by the National Energy Technology Laboratory and represents a summary of carbon sequestration news covering the past month. Readers are referred to the actual article(s) for complete information. It is produced by the National Energy Technology Laboratory to provide information on recent activities and publications related to carbon sequestration. It covers domestic, international, public sector, and private sector news.

Highlights

***Fossil Energy Techline*, "President Requests $881.6 Million for Fossil Energy Programs."**

President Barack Obama requested $881.6 million for the Office of Fossil Energy (FE) Fiscal Year (FY) 2010 budget to enhance energy security and develop climate-oriented technology. The request includes $617.6 million for Fossil Energy Research and Development (FE R&D). FE R&D consists of the Fuels and Power Systems and Natural Gas Technologies Programs, which are designed to ensure the continued use of the Nation's abundant fossil resources. The FY 2010 budget request for FE's Fuels and Power Systems Program is $403.9 million; among other initiatives, efforts entail the creation of technologies that can capture and permanently store carbon dioxide (CO_2) from power plants and other industrial processes. The U.S. Department of Energy (DOE) requested $179.9 million for FE's Carbon Sequestration Program to support carbon capture and sequestration (CCS) site selection and characterization, regulatory permits, community outreach, and the completion of site operations plans for large-scale, geologic CO_2 storage tests. In addition, the request will fund large-scale CO_2 injections and infrastructure development. Two important initiatives under FE's Carbon Sequestration Program are the National Energy Technology Laboratory's (NETL) Regional Carbon Sequestration Partnerships (RCSPs), which unite public and private entities to complete small- and large-scale CO_2 injection tests across the Nation, and the Carbon Sequestration Leadership Forum (CSLF), which encourages U.S. collaboration with the global community. For more information about DOE's RCSP Program, visit: http://www.netl.doe.gov/technologies/carbon_seq/partnerships/partnerships.html, or click: http://www.cslforum.org/ for details about CSLF. To view FE's FY 2010 Budget Chart, click: http://www.fossil.energy.gov/aboutus/budget/10/FY_2010_Budget.html. May 8, 2009, http://www.fossil.energy.gov/news/techlines/2009/09026-FE_Releases_FY10_Funding_Request.html.

***Fossil Energy Techline*, "Secretary Chu Announces $2.4 Billion in Funding for Carbon Capture and Storage Projects."**

On May 15, 2009, U.S. Secretary of Energy Steven Chu announced that $2.4 billion from the American Recovery and Reinvestment Act will be used to expand and accelerate the commercial deployment of CCS technology. To issue this funding, DOE will post Notices of Intent supporting the Clean Coal Power Initiative (CCPI) ($800 million), industrial CCS projects ($1.52 billion), geologic sequestration site characterization ($50 million), and geologic sequestration training and research ($20 million). CCPI funding will expand the range of technologies, applications, fuels, and geologic formations for commercial-scale CCS tests. Industrial CCS funding will be used for a two-part, competitive solicitation for large-scale CCS from industrial sources, such as cement plants, chemical plants, refineries, steel and aluminum plants, manufacturing facilities, and petroleum coke-fired and other power plants. With respect to geologic sequestration site characterization, a competitive solicitation will be funded to characterize a minimum of 10 geologic formations to build upon the work done by DOE's RCSPs. Finally, geologic sequestration training and research funding will be

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

One West Third Street, Suite 1400
Tulsa, OK 74103-3519

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South, Suite 201
Fairbanks, AK 99709

Sean I. Plasynski
412-386-4867
sean.plasynski@netl.doe.gov

Dawn M. Deel
304-285-4133
dawn.deel@netl.doe.gov

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681

Highlights (Continued)

used to educate and train a future generation of geologists, scientists, and engineers in geology, geophysics, geomechanics, geochemistry, and reservoir engineering. For more information about DOE's Carbon Sequestration Program, visit: http://www.fossil.energy.gov/programs/sequestration/index.html. May 15, 2009, http://www.fossil.energy.gov/news/techlines/2009/09029-DOE_Announces_Stimulus_Funding.html.

Sequestration in the News

***Kentucky Geological Society News Release*, "Drilling of Test Well to Research Carbon Dioxide Storage is Underway in Western Kentucky,"** and ***Oil and Gas Journal*, "Kentucky Sets CO_2 EOR, Sequestration Projects."**

Fifteen months after initial project planning, drilling has initiated for a test well in Hancock County, Kentucky, to research the permanent storage of CO_2 deep underground in western Kentucky. The 8,300-foot well will be used to determine the feasibility of injecting CO_2 into geologic formations to reduce greenhouse gas (GHG) emissions. The project, which is a joint effort between Kentucky state government agencies, the Kentucky Geological Survey (KGS), and a consortium of public and private participants, is funded by a $5 million grant awarded to KGS from the Kentucky Department for Energy Development and Independence. Well drilling, expected to take 45 to 65 days, will take place in the Knox and Mount Simon Formations. The upper 3,800 feet of the well will be lined with steel casing to protect shallow groundwater and oil and gas resources. Samples of geologic formations will be taken for analysis and up to 1,500 tons of CO_2 will be injected into the well beginning in mid-May. In another project in western Kentucky, approximately 8,000 tons of CO_2 will be injected over a six-month timeframe into the Mississippian Jackson sandstone at 1,870 feet in a well in Sugar Creek field in Hopkins County. To learn more about these projects, visit the Kentucky Consortium for Carbon Storage website, at: www.kyccs.org. April 27, 2009, http://www.uky.edu/KGS/announce/joint_project.htm, and April 29, 2009, http://www.ogj.com/display_article/360716/7/ONART/none/DriPr/1/Kentucky-sets-CO-2--EOR,-sequestration-projects/.

***Canadian Business Online*, "Leaders of Montana, Saskatchewan Agree to Pursue $270 Million Cross-Border Climate Project,"** and ***Government of Saskatchewan News Release*, "Saskatchewan and Montana Join Forces on Carbon Capture and Storage."**

On May 7, 2009, officials in Montana and Saskatchewan signed a Memorandum of Understanding (MOU) to develop North America's first large-scale initiative to capture and store GHGs from a coal-fired power plant. The $230 million project would retrofit an existing

Sequestration in the News (Continued)

existing Canadian coal-fired power plant, owned by SaskPower, for CO_2 capture, piping the GHG into northern Montana where it would be injected into deep geological formations for storage. Construction is scheduled for early Fall 2009 and the project is set to go online in 2011. Saskatchewan is investing $42 million and seeking an additional $85 million from the Canadian government; Montana is pursuing a $100-million grant in addition to its contributions of a CO_2 pipeline and underground storage facilities. The captured CO_2 could also be used for enhanced oil recovery (EOR). Early indications by state officials show that Montana's Popular Dome geological formation, east of Medicine Lake, offers the best storage site. The project goal is to capture 1.1 million tons of CO_2, approximately 30 percent of the plant's emissions, over the next four years. May 7, 2009, http://www.canadianbusiness.com/markets/market_news/article.jsp?content=D981O7I00&page=3, and May 7, 2009, http://www.gov.sk.ca/news?newsId=c06068a6-59d6-40ba-a2f7-43d07b24441c.

***Offshore Magazine*, "Study Reveals CO_2 Storage Potential Offshore Scotland,"** and ***Power Engineering International*, "Scottish North Sea Waters Can Hold up to 46bn Tonnes of CO_2 – Report."**

According to a one-year collaborative study of Scottish waters conducted by the Scottish Centre for Carbon Storage (SCCS), the Scottish Government, and several industry partners, approximately 5,070 to 50,706 million tons of industrial CO_2 emissions can be stored beneath the Scottish area of the northern and central North Sea. The report also states that a storage capacity of this size could potentially store 100 years worth of the United Kingdom's industrial CO_2 emissions and several sites could potentially store Scotland's total CO_2 output for the next 200 years. The study identifies a list of CO_2 storage sites in the North Sea, including saline formations and depleted oilfields. Results show that more than 90 percent of this storage could be in saline formations. The study recommends scientists undertake a more detailed mapping and evaluation of specific saline aquifers. (See Recent Publications section in this newsletter to view a portion of the Executive Summary and a link to SCCS's "Opportunities for CO_2 Storage Around Scotland.") May 1, 2009, http://www.offshore-mag.com/display_article/360865/9/ONART/none/RGRPT/1/Study-reveals-CO_2-storage-potential-offshore-Scotland/, and May 1, 2009, http://pepei.pennnet.com/display_article/360833/6/ARTCL/none/none/1/Scottish-North-Sea-waters-can-hold-up-to-46bn-tonnes-of-CO2---report/.

***The New York Times*, "A Plan for U.S. Emissions to Be Buried Under Sea,"** and ***Greenwire*, "N.J. Coal Plant Would Capture CO_2, Bury it Under Atlantic."**

SCS Energy, a power company based in Concord, Massachusetts, says it can build a coal-fired power plant at an old industrial site in Linden, New Jersey, that can capture and store 90 percent of its CO_2 emissions beneath the Atlantic Ocean. The company would use a buried steel pipe, two feet in diameter, to transport the liquid CO_2 70 miles offshore to a well beneath half of a mile of water. From there, the CO_2 would be injected into a layer of sandstone approximately one mile below the sea floor. SCS Energy has agreed to pay $95 million for an old DuPont chemical factory site at Grasselli Point in Linden, which is located near rail lines and barges that can deliver coal. April 17, 2009, http://www.nytimes.com/2009/04/18/business/energy-environment/18clean.html?_r=3 (subscription required), and April 20, 2009, http://www.eenews.net/Greenwire/2009/04/20/16/.

Announcements

DOE Funds Center for Nanoscale Control of Geologic CO_2.
Donald DePaolo, head of the Earth Sciences division at Lawrence Berkeley National Laboratory (LBNL), was awarded DOE funding to create the Center for Nanoscale Control of Geologic CO_2, which will examine how CO_2 interacts with the pores inside underground rocks and minerals. These techniques could be used to predict the performance of long-term, subsurface storage. For more information, click: http://newscenter.lbl.gov/feature-stories/2009/04/28/efrc-co2/.

RGGI Receives Climate Protection Award.
The U.S. Environmental Protection Agency (EPA) granted the 10 states participating in the Regional Greenhouse Gas Initiative (RGGI) a Climate Protection Award that commends RGGI for serving as a global leader in protecting the climate and a potential model for Federal climate legislation. The awards are granted based on originality and public purpose, global perspective, and GHG emission reductions. To view the RGGI website, click: http://www.rggi.org/.

SEG CO_2 Sequestration Geophysics Workshop.
This Society of Exploration Geophysicists- (SEG) hosted workshop, scheduled for August 23-27, 2009, will focus on the geophysical aspects of CCS, such as rock and fluid physics, flow-to-seismic simulations, site characterization, CO_2 plume imaging and monitoring, quantitative CO_2 estimation and inversion, risk assessment, and novel case studies. For detailed information, visit: http://www.seg.org/SEGportalWEBproject/portals/SEG_Online.portal?_nfpb=true&_pageLabel=pg_gen_content&Doc_Url=prod/SEG-Meetings/Mtgs-Upcoming-Mtgs/SRW2009Alberta/index.htm.

Announcements (Continued)

MIT Geological Carbon Sequestration Course.

On July 20-22, 2009, the Massachusetts Institute of Technology (MIT) will hold a course covering the scientific, technological, and regulatory aspects of CCS. Subjects to be addressed include: the role of carbon sequestration in the climate change mitigation portfolio; site selection and risk assessment; and the role of policy in establishing market opportunities for CCS. A course summary is available at: http://web.mit.edu/professional/short-programs/courses/geological_carbon_sequestration.html?c1=email&source=sp+energy+central#schedule.

Course on the Design and Planning of CCS Projects.

The Alberta Research Council (ARC) is offering a CCS course on June 15-16, 2009, to provide a better understanding of CCS implementation across the CCS project life cycle, from selecting appropriate CO_2 capture technology for a facility; characterizing potential CO_2 storage sites; meeting regulatory requirements and stakeholder expectations; and designing and implementing a CO_2 monitoring program. A course outline is available at: http://www.arc.ab.ca/documents/Alberta%20Research%20Council%20CCS%20Course.pdf.

UK Forms Carbon Research Group.

The University of Kentucky's Center for Applied Energy Research (CAER) created a consortium to study technologies that reduce and manage CO_2 emissions from coal-fired power plants. The consortium will examine pilot-scale, post-combustion CO_2 capture and study large-scale CO_2 capture in a portable unit that will be constructed and operated at the power plants of the consortium's industry members. For more information about CAER, go to: http://www.caer.uky.edu/.

Science

***Science Daily*, "Ants In Southern Hemisphere Richer And More Diversified Than Northern Hemisphere Ants."**

An international team of more than 26 researchers have concluded that there are fewer species of ants in the northern hemisphere than in the southern hemisphere as a result of climate changes that occurred 53 to 54 million years ago. The group of researchers studied 1,003 local ant groups on five different continents. The conclusions from their study are attributed to climate-related and historical variables, such as regional history, disturbance history, and the history of climate change. Ant species richness ranges from zero to 184 different species, with variations caused by temperature and rainfall. According to the researchers, 49 percent of the variation in the number of species between the different locations studied is due to climate differences. Unlike birds, amphibians, or plants, ant species richness is greater in dry habitats. For example, the warm region of Australia has greater ant species richness than the entire northern hemisphere. The information gathered from the research was used to create the Global Ant Community Database, which researchers claim contains statistics on more than 3,000 sites around the world. The complete journal article, titled, "Climatic drivers of hemispheric asymmetry in global patterns of ant species richness," is available at: http://web.utk.edu/~nsanders/Pubs/2009-DunnEcoLetts.pdf. May 13, 2009, http://www.sciencedaily.com/releases/2009/05/090506094103.htm.

***Science Daily*, "For Northern Shrimp Populations In North Atlantic, Timing Is Everything,"** and ***Reuters*, "Shrimp Said at Risk from North Atlantic Warming."**

According to scientists, a $500-million North Atlantic shrimp fishery may be vulnerable to potential climate change that could disrupt the crustaceans' life cycle. Their research found that the crustaceans living from the Gulf of Maine to the Arctic waters north of Norway time their mating with water temperatures on the seabed. The timing is based on their eggs hatching when algae, shrimp larvae's food source, are most abundant. Warmer waters have the potential to disrupt their natural timing. The study claims a changing climate may increase bottom water temperatures, which would result in shorter development time for eggs. As a result, the eggs may hatch too early for survival. Shrimp represent an important link in the food chain because they feed on algae and are in turn consumed by fish. The complete journal article, titled, "Basin-Scale Coherence in Phenology of Shrimps and Phytoplankton in the North Atlantic Ocean," is available at: http://www.sciencemag.org/cgi/content/abstract/sci;324/5928/791. May 13, 2009, http://www.sciencedaily.com/releases/2009/05/090507145749.htm, and May 7, 2009, http://www.reuters.com/article/environmentNews/idUSTRE5465T120090507?feedType=RSS&feedName=environmentNews.

Policy

***Governor Joe Manchin News Release*, "Governor Announces AEP Plant Receives State's First Carbon Sequestration Permit,"** and ***The Charleston Gazette*, "Apco Receives 1st Carbon Capture Permit in Wva."**

On May 4, 2009, the West Virginia Department of Environmental Protection issued an underground injection control permit for geologic CO_2 storage to the Appalachian Power Company's Mountaineer Plant

Policy (Continued)

located in New Haven. It is the first CO_2 sequestration permit issued in the state, according to an announcement from West Virginia Governor Joe Manchin. The Mountaineer Plant project, which will be one of the largest pilot projects in the country, will capture and inject up to a maximum of 165,000 metric tons of CO_2 per year using CCS technologies over a period of four to five years. The CO_2 will be captured from flue gas produced by fossil fuel-fired power plants, converted from a gaseous state to a supercritical fluid, and transported to the sequestration site by pipeline. From there it will be injected into deep subsurface rock formations through one or more injection wells. House Bill (HB) 2860 (available at: http://www.legis.state.wv.us/bill_status/bills_history.cfm?year=2009&sessiontype=RS) provides the legal and regulatory framework for the permitting of CO_2 sequestration operations in West Virginia. May 4, 2009, http://www.wvgov.org/sec.aspx?id=32&articleid=1771, and May 5, 2009, http://wvgazette.com/ap/ApTopStories/200905050160.

"Valuation of Carbon Capture and Sequestration under Greenhouse Gas Regulations."

The following is the Abstract of this article: "The value assigned to CCS depends on the type of [GHG] regulation chosen and details of how the market is implemented. This article describes some ways in which CCS can be incorporated into [GHG] regulations, together with their implications, and how CCS is treated in current regulations for regulated entities." **Elizabeth Lokey**, *The Electricity Journal*, Available online April 24, 2009, doi:10.1016/j.tej.2009.03.014, http://www.sciencedirect.com/science/article/B6VSS-4W4S34V-1/2/d521defe7196e81dbfbbe71e90786464. (Subscription may be required.)

"Anticipating public attitudes toward underground CO_2 storage."

The following is the Abstract of this article: "CCS may play a central role in managing carbon emissions from the power sector and industry, but public support for the technology is unclear. To address this knowledge gap, and to test the use of discrete choice analysis for determining public attitudes, two focus groups and a national survey were conducted in Canada to investigate the public's perceptions of the benefits and risks of CCS, the likely determinants of public opinion, and overall support for the use of CCS. The results showed slight support for CCS development in Canada, and a belief that CCS is less risky than normal oil and gas industry operations, nuclear power, or coal-burning power plants. A majority of respondents indicate that they would support the use of CCS as part of a [GHG] reduction strategy, although it would likely have to be used in combination with energy efficiency and alternative energy technologies in order to retain public support." **Jacqueline D. Sharp, Mark K. Jaccard, and David W. Keith**, *International Journal of Greenhouse Gas Control*, Available online May 6, 2009, doi:10.1016/j.ijggc.2009.04.001, http://www.sciencedirect.com/science/article/B83WP-4W7B58F-1/2/e2c9abdef41b0c259281847091aceff6. (Subscription may be required.)

Geology

"Geochemical effects of CO_2 sequestration on fractured wellbore cement at the cement/caprock interface."

The following is the Abstract of this article: "The potential impact to the integrity of wellbore cements as a result of exposure to supercritical carbon dioxide ($SCCO_2$) has been raised as an area of some concern with respect to long-term effectiveness of CO_2 storage in geological formations. In flow-through experiments, [the authors] simulated diffusion of brine and $SCCO_2$ from the interface between wellbore cement and caprock into a fracture-bearing Portland cement. The experiments were performed at in-situ reservoir pressure (pore pressure: 19.9 MPa) and temperature (54°C) conditions for 113 days. For this purpose [the authors] saturated illite-rich shale and the Portland cement core (2.02 cm × 5.35 cm) with 1.65 M brine for 14 days. After this period of time, [the authors] injected $SCCO_2$ into the system for 99 days and simulated a diffusion process by using a pressure gradient of 0.7 MPa. Calcite precipitation occurred within the fracture and the induced pressure of crystal growth may explain an increase in the relative permeability along the fracture with time. $SCCO_2$-induced reactions extended ~5 mm into the Portland cement core from the fracture and formed an orange-colored zone. The orange-colored zone is nearly completely carbonated with crystalline phases consisting mainly of calcite, aragonite, and vaterite. The only crystalline cement component that persisted in the orange-colored zone was brownmillerite. Interior portions of the hydrated cement were partially carbonated, modified in texture and contained newly formed calcite, hydrogarnet and hydrocalumite (Friedel's salt). Cement porosity decreased from 37.8 [percent] to 23.8 [percent] during carbonation and was associated with a 19.6 [percent] increase in mass." **Marcus Wigand, John P. Kaszuba, J. William Carey, and W. Kirk Hollis**, *Chemical Geology*, Available online April 21, 2009, doi:10.1016/j.chemgeo.2009.04.008, http://www.sciencedirect.com/science/article/B6V5Y-4W3HX8Y-2/2/a3510a116cb065d0a3f402b427c727e6. (Subscription may be required.)

"Experimental ageing of oolitic limestones under CO_2 storage conditions: Petrographical and chemical evidence."

The following is the Abstract of this article: "The reactivity of an oolitic limestone in contact with CO_2 was investigated on core samples in a 2 l batch reactor. Three types of experiments were conducted on wet samples at 150 bar of gas pressure and 80°C in the presence of (1) supercritical CO_2 and pre-equilibrated saline solution, (2) supercritical CO_2 without aqueous solution, and (3) N_2 and pre-equilibrated saline solution. Microscopic observations using optical and electronic microscopy showed little evidence of transformations although some dissolution/precipitation patterns were suspected in all experiments. Similarly, results from Hg porosity measurements, mechanical behavior and velocity of ultrasonic waves were also slightly modified after experiments. Statistical image analysis of interoolite porosity

Geology (Continued)

measurements recorded by confocal scanning laser microscopy showed slight modifications of the pore distribution, connectivity and roughness in the case of the first experiment carried out with aqueous solution and CO_2. Such observations are in good agreement with water analyses and thermodynamic simulations which predict high limestone stability with calcite dissolution of <1 [percent] in mass. This study confirms that massive calcite dissolution is not possible since CO_2 pressure and pH exert opposing effects on calcite stability. The low impact of dry supercritical CO_2 on calcite dissolution was also demonstrated." **J. Sterpenich, J. Sausse, J. Pironon, A. Géhin, G. Hubert, E. Perfetti, and D. Grgic**, *Chemical Geology*, Available online April 21, 2009, doi:10.1016/j.chemgeo.2009.04.011, http://www.sciencedirect.com/science/article/B6V5Y-4W45WMR-1/2/2e24eb7d14cc46516ae0140fd1758d5b. (Subscription may be required.)

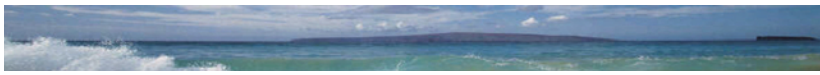
"Experimental determination of porosity and permeability changes induced by injection of CO_2 into carbonate rocks."

The following is the Abstract of this article: "A set of four reactive flow-through experiments at temperature T = 100°C and total pressure P = 12 MPa was performed in limestone reservoir samples. By using various ranging from 0.7 to 10 MPa, these experiments mimic mass transfers occurring (1) near the injection well, where the brine is almost saturated with CO_2 (i.e. $P_{CO2} \approx P$), and (2) at increasing distances from the injection well, where the fluid displays lower values and higher divalent cation concentrations due rock dissolution along the fluid pathway. Results for P_{CO2} = 10 MPa show non-uniform dissolution features associated with transport-controlled mass transfer, while reaction-controlled uniform dissolution is observed for P_{CO2} = 2.5 MPa. The experiment with P_{CO2} = 6 MPa allows investigating in detail the transition from transport- to reaction-controlled dissolution. Conversely, the experiment reproducing conditions far from the injection well (P_{CO2} = 0.7 MPa), shows a decrease of porosity triggered by the precipitation of Mg-rich calcite. For all the dissolution experiments, the time-resolved porosity $\Phi(t)$ can be modeled by a simple non-linear equation including parameters that characterize the dissolution regime triggered by the reactivity of the inlet fluid (measured by the Damköhler number, Da). Furthermore, all dissolution experiments display power scaling between permeability (k) and porosity (Φ) with distinctly different scaling exponents characterizing the reactivity of the fluid percolating the sample, independently from the decrease with time of the reactive surface area. It is shown also that dissolution at moderate positive values of Da seems the most efficient to increase permeability and promote a rapid spreading of the reaction front, while inducing minimal modification of the porosity in the vicinity of the CO_2 injection well. These results can be used to parameterize the k-α function for modeling the earliest dissolution processes occurring in the vicinity of the reaction front." **L. Luquot and P. Gouze**, *Chemical Geology*, Available online April 2, 2009, doi:10.1016/j.chemgeo.2009.03.028, http://www.sciencedirect.com/science/article/B6V5Y-4W04KMP-2/2/f5147b4b771ce8c8e0a0e01fec487815. (Subscription may be required.)

Technology

"Modeling Gas Transport in the Shallow Subsurface During the ZERT CO_2 Release."

The following is the Abstract of this article: "[The authors] used the multiphase and multicomponent TOUGH2/EOS7CA model to carry out predictive simulations of CO_2 injection into the shallow subsurface of an agricultural field in Bozeman, Montana. The purpose of the simulations was to inform the choice of CO_2 injection rate and design of monitoring and detection activities for a CO_2 release experiment. The release experiment configuration consists of a long horizontal well (70 m) installed at a depth of approximately 2.5 m into which CO_2 is injected to mimic leakage from a geologic carbon sequestration site through a linear feature such as a fault. [The authors] estimated the permeability of the soil and cobble layers present at the site by manual inversion of measurements of soil CO_2 flux from a vertical-well CO_2 release. Based on these estimated permeability values, predictive simulations for the horizontal well showed that CO_2 injection just below the water table creates an effective gas-flow pathway through the saturated zone up to the unsaturated zone. Once in the unsaturated zone, CO_2 spreads out laterally within the cobble layer, where liquid saturation is relatively low. CO_2 also migrates upward into the soil layer through the capillary barrier and seeps out at the ground surface. The simulations predicted a breakthrough time of approximately two days for the 100kg d−1 injection rate, which also produced a flux within the range desired for testing detection and monitoring approaches. The seepage area produced by the model was approximately five meters wide above the horizontal well, compatible with the detection and monitoring methods tested. For a given flow rate, gas-phase diffusion of CO_2 tends to dominate over advection near the ground surface, where the CO_2 concentration gradient is large, while advection dominates deeper in the system." **Curtis M. Oldenburg, Jennifer L. Lewicki, Laura Dobeck, and Lee Spangler**, *Earth and Environmental Science*, Available online April 15, 2009, doi:10.1007/s11242-009-9361-x, http://www.springerlink.com/content/f044l20j7h111875/?p=85f8401c8fe94d709f0cb2d084898b0a&pi=5. (Subscription may be required.)



Terrestrial

"Changes in soil organic carbon, nutrients and aggregation after conversion of native desert soil into irrigated arable land."

The following is the Abstract of this article: "This study aimed at investigating the effects of agricultural exploitation on desert soil organic [carbon], [nitrogen (N)] and [phosphorus (P)], and soil aggregation. Four

Terrestrial (Continued)

land uses were assessed: (1) 5-year wheat (Triticum aestivum L.)/ barley (Hordeum vulgare L.) + 5-year maize (Zea mays L.); (2) 5-year wheat/barley + 5-year alfalfa (Medicago sativa L.); (3) 6-year wheat/ barley + 4-year acacia (Robinia pseudoacacia L.); and (4) uncultivated desert soil. The desert soil contained total organic [carbon] (TOC) of 3.1, 3.7, and 4.2 g kg^{-1} and particulate organic [carbon] (POC) of 0.6, 0.7, and 0.8 g kg−1 at 0-10, 10-20, and 20-30 cm depths, respectively. The soil TOC concentration was increased by 32-68 [percent] under wheat–maize rotation and by 27-136 [percent] under wheat–acacia at 0-20 cm depth, and by 48 [percent] under wheat–alfalfa only at 0-10 cm depth. This contrasted with an increase in the soil POC concentration by 143-167 [percent] at depth 0-20 cm under wheat–maize and by 217 [percent], 550 [percent] at depth 0-10 cm under wheat–alfalfa and wheat–acacia, respectively. The desert soil had 13 Mg ha^{-1} TOC stock and 2 Mg ha^{-1} POC stock at depth 0-30 cm, whereas crop rotations increased the soil TOC stock by 30-65 [percent] and POC stock by 200-350 [percent]. Over the 10-year period, the rates of TOC accumulation were 0.6, 0.3, 0.8 Mg ha^{-1} $year^{-1}$ and the rates of POC accumulation were 0.4, 0.4, and 0.7 Mg ha^{-1} $year^{-1}$ under wheat–maize, wheat–alfalfa and wheat–acacia rotations, respectively. At 0-30 cm depth, total soil N was increased by 61-64 [percent] under wheat–maize and wheat–acacia, but total soil P was reduced by 38 [percent] under wheat–alfalfa. A significant improvement in clay stability but not in aggregate water-stability was observed in cultivated soils. The results showed a significant increase in soil organic [carbon] pool but unimproved macro-aggregation of the desert soil after 10 years of cultivation." **Xiao Gang Li, Yin Ke Li, Feng Min Li, Qifu Ma, Ping Liang Zhang, and Ping Yin**, *Soil and Tillage Research*, Available online April 24, 2009, doi:10.1016/j.still.2009.03.002, http://www.sciencedirect.com/science/article/B6TC6-4W4S2YW-1/2/292d64d079dcede7cd192277775a0473. (Subscription may be required.)

Carbon Market Update, May 13, 2009	
CCX-CFI 2009 ($/$tCO_2$) $1.15 (Vintage 2009)	EU ETS-EUA DEC 2009 ($/$tCO_2$) $19.84 (Converted from € to US$)

Trading

***RGGI News Release*, "Report: RGGI Trading Volumes Grow in First Quarter of 2009,"** and ***E&E News*, "Carbon Trading Increases in Eastern States."**

The 10 Northeast and Mid-Atlantic states participating in RGGI released a report on May 7, 2009, showing the continued maturation of the secondary market for RGGI CO_2 allowances. According to the report, titled, "Report on the Secondary Market for RGGI CO_2 Allowances," an average of 979,000 tons of CO_2 was moved each day in March 2009. In December 2008, the daily movement of permits was 303,000 tons. The report, which addresses trading in the first quarter of 2009 and was issued by the independent market monitor, Potomac Economics, also states the market is less volatile now than in December. In addition, futures contracts increased from an average of 303 daily transactions in December to 979 in March; likewise, options contracts increased from a 199 transactions to 363 during the same timeframe. The report concludes that 26 firms held a significant quantity of futures and options contracts on secondary market exchanges by the end of the first quarter of 2009. May 7, 2009, http://www.rggi.org/docs/Secondary_Market_Report_May_2009.pdf, and May 8, 2009, http://www.eenews.net/climatewire/print/2009/05/08/5.

Recent Publications

"Opportunities for CO_2 Storage Around Scotland."

The following is from the Executive Summary of this document: "CCS is one of the critical technologies worldwide which will enable reduction of CO_2 emissions arising from large industrial sites. CCS allows the continued use of a diverse mix of energy sources, including fossil fuels, which improves the security of cost-effective electricity supply. Scotland has the opportunity and responsibility to reduce CO_2 emissions arising from burning of fossil fuels and their impact on climate change. The [European Union (EU)] plans to have 12 CCS plants operating by 2015. In February 2009, the UK Secretary of State for Energy and Climate Change stated an aspiration for the UK to have more than one demonstration project in operation enabled by government funding. However, these targets cannot be delivered without the underpinning knowledge from studies such as this. Commitment to large-scale investment in CO_2 capture plant will require proven storage capability. This study (1) presents the first high-level screening of CO_2 storage sites available to Scotland; (2) evaluates the means by which CO_2 can be transported from power plants and other industrial activities to storage sites; and (3) investigates the costs and business constraints. This is the most comprehensive and fully integrated study performed in the UK, and was achieved by a collaborative partnership of Scottish Government, research universities and institutes, and a broad base of support from industry and business. The conclusions show that Scotland has an extremely large CO_2 storage resource. This is overwhelmingly in offshore saline aquifers (deeply buried porous sandstones filled with salt water) together with a few specific depleted hydrocarbon fields. The resource can easily accommodate the industrial CO_2 emissions from Scotland for the next 200 years. There is very likely to be sufficient storage to allow import of CO_2 from NE England, this equating to over 25 [percent] of future UK large industry and power CO_2 output. Preliminary indications are that Scotland's offshore CO_2 storage capacity is very important on a European scale, comparable with that of offshore Norway, and greater than Netherlands, Denmark and Germany combined." The document is available at: http://www.geos.ed.ac.uk/research/sccs/regional-study/CO2-JointStudy-Full.pdf.

Recent Publications (Continued)

"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007."

The following is from the Executive Summary of this document: "An emissions inventory that identifies and quantifies a country's primary anthropogenic sources and sinks of GHGs is essential for addressing climate change. This inventory adheres to both (1) a comprehensive and detailed set of methodologies for estimating sources and sinks of anthropogenic GHGs, and (2) a common and consistent mechanism that enables Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to compare the relative contribution of different emission sources and GHGs to climate change." The complete EPA document is available at: http://www.epa.gov/climatechange/emissions/downloads09/InventoryUSGhG1990-2007.pdf.

Legislative Activity

***Forbes*, "Carbon Storage Measure Becomes Law in Montana,"** and ***Helena Independent Record*, "Governor Signs Carbon Dioxide Storage Bill."**

On May 6, 2009, Montana Governor Brian Schweitzer signed a bill that creates the regulatory guidelines for storing CO_2 underground in Montana. The bill resolves the question of how long a company would be required to monitor a site and remain liable after finishing its CO_2 injection in Montana. Under Senate Bill (SB) 498, a storage company could transfer a site to the state if it is problem free after 30 years, with the Montana Land Board having final authority to decide if the state should assume liability. If approved, the state would then assume site monitoring and liability obligations. Also, the bill gives ownership of underground pore space to surface landowners. The Montana Land Board is responsible for overseeing the management of 5.2 million acres of school trust land in Montana. To view SB 498, go to: http://data.opi.mt.gov/bills/2009/billpdf/SB0498.pdf. May 7, 2009, http://www.forbes.com/feeds/ap/2009/05/07/ap6392460.html (subscription required), and May 11, 2009, http://www.helenair.com/articles/2009/05/07/top/65st_090507_co2.txt.

Events

June 9-10, 2009, **The Petroleum Economist Forum on CCS**, *London, UK*. This CCS forum investigates the challenges of implementing CCS projects and explores the regulatory framework supporting the drive for a reduction in CO_2 emissions. This forum will also cover the political opportunities in CCS, as well as the development of key commercial strategies for CCS. For more information, visit the conference website at: http://www.petroleum-economist.com/default.asp?page=19&searchtype=6&productid=10032.

June 16-17, 2009, **The 5th Trondheim Conference on CO_2 Capture, Transport and Storage**, *NTNU Campus in Trondheim, Norway*. This conference will focus on research and development (R&D) of CCS technologies. Topics to be discussed include: pre-, post-, and oxy-combustion capture; storage site screening; international R&D projects; risk analysis; and policy issues. To view a detailed program, visit the conference website, at: http://www.energy.sintef.no/arr/CO2_2009/index.asp.

June 17-18, 2009, **Carbon Capture, Storage, and Transport Summit 2009**, *Le Meridien Piccadilly, London, United Kingdom*. The 2nd Annual Carbon Capture, Storage, and Transport Summit is a senior level forum directed at covering commercial, technical, legislative, and scientific challenges in carbon capture, storage, and transport implementation. To view the conference website, which includes a downloadable brochure, go to: http://www.iqpc.com/ShowEvent.aspx?id=173566.

June 23-24, 2009, **The 3rd Annual Wyoming CO_2 Conference**, *Parkway Plaza Hotel and Conference Centre, Casper, Wyoming, USA*. This conference will have presentations covering the following topics: current CO_2 EOR projects; current and developing CO_2 EOR supplies; Federal and state legislative updates; and infrastructure and pipelines. There will also be a special session on CO_2 capture technologies. For more information, click: http://eori.gg.uwyo.edu/CO2Conf2009.asp.

Events (Continued)

July 15-17, 2009, **3rd Annual Carbon Capture: Status & Outlook**, *AED Conference Center, Washington DC, USA*. This event focuses on the business side of carbon capture solutions by assessing the impact of new funding, policies, and technology, as well as highlighting the leading domestic and international CO_2 capture pilot projects. To learn more about this event, click: http://www.infocastinc.com/index.php/conference/carbon09.

August 19-21, 2009, **COAL-GEN 2009**, *Charlotte Convention Center, Charlotte, North Carolina, USA*. This three-day event covers the current state of the coal industry and offers attendees the opportunity to learn how to capitalize on the upcoming challenges affecting coal-fired power plants. Also included are technical tours of Duke Energy's Cliffside and Allen Steam Stations. For more information, visit: http://www.coal-gen.com/index/exhibition.html.

September 13-19, 2009, **8th International Carbon Dioxide Conference**, *Friedrich-Schiller-University, Jena, Germany*. This conference provides a multidisciplinary forum for all aspects of modern carbon cycle research relevant to understanding the natural and anthropogenic controls of atmospheric CO_2 and its interactions in the global ecosystem. For registration information, visit the conference website at: http://www.conventus.de/icdc8/.

September 14-15, 2009, **Carbon Capture and Sequestration Summit**, *Omni Shoreham Hotel, Washington DC, USA*. The goal of this summit is to develop a greater understanding of current and future needs for the commercialization of CCS. Topics to be discussed include: the current Federal and state legal and regulatory environments; CCS economics and business models; and the challenges facing transportation and storage. To learn more, click: http://www.americanconference.com/energy/Energy.htm?PageMode=Search.

September 14-15, 2009, **Platts 2nd Annual Carbon Capture & Sequestration**, *Westin Grand Hotel in Washington D.C, USA*. This two-day conference has three main focuses – new policy directions and economic challenges for large-scale deployment; jurisdiction and regulatory framework; and CCS economics. To view the full agenda, visit the conference website by clicking: http://www.platts.com/Events/2009/pc919/index.xml.

September 30-October 2, 2009, **5th Conference on Carbon Credit Market and Carbon Capture and Storage**, *Rome Fair Centre, Rome, Italy*. The only Italian event specializing in GHG emissions and the technology used for GHG reductions, this conference will take place in conjunction with CCS EXPO, the first event for the Mediterranean area focused on CCS. To learn more information, click: http://www.zeroemissionrome.eu/en/index_co2.asp.

For subscription details...

Please visit http://listserv.netl.doe.gov/mailman/listinfo/sequestration, enter your email address, and create a password. This will enable you to receive a pdf version of the Carbon Sequestration Newsletter at no cost.

To view an archive with past issues of the newsletter, see: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/subscribe.html.

To learn more about DOE's Carbon Sequestration Program, please contact Sean Plasynski at sean.plasynski@netl.doe.gov, or Dawn Deel at dawn.deel@netl.doe.gov.