THE NETL CARBON SEQUESTRATION NEWSLETTER: ANNUAL INDEX

SEPTEMBER 2008 – AUGUST 2009

This is a compilation of the past year's monthly National Energy Technology Laboratory Carbon Sequestration Newsletter. The newsletter is produced by the NETL to provide information on activities and publications related to carbon sequestration. It covers domestic, international, public sector, and private sector news. This compilation covers newsletters issued between September 2008 and August 2009. It highlights the primary news and events that have taken place in the carbon sequestration arena over the past year. Information that has become outdated (e.g. conference dates, paper submittals, etc.) was removed.

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HIGHLIGHTS

September 2008

***Fossil Energy Techline*, "DOE Project Starts CO_2 Sequestration in New Mexico Coalbed."** The US Department of Energy's (DOE) Southwest Regional Partnership (SWP) began injecting a planned 35,000 tons of carbon dioxide (CO_2) in an enhanced coalbed methane (CBM) recovery project that will develop methods to maximize permanent storage of CO_2 at the San Juan Basin near Navajo City, New Mexico. The San Juan Basin, which contains coal at approximate depths of 3,000 feet, was chosen for the six-month demonstration project because it is regarded as one of the top basins in the world for CBM recovery due to its favorable geology, high methane content, nearby availability of CO_2 from power plants, low capital and operating costs, and well-developed natural gas and CO_2 pipelines. The basin consists of three CBM-producing wells and a centrally located injection well. The coal seams are approximately 75 feet thick and are split among three seams over a 175-foot interval. In addition, the San Juan Basin contains highly permeable coal that is required for maintaining effective CO_2 injective rates over time; DOE established the maintenance of high injection rates as a goal for large-scale CO_2 sequestration in coal. CBM production typically results in a heavy amount of produced water, which SWP plans to desalinate and use to irrigate nearby areas affected by prolonged drought. The resulting vegetation growth could induce additional CO_2 uptake. The SWP, led by the New Mexico Institute of Mining and Technology, is one of seven Regional Carbon Sequestration Partnerships (RCSPs) managed by DOE's National Energy Technology Laboratory (NETL). The partnership includes the states of Colorado, Oklahoma, New Mexico, Utah, and portions of Arizona, Kansas, Texas, and Wyoming. SWP is currently conducting three geological field tests and two terrestrial field tests, each designed to validate promising carbon sequestration technologies and infrastructure concepts. To learn more about NETL's RCSP Program, visit: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html. For information about SWP, go to: http://www.southwestcarbonpartnership.org/. August 4, 2008, http://www.fossil.energy.gov/news/techlines/2008/08031-San_Juan_Basin_CO2_Injection.html.

***Fossil Energy Techline*, "DOE to Provide $36 Million to Advance Carbon Dioxide Capture."** On July 31, DOE announced that 15 projects will receive $36 million to further develop new, cost-effective technologies that capture CO_2 from the existing fleet of coal-fired power plants. The technologies involve membranes, solvents, sorbents, oxycombustion (both flue gas purification and boiler development), and chemical looping. In particular, membrane-based projects will address technical issues like large flue gas volume, relatively low CO_2 concentration, low flue gas pressure, flue gas contaminants, and the need for high membrane surface area. Solvent-based and solid sorbent-related projects will address technical challenges such as large flue gas volume, relatively low CO_2 concentration, and flue gas contaminants, among other issues. Oxycombustion flue gas purification and boiler development will develop methods to reduce the levels of unwanted compounds (e.g., nitrogen, sulfur oxides [SO_X], nitrogen oxides [NO_X], and/or mercury [Hg]) in flue gas and conduct laboratory- and bench-scale research into boiler characteristics and design. Chemical looping projects will research solids handling and oxygen carrier capacity, reactivity, and attrition. For more information about DOE's carbon capture projects for existing power plants, visit: http://www.fossil.energy.gov/programs/powersystems/pollutioncontrols/index.html. July 31, 2008, http://www.fossil.energy.gov/news/techlines/2008/08030-CO2_Capture_Projects_Selected.html.

October 2008

***NETL News Release*, "Underground Monitoring of Carbon Storage Site Begins in Mississippi."** The U.S. Department of Energy's (DOE) Southeast Regional Carbon Sequestration Partnership (SECARB) is using innovative, real-time monitoring equipment installed two miles beneath the Earth's surface to track the movement of carbon dioxide (CO_2) being injected for oil recovery. The project, led by the Southern States Energy Board and hosted by Denbury Resources, includes downhole pressure and

temperature measurements conducted by the Gulf Coast Carbon Center (GCCC) at the Bureau of Economic Geology, University of Texas at Austin. The effort will examine the instrumentation necessary to ensure safe CO_2 storage by verifying CO_2 retention in the injection zone, quantify storage capacity, and quantify near- and far-field pressure response to injection. SECARB began injecting CO_2 on July 15, 2008, at a depth of 10,300 feet for enhanced oil recovery (EOR) at the Cranfield oilfield near Natchez, Mississippi. The naturally occurring CO_2 is obtained from Jackson Dome and transported by pipeline to the injection site. SECARB plans to inject CO_2 at a rate of 250,000 to 500,000 metric tons per year over the next several years into the lower Tuscaloosa Formation. The Tuscaloosa Formation, which is representative of the CO_2 storage options that exist throughout the Gulf Coast region, lies beneath an area of approximately 46,000 square miles in southern Alabama and Mississippi, the Florida Panhandle, and Louisiana. The Massachusetts Institute of Technology (MIT) projected that the Tuscaloosa Formation has a potential storage capacity of 10 billion metric tons of CO_2. SECARB, one of seven National Energy Technology Laboratory- (NETL) managed Regional Carbon Sequestration Partnerships (RCSPs), includes 13 southeastern states – Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, Virginia, and West Virginia – and roughly 100 partners and stakeholders. The Cranfield test is one of four pilot tests that SECARB is conducting during the effort's Validation Phase to evaluate storage potential in advance of a large-scale injection that will occur during the initiative's Deployment Phase. For more information about SECARB, visit: http://www.secarbon.org/, or click: http://www.beg.utexas.edu/environqlty/co201.htm to learn more about GCCC. August 27, 2008, http://www.netl.doe.gov/publications/press/2008/08035-Carbon_Storage_Monitoring_Begins.html

November 2008

***Fossil Energy Techline*, "DOE Releases Methodology Used to Estimate Carbon Dioxide Storage Potential."** The US Department of Energy (DOE) released its "Methodology for Development of Geologic Storage Estimates for Carbon Dioxide," a document detailing the procedures used to produce the geologic resource estimates for carbon dioxide (CO_2) storage potential in the 2008 Carbon Sequestration Atlas of the United States and Canada (Atlas II). The document outlines the procedures for estimating CO_2 storage potential in three types of geological formations found in the United States and Canada: saline formations, unmineable coal seams, and oil and gas reservoirs. The methodologies are based on widely accepted assumptions associated with fluid distribution and displacement processes commonly applied in petroleum and groundwater science. Leadership for this document was provided by the Capacity and Fairways Subgroup, a subcommittee convened in 2006 by the Regional Carbon Sequestration Partnerships' (RCSP) Geological Working Group to develop the first carbon sequestration atlas. The document will be presented as an appendix in Atlas II, which DOE expects to release later this year. The Atlas recently won an APEX Grand Award for publication excellence. (**See Recent Publications section for abstract and link to DOE's "Methodology for Development of Geologic Storage Estimates for Carbon Dioxide."**) To view the March 2007 Carbon Sequestration Atlas of the United States and Canada (Atlas I), visit: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlas/index.html. October 1, 2008, http://www.fossil.energy.gov/news/techlines/2008/08055-DOE_Releases_Carbon_Storage_Method.html.

***DOE Press Release*, "DOE Announces Solicitation for $8.0 Billion in Loan Guarantees."** DOE announced a solicitation for up to $8.0 billion in Federal loan guarantees for projects that employ advanced technologies that avoid, reduce, or sequester greenhouse gas (GHG) emissions resulting from coal-based power generation, industrial gasification, or advanced coal gasification facilities. This solicitation, marking the third round of solicitations for DOE's Loan Guarantee Program, will make $6 billion in loan guarantee authority available for the incorporation of carbon capture and storage (CCS) technologies into industrial gasification activities, as well as retrofitted or new coal-based power generation facilities. An additional $2 billion in loan guarantee authority will be made available for advanced coal gasification projects, which convert coal into electricity, hydrogen, and other energy products. The selection criteria for the clean energy projects will focus on a project's ability to avoid,

reduce, or sequester GHG emissions; the speed that the technologies can be commercialized; the prospect of repayment of the guaranteed debt; and the potential for long-term market success. Authorized by Title XVII of the Energy Policy Act of 2005 (EPAct), DOE's Loan Guarantee Program aims to facilitate commercialization of new or significantly improved technologies in energy-related projects. Additional information regarding this solicitation and DOE's Loan Guarantee Program is available at: http://www.lgprogram.energy.gov/. September 22, 2008, http://www.energy.gov/news/6565.htm.

December 2008

***Fossil Energy Techline*, "DOE Completes Large-Scale Carbon Sequestration Project Awards."** On November 17, the U.S. Department of Energy (DOE) awarded $66.9 million to the Big Sky Carbon Sequestration Partnership (BSCSP), the last of seven awards administered for the third phase of the Regional Carbon Sequestration Partnership (RCSP) Program's large-scale carbon sequestration projects. BSCSP, headed by Montana State University-Bozeman, plans to conduct a large-scale test in the Nugget Sandstone formation at the Riley Ridge Unit on the LaBarge Platform in Southwest Wyoming. The test will demonstrate the ability of a geological formation to safely, permanently, and economically store more than 2 million tons of carbon dioxide (CO_2); examine the entire CO_2 injection process from pre-injection characterization, injection process monitoring, and post-injection monitoring; and provide the groundwork for future carbon capture and storage (CCS) opportunities in the region. The eolian sandstone formations present throughout the region offer the opportunity to store more than 100 years of CO_2 emissions from regional point sources. BSCSP plans to drill a CO_2 injection well and inject up to 1 million tons of CO_2 per year into the Nugget Sandstone formation at an approximate depth of 11,000 feet. The CO_2 will be supplied by Cimarex Energy Company's planned helium and natural gas processing plant at Riley Ridge. Including the partnership's cost share, the project is estimated to cost $130.6 million (subject to annual appropriations from Congress). For more information about the National Energy Technology Laboratory- (NETL) managed BSCSP, visit: http://www.bigskyco2.org/. November 17, 2008, http://www.fossil.energy.gov/news/techlines/2008/08059-DOE_Makes_Sequestration_Award.html.

***Fossil Energy Techline*, "DOE Announces Release of Second Carbon Sequestration Atlas."** DOE released its second Carbon Sequestration Atlas of the United States and Canada, documenting more than 3,500 billion metric tons of CO_2 storage potential in oil and gas reservoirs, coal seams, and saline formations. The second edition of the atlas updates the CO_2 storage portfolio, documents differences in CO_2 resource and CO_2 capacity, and provides updated information on the RCSPs' field activities. It provides updated information on the location of stationary CO_2 emission sources, the locations and storage potential of various geologic sequestration sites, and information about commercial opportunities for CCS technologies for each RCSP. NETL created the initial atlas and developed it with the RCSPs, as well as the National Carbon Sequestration Database and Geographical Information System (NATCARB). DOE has published both print and interactive editions of the atlas. The print version is available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasII/. The interactive version is available at: http://www.natcarb.org/Atlas/ims_map.html. November 17, 2008, http://www.fossil.energy.gov/news/techlines/2008/08060-DOE_Releases_Sequestration_Atlas.html.

January 2009

***Lawrence Livermore National Laboratory News Release*, "Livermore Lab and American Shale Oil Team to Study Carbon Sequestration,"** and ***Greenwire*, "DOE Lab to Test Carbon Dioxide Storage in Western Oil Shale."** On December 3, Lawrence Livermore National Laboratory (LLNL) and American Shale Oil, LLC (AMSO) announced a technical cooperation agreement to develop carbon sequestration technologies for in-ground shale oil production processes. The partners will study the use of depleted underground oil shale for the permanent storage of carbon dioxide (CO_2) generated during the oil shale extraction process. AMSO, which holds a research, development, and demonstration (RD&D) lease from

the U.S. Bureau of Land Management for a 160-acre parcel of Federal land in northwest Colorado's oil-shale rich Piceance Basin, will provide technical assistance and oil shale core samples. If AMSO can demonstrate an economically viable and environmentally acceptable extraction process, it retains the right to acquire a 5,120-acre commercial lease. When subject to high temperatures and high pressures, oil shale (a sedimentary rock that is rich in hydrocarbons) can be converted into oil. Through mineralization, the CO_2 could be stored in the shale that remains in the ground following the extraction process. LLNL is managed by Lawrence Livermore National Security, LLC for the U.S. Department of Energy (DOE). For more information about LLNL, click: https://www.llnl.gov/. December 3, 2008, https://publicaffairs.llnl.gov/news/news_releases/2008/NR-08-12-02.html, and December 4, 2008, http://www.eenews.net/Greenwire/2008/12/04/9/.

February 2009

***U.S. Department of Agriculture News Release*, "Secretary Schafer Announces $300 Million Loan for the First Commercial Scale Carbon Sequestration Project at an Existing Coal-Fired Power Plant,"** and ***Basin Electric Power Cooperative News Release*, "USDA Approves Loan for CO_2 Capture Project."** On January 15, 2009, the U.S. Department of Agriculture (USDA) announced the approval of a $300 million loan to finance the modification of a coal-fired power plant to capture and sequester 3,000 tons of carbon dioxide (CO_2) per day. The project, which will take place at Basin Electric Power Cooperative's Antelope Valley Station near Beulah, North Dakota, is expected to be the first of its type in the United States to operate on a commercial scale. Basin Electric will utilize a CO_2 capture technology currently being tested on a pilot-scale basis; based on the tests results, the technology would be expanded to a demonstration project at the Antelope Valley Station. Antelope Valley Station is located adjacent to the Great Plains Synfuels Plant, which already captures and ships more than 3 million tons of CO_2 per year to Canadian oilfields through a 205-mile long pipeline. The CO_2 captured from the coal-fired power plant will be cleaned, sent to the Synfuels plant, and then placed into the pipeline for use during enhanced oil recovery (EOR). Basin Electric also plans to inject a small percentage of CO_2 into a deep saline formation. The demonstration project at Antelope Valley would capture about 1 million tons of CO_2 per year. The loan was made possible through USDA's Rural Development's Rural Utilities Program. For more information about Basin Electric's Antelope Valley Station, visit: http://www.basinelectric.com/Energy_Resources/Electricity/Baseload_Power/Antelope_Valley_Station/index.html. January 15, 2009, http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?contentidonly=true&contentid=2009/01/0014.xml, and January 15, 2009, http://www.basinelectric.com/News_Center/News_Releases/USDA_approves_loan_for_CO2_cap.html.

March 2009

***Fossil Energy Techline*, "DOE Regional Partner Initiates CO_2 Injection Study in Virginia."** The U.S. Department of Energy's (DOE) Southeast Regional Carbon Sequestration Partnership (SECARB), one of the seven Regional Carbon Sequestration Partnerships (RCSPs), will determine the feasibility of carbon dioxide (CO_2) storage and the potential for enhanced coalbed methane (ECBM) recovery in unmineable coal seams by injecting CO_2 into coal seams in the Central Appalachian Basin. The Central Appalachian Basin, a 10,000-square mile area located in southern West Virginia and southwestern Virginia, was selected because, according to researchers, it has the capacity to store 1.3 billion tons of CO_2 while increasing natural gas production up to 2.5 trillion cubic feet. SECARB initiated CO_2injection in mid-January at its test site in Russell County, Virginia. An existing coalbed methane (CBM) well was converted for CO_2 injection and the two wells were drilled to monitor reservoir pressure, gas composition, and the CO_2 plume. The targeted coal seams, which are in the Pocahontas and Lee formations, range from 1,400 feet to 2,200 feet in depth and from .7 feet to 3.0 feet in thickness. Over a 45-day period, 1,000 tons of CO_2 will be injected. Through the exploration of the multiple uses of subsurface storage volume and the injection of CO_2 into coal seems, the Central Appalachian Basin CO_2

Storage Project will boost CBM recovery, provide commercial benefit, and offset infrastructure development costs while providing long-term CO_2 storage. The results of the study will be used to assess the potential of carbon storage in coal seams as a safe and permanent method to mitigate greenhouse gas (GHG) emissions while enhancing production of natural gas. It is one of four pilot-scale tests that SECARB is sponsoring for the RCSP Program's Validation Phase. To learn more about DOE's RCSP Program, visit: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html. February 11, 2009, http://www.fossil.energy.gov/news/techlines/2009/09006-Coal_Seam_Injection_Begins.html.

April 2009

***Fossil Energy Techline*, "Carbon Sequestration Partner Initiates Drilling of CO_2 Injection Well in Illinois Basin."** The Midwest Geological Sequestration Consortium (MGSC), one of the U.S. Department of Energy's (DOE) seven Regional Carbon Sequestration Partnerships (RCSPs), has begun drilling the injection well for their large-scale carbon dioxide (CO_2) injection test in Decatur, Illinois. The large-scale project will capture CO_2 from the Archer Daniels Midland (ADM) Ethanol Production Facility and inject it more than one mile underground into a deep saline formation. The injection, which will occur over a three-year period and is slated to start in early 2010, will compress up to 1 million metric tonnes of CO_2 from the ADM ethanol facility into a liquid-like, dense phase. The targeted rock formation, the Mt. Simon Sandstone, is the thickest and most widespread saline reservoir in the Illinois Basin, with an estimated CO_2 storage capacity of 27 to 109 billion metric tonnes. A comprehensive monitoring program, which will be evaluated yearly, will be implemented after the injection to ensure the injected CO_2 is stored safely and permanently. The RCSP Program was launched by the Office of Fossil Energy (FE) in 2003 to determine the best approaches for the permanent capture and storage of greenhouse gases (GHGs). MGSC is the first of the RCSPs to begin drilling a Development Phase injection well. The drilling is expected to take approximately two months to complete. To view the MGSC website, go to: http://sequestration.org/. To visit the National Energy Technology Laboratory's (NETL) RCSP website, click: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html. February 17, 2009, http://www.fossil.energy.gov/news/techlines/2009/09008-CO2_Injection_Well_Drilling_Begins.html.

***Fossil Energy Techline*, "DOE Partner Begins Injecting 50,000 Tons of Carbon Dioxide in Michigan Basin."** DOE's Midwest Regional Carbon Sequestration Partnership (MRCSP), led by Battelle, has begun injecting 50,000 tons of CO_2 into the Michigan Basin near Gaylord, Michigan. The activity builds upon an initial injection project of 10,000 metric tons of CO_2 in the same formation and will take place in a deep saline formation, the Silurian-age Bass Island dolomite. The project is expected to last six months, with injections happening at an average rate of 250 tons per hour up to a maximum rate of 600 tons. The first test will take place at an existing oil and gas field, which would also allow for continued enhanced oil recovery (EOR) operations. This area is ideal for the injection test as it already contains CO_2 compressors, injection systems, existing wells, pipelines, and other needed infrastructure. During the injection process, the team will record geochemical changes to the system and the distribution of the CO_2 along the wellbore. The CO_2 will be transported to the well via an eight-mile pipeline. As the depth of the injection is 3,500 feet, the injection will occur well below the 1,000-foot level of drinking water sources. When complete, the total 60,000-metric ton injection will mark the largest deep saline reservoir injection in U.S. history. The 6-month project and related activities are expected to create more than 230 jobs and 2,900 total project job years. To view the MRCSP website, click: www.mrcsp.org. February 27, 2009, http://www.fossil.energy.gov/news/techlines/2009/09012-DOE_Partners_Begin_CO2_Injection.html.

***Fossil Energy Techline*, "DOE Regional Partnership Initiates CO_2 Injection in Lignite Coal Seam."** The Plains CO_2 Reduction Partnership (PCOR) has begun injecting CO_2 into a deep lignite coal seam in North Dakota to demonstrate the economic and environmental viability of geologic CO_2 storage in the U.S. Great Plains Region. PCOR's Lignite Field Validation Test, one of four tests PCOR is conducting under the Validation Phase of the RCSP program, will inject approximately 400 tons of CO_2 into a 10-foot thick lignite seam approximately 1,100 feet deep. In 2007, a five-spot well configuration was drilled in

collaboration with Eagle Operating Inc., consisting of a center injection well surrounded by four monitoring wells. In addition to evaluating the lignite seam's CO_2 storage potential, the project will also study coalbed methane extraction. The results of PCOR's Phase I characterization activities, which showed that the region's low-rank coal seams have the capacity to store up to 8 billion tons of CO_2, also suggested that more than 17 trillion cubic feet of methane could be produced from low-rank coal seams. This will be the first field study conducted on the ability of lignite coal seams to store CO_2. To view the PCOR website, go to: http://www.undeerc.org/pcor/. March 10, 2009, http://www.fossil.energy.gov/news/techlines/2009/09015-CO2_Injection_Begins.html.

***Fossil Energy Techline*, "DOE Releases Report on Techniques to Ensure Safe, Effective Geologic Carbon Sequestration."** NETL has prepared and released a comprehensive report describing existing and emerging monitoring, verification, and accounting (MVA) techniques for CO_2 stored in geologic formations. The report, titled, "Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations," was prepared with input from the seven RCSPs in order to provide an overview of MVA techniques in use and under development; summarize DOE's MVA research and development (R&D) program; and ensure the safety and effectiveness of carbon storage projects. (**See Recent Publications section in this newsletter to view a portion of the Introduction and a link to DOE's "Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations."**) For more information on DOE's Carbon Sequestration Research Program, visit: http://www.fossil.energy.gov/programs/sequestration/index.html. March 17, 2009, http://www.fossil.energy.gov/news/techlines/2009/09016-DOE_Releases_MVA_Report.html.

May 2009

***Fossil Energy Techline*, "First U.S. Large-Scale CO_2 Storage Project Advances."** The Midwest Geological Sequestration Consortium (MGSC) has nearly completed drilling the first large-scale carbon dioxide (CO_2) injection well in the United States at the Archer Daniels Midland Company's (ADM) ethanol facility in Decatur, Illinois. The injection well is being drilled into a test area approximately 2,000 feet thick in the Mount Simon Sandstone to a depth more than one mile beneath the surface where core samples of the sandstone will be acquired and analyzed to determine the best area for injection. Once the area is selected, up to 1 million metric tons of CO_2 captured from ADM's ethanol production facility will be injected into a deep saline formation from 2010 to 2013. The results of the injection, which will be monitored to ensure safe and permanent storage of the CO_2, will provide analysis on the future of carbon sequestration as a viable option for CO_2 storage. This is the first drilling into the Mount Simon Sandstone since oil and gas exploratory drilling was conducted some 15 to 40 years ago. Drilling operations for the injection well began in February 2009 and the 10-year life of the project is expected to create nearly 250 full-time jobs. The injection test is part of the Regional Carbon Sequestration Partnership (RCSP) Program's Development Phase managed by the National Energy Technology Laboratory (NETL) for the U.S. Department of Energy's (DOE) Office of Fossil Energy (FE). MGSC is led by the Illinois State, Indiana, and Kentucky Geological Surveys and is one of seven NETL-managed RCSPs. For more information about MGSC, visit: http://www.sequestration.org/, or click: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html for information about the NETL-managed RCSP Program. April 6, 2009, http://www.fossil.energy.gov/news/techlines/2009/09022-Large-Scale_CCS_Advances.html.

June 2009

***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 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.

July 2009

***Fossil Energy Techline*, "Small-Scale Carbon Sequestration Field Test Yields Significant Lessons Learned."** A preliminary geologic characterization and sequestration field test has been completed by the Midwest Regional Carbon Sequestration Partnership (MRCSP) at FirstEnergy's R.E. Burger Plant near Shadyside, Ohio. The targets for the geologic storage of carbon dioxide (CO_2) at the site were the Oriskany and Clinton Sandstones at depths in the range of 5,500 feet to 8,000 feet in the Appalachian Basin. The data compiled from the project evaluation indicated that the porosity, void space, and permeability of the target formations were lower than expected, and that the pressure in the formations increased with low injection rates. These results confirm the complex nature of the formations and demonstrate the importance of extensive drilling, formation evaluation, and testing to characterize and identify appropriate formations for CO_2 storage within the Appalachian Basin prior to injection. In addition to providing a significant geologic understanding of the formation, the project also provided several "lessons learned," ranging from practices regarding site selection; design of robust formation imaging, evaluation, and testing programs; formation simulation(s); well completion; and communication with stakeholders. MRCSP is one of seven Regional Carbon Sequestration Partnerships (RCSPs) managed by the National Energy Technology Laboratory (NETL) for the U.S. Department of Energy (DOE) to advance carbon capture and storage (CCS) techniques. For more information about DOE's RCSP

Program, visit: http://www.netl.doe.gov/technologies/carbon_seq/partnerships/partnerships.html, or click: www.mrcsp.org for details about MRCSP. May 20, 2009, http://www.fossil.energy.gov/news/techlines/2009/09031-CCS_Test_Yields_Valuable_Informati.html.

***Fossil Energy Techline*, "DOE Regional Partnership Begins Core Sampling for Large-Volume Sequestration Test."** The Plains CO_2 Reduction Partnership (PCOR) has begun collecting core samples from a new characterization well near Spectra Energy's Fort Nelson natural gas processing plant in British Columbia, Canada. The coring of the Elk Point rock formations at Fort Nelson will provide characterization data of the carbonate formations and impermeable shale layers that will serve as a caprock to store CO_2; in addition, numerous geochemical and geomechanical tests will be preformed to evaluate the performance of the reservoir and containment seals. PCOR will then implement a comprehensive monitoring, verification, and accounting (MVA) protocol that will aid in the development of a set of cost-effective MVA protocols that can be utilized at other locations. The Fort Nelson project, which will inject more than 2 million tons of CO_2 per year, is on track to become one of the first commercial-scale CCS projects in a saline aquifer in North America and will also be one of the largest carbon sequestration projects in the world. PCOR is undertaking two large-volume tests in the RCSP Program's Development Phase – the Fort Nelson project and a test planned for the Williston Basin in North Dakota. PCOR's initiatives will result in more than 400 jobs through 2017. To learn more about PCOR, go to: http://www.undeerc.org/pcor/. May 22, 2009, http://www.fossil.energy.gov/news/techlines/2009/09033-CCS_Core_Sampling_Begins.html.

August 2009

***Fossil Energy Techline*, "Field Test to Advance Geological Carbon Storage While Enhancing Domestic Oil Supply."** The Midwest Geological Sequestration Consortium (MGSC) has begun injecting carbon dioxide (CO_2) into a mature oil field in Hopkins County, Kentucky, to assess the region's CO_2 storage capacity and feasibility for enhanced oil recovery (EOR). The test is designed to inject up to 8,000 tons of CO_2 over a period of six to eight months into an existing brine-water injection well at a depth of approximately 1,900 feet; at these depths, the CO_2 will remain in a gaseous state and partially mix with the oil it encounters. The Kentucky Geologic Survey (KGS) will monitor the CO_2 through a program that will track the rate and volume of the injection and the pressures and temperatures within the wall. The results will provide an indication of how efficiently the CO_2 displaces oil within the reservoir and how it stores the CO_2. The project will span more than two years and is expected to create 13 full-time jobs. The test is part of the Regional Carbon Sequestration Partnership (RCSP) Program's Validation Phase, which consists of 22 nationwide field tests conducted in saline formations, depleted oil and gas fields, and unmineable coal seams. To visit the MGSC website, click: http://sequestration.org/. June 25, 2009, http://www.fossil.energy.gov/news/techlines/2009/09041-DOE_Partner_Begins_Carbon_Storage_.html.

***Fossil Energy Techline*, "Secretary Chu Announces Two New Projects to Reduce Emissions from Coal Plants."** On July 1, 2009, U.S. Department of Energy (DOE) Secretary Steven Chu announced the selection of two projects for up to $408 million in funding from the American Recovery and Reinvestment Act (ARRA). The two projects will incorporate advanced technologies to reduce CO_2 emissions. In one project, DOE will provide the Basin Electric Power Cooperative with $100 million to demonstrate the removal of CO_2 from the flue gas from a lignite-based boiler at an existing power plant in Beulah, North Dakota. In the second project, DOE will provide Hydrogen Energy International LLC with $308 million to design, construct, and operate an Integrated Gasification Combined Cycle (IGCC) power plant in Kern County, California, that will utilize blends of coal and petroleum coke and convert them into hydrogen and CO_2. The goal of both projects is to achieve at least 90 percent CO_2 capture efficiency. The selection of the two projects is part of the third round of the Clean Coal Power Initiative (CCPI), a cost-shared collaboration between the Federal government and private industry to increase investment in low-emission coal technology by demonstrating advanced, coal-based power generation technologies. To

view the CCPI Program fact sheet, go to: http://www.fossil.energy.gov/programs/powersystems/cleancoal/ccpi/Prog052.pdf. July 1, 2009, http://www.energy.gov/news2009/7559.htm.

***Fossil Energy Techline*, "New Jersey Joins the Energy Department's Carbon Sequestration Regional Partnership Program."** New Jersey has become the 43rd state to join DOE's RCSP Program, the centerpiece of U.S. efforts to deploy carbon sequestration technologies and reduce greenhouse gas (GHG) emissions. As a member of the Midwest Regional Carbon Sequestration Partnership (MRCSP) and a participant in the MRCSP Phase II Validation Phase projects, New Jersey will focus on developing and integrating data for the potential geologic and terrestrial sequestration capacity within the state. The New Jersey Department of Environmental Protection and Rutgers University will contribute by building and refining the state's geologic and terrestrial sequestration frameworks. Also, due to the abundance of offshore storage potential in New Jersey, MRCSP will include offshore reservoirs in its potential geologic and terrestrial sequestration capacity database for the first time. To learn more about MRCSP, go to: www.mrcsp.org. For more information about DOE's RCSP Program, visit: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html. June 24, 2009, http://www.fossil.energy.gov/news/techlines/2009/09040-New_Jersey_Joins_Regional_Partners.html.

Sequestration in the News

September 2008

***EERC News Release*, "EERC's Plains CO_2 Reduction Partnership and Ducks Unlimited Announce Carbon Credit Program."** A carbon offset program has been created by the Energy and Environmental Research Center's (EERC) Plains CO_2 Reduction Partnership (PCOR) and Ducks Unlimited, Inc., a leading waterfowl conservation organization. The program intends to help mitigate the effects of climate change by securing native and planted grasslands, reducing negative impacts on duck and other wildlife habitats, and ensuring that existing soil carbon will not be exposed to the atmosphere. Participating landowners who wish to ensure that existing soil carbon remains sequestered in their native prairie or expired Conservation Reserve Program land can enroll in the US Fish and Wildlife Service's Grassland Easement Program, which prohibits their grassland from being plowed. When the land is secured by the US Fish and Wildlife Service, Ducks Unlimited will purchase the carbon rights to the land, which will then be transferred to the Eco Products Fund (EPF); EPF will then sell the credits in the voluntary carbon market. Landowners who enroll and forward the carbon rights to Ducks Unlimited will be provided with a one-time payment through the carbon credit program. Ducks Unlimited is a member of PCOR, one of the seven RCSPs funded by NETL, and researches best management practices for PCOR's terrestrial field validation test. To view the PCOR website, go to: http://www.undeerc.org/pcor/default.asp. To visit the Ducks Unlimited website, click: http://www.ducks.org/. August 8, 2008, http://www.undeerc.org/news/newsitem.aspx?id=321.

***Daily Press*, "Va. Project Aimed at Reducing Carbon Footprint,"** and ***TriCities.com*, "Carbon Storage Test Called Key to Coal's Future."** A Southeast Carbon Sequestration Partnership (SECARB) project that will inject 1,000 tons of CO_2 into unmineable coal seams is underway in Russell County in southwest Virginia. The project, which is the first of its kind in the central Appalachian region, will use a pre-existing CBM well that was converted for CO_2 injection. The test is the second of three phases in a project aimed at demonstrating the commercial viability of carbon storage technology. Results are expected in January 2009. The first phase of SECARB's efforts entailed a characterization study that showed a storage capacity of up to 1.34 billion tons. The $100 million third phase, requiring a $60 million Federal investment co-funded by state and industry investments, is planned as a large-scale test to inject 100,000 tons of CO_2. A similar test is planned for the Black Warrior Basin in Alabama. The Virginia Center for Coal and Energy Research (VCCER) at Virginia Tech will conduct the research for this project through the Southern States Energy Board, the lead entity for SECARB. For information about SECARB

projects, visit: http://www.secarbon.org/, or click: http://www.netl.doe.gov/publications/factsheets/project/Proj442.pdf to view the NETL project fact sheet. August 18, 2008, http://www.dailypress.com/news/local/virginia/dp-va--carbondioxiderese0818aug18,0,4329136.story, and August 18, 2008, http://www.tricities.com/tri/news/local/article/carbon_storage_test_called_key_to_coals_future/12834/. (Video included.)

***Providence Press Release*, "Providence and Star Energy Commence 'ULYSSES' Project,"** and ***The Telegraph*, "Irish Energy Group in Carbon Capture Scheme."** Providence Resources, an Irish oil and gas production and development company, has teamed with Star Energy Group, a United Kingdom-based gas storage company, to study the CO_2 sequestration potential of the Kish Bank Basin located in the Irish Sea. The CO_2 sequestration assessment, called the Undersea Large-scale Saline Sequestration and Enhanced Storage (ULYSSES) Project, is part of a larger work program that will also evaluate natural gas storage. Over the next year, the ULYSSES Project will investigate the possible use of Triassic-aged saline sandstone reservoirs as CO_2 storage sites; these locales have been determined by numerous oil and gas wells drilled into the basin over the past 30 years. The saline reservoirs, located about 12.4 miles offshore of Dublin, Ireland, and approximately one mile below the seabed, are covered by an overlying layer of shale. If successful, two Dublin-based power plants at the Ireland Electricity Supply Board-owned Poolbeg Generating Station will be targeted to capture CO_2. The project is similar to the Sleipner CO_2 sequestration project, which has successfully sequestered 10 million tonnes of CO_2 in the Norwegian North Sea since project start-up in 1996. The project recently received a three-year licensing option over several blocks in the Kish Bank Basin by the Irish government's Department of Energy, Communications and Natural Resources. August 18, 2008, http://www.providenceresources.com/html/documents/PROVIDENCEANDSTARCOMMENCEULYSSESSTUDY-AUGUST2008.pdf, and August 17, 2008, http://www.telegraph.co.uk/money/main.jhtml?view=DETAILS&grid=&xml=/money/2008/08/18/cnulys118.xml.

***Reuters*, "Norway Agrees $60 Million Carbon Capture Research,"** and ***Aker Clean Carbon Press Release*, "Major Research Programme for CO_2-Capture."** A collaborate of Norwegian research groups and Aker ASA agreed to invest $58.97 million for a research project to generate more cost effective CO_2 capture technology. The first research phase of the project will run until late 2010 and test amine-based solutions that have the ability to cleanse CO_2 emissions from coal- and gas-fired power stations. A new laboratory will house a test center for pilot projects, complete with a 98-foot tall tower and processing column that reaches 82 feet – similar to the height of full-scale industrial facilities. The eight-year science and development program, called SOLVit, was created by the independent research organization SINTEF, the Norwegian University of Science and Technology, and Aker Clean Carbon. August 14, 2008, http://uk.reuters.com/article/scienceNews/idUKLE13903620080814?pageNumber=1&virtualBrandChannel=10174&sp=true, and August 14, 2008, http://www.akercleancarbon.com/publish_files/SOLVIT-endelig-eng.pdf.

October 2008

***MRCSP News Release*, "MRCSP has Received the Final Permit from the Ohio Environmental Protection Agency (OEPA) to Begin Injection of Carbon Dioxide,"** and ***State of Ohio Environmental Protection Agency News Release*, "Ohio EPA Issues Permit for Carbon Sequestration Project: Capturing Carbon Dioxide May Help Fight Global Warming."** The Midwest Regional Carbon Sequestration Partnership (MRCSP) received the final permit needed from the Ohio Environmental Protection Agency (OEPA) for Battelle Memorial Institute to initiate the injection of 3,000 tons of CO_2 at First Energy Corporation's R.E. Burger Plant in Shadyside, Ohio. Beginning in mid-September, MRCSP plans to inject CO_2 over a three- to eight-week timeframe, dependant upon injection zone properties, project setup, and regulatory oversight and monitoring. The OEPA permit allows for the

CO_2 captured from the coal-fired power plant to be heated under pressure and injected underground for long-term storage. In addition, the permit authorizes injection into three different rock formations: 8,207- to 8,274-foot deep Clinton sandstone; 5,923- to 5,954-foot deep Oriskany sandstone; and the 6,734- to 7,470-foot deep Salina formation. OEPA's well regulations are designed to protect underground sources of drinking water (USDWs) from the injected CO_2. For more information about MRCSP, visit: http://www.mrcsp.org. September 5, 2008, http://216.109.210.162/NewsPage.aspx?action=view&newsid=27, and September 9, 2008, http://www.epa.state.oh.us/pic/nr/2008/september/BattelleUIC.html.

***Carbon Capture Journal*, "DNV Developing First CO_2 Pipeline Standard."** DNV, a risk management service, is teaming with several industry partners and government representatives to develop a new standard for the transportation of dense, high pressure CO_2 in pipelines within the next 18 months. The guideline, intended to help designers and operators limit and manage the risks related to the transmission of CO_2 by pipeline, will incorporate current knowledge related to both offshore and onshore operations. DNV will use lessons learned from existing and previous projects to craft guidelines for managing risks throughout the pipeline's lifetime, ranging from CO_2 pipeline design, testing, inspection, operation, maintenance, and decommissioning phases. As some issues related to CO_2 transportation in dense, high pressure phases are not covered in existing pipeline standards or regulations, the point of departure will be pipeline standards for the transmission of hydrocarbons, such as International Standard for Organization (ISO) 13623 and DNV OS-F101. For more information about DNV's carbon capture and storage (CCS) initiatives, go to: http://www.dnv.com/industry/energy/segments/carbon_capture_storage/index.asp. August 27, 2008, http://www.carboncapturejournal.com/displaynews.php?NewsID=262?PHPSESSID=d209a20e427c384e9ea7c8c8ee318a97. (Subscription may be required.)

***ClimateWire*, "Germans to Unveil Clean-Coal Plant Prototype,"** and ***GreenTech Media*, "Vattenfall to Trap Carbon Emissions."** The 30-megawatt Schwarze Pumpe power plant began operating in Germany on September 8, following two and a half years of construction at a cost of $100 million. The Schwarze Pumpe, a pilot-scale operation equipped with CCS technology, will capture CO_2 and transport it to a depleted natural gas field owned by Gaz de France in northern Germany. Vattenfall plans to operate the plant, which is expected to produce nine metric tons of CO_2 per hour, for nearly 10 years in order to advance the design for future demonstration plants in Germany, Norway, and Denmark. The larger, 250- to 350-megawatt demonstration plants are the next step in Vattenfall's efforts to commercialize CCS technology within the 2015 to 2020 timeframe. The pilot-scale project will employ Alstom's oxyfuel combustion process, in which coal is burned in oxygen, resulting in a flue gas consisting of high purity CO_2 that can be transported to the sequestration site. For more details about Vattenfall's Schwarze Pumpe-related CCS operations, visit: http://www.vattenfall.com/www/vf_com/vf_com/365787ourxc/366203opera/366779resea/366811co2-f/index.jsp, or click: http://www.vattenfall.com/www/co2_en/co2_en/879177tbd/879211pilot/901887test/index.jsp to view a live web-camera of the site. A photo gallery is available at: http://www.spiegel.de/fotostrecke/fotostrecke-35101.html. September 5, 2008, http://www.eenews.net/climatewire/2008/09/05/5/, and September 8, 2008, http://www.greentechmedia.com/articles/vattenfall-to-trap-carbon-emissions-1362.html.

***Reuters*, "Norway Surveys Troll Field for Carbon Storage,"** and ***Norwegian Petroleum Directorate Press Release*, "Seismic Survey of Potential Carbon Dioxide Storage Site."** On September 5, Norwegian Petroleum Directorate (NPD) officials announced that 3-D seismic surveys will be conducted at the Troll natural gas and oil field to determine whether the Johansen formation located beneath the field is suitable for storing CO_2 emissions. The Johansen formation, located approximately 8,200 feet beneath the Earth's surface, is believed to be one of the three potential North Sea sites for storing CO_2 emissions generated by power plants in Mongstad and Kårstø. By using a vessel to transmit pressure waves into the earth, 3-D seismic surveys map the subsurface; these waves are then reflected back when they encounter interfaces between different layers of rock, which are captured by long cables

towed behind the vessel. These signals are then used to create an image of subsurface characteristics. The processing and interpretation of the 3-D seismic data will be carried out by StatoilHydro and is expected to be completed in early 2009. Troll field, which has been on stream since 1996, holds more than 1 billion barrels of oil equivalent of recoverable reserves – nearly one-third of Norway's total reserve estimate. September 5, 2008, http://www.reuters.com/article/environmentNews/idUSL566817720080905, and September 5, 2008, http://www.npd.no/English/Aktuelt/Pressemeldinger/2008/2008_9_5_pressemelding.htm.

November 2008

***Government of Alberta News Release*, "First Field Tests of Carbon Capture and Storage to Begin,"** and ***Edmonton Journal*, "Shell Goes Deep with $20M Carbon Dioxide Research Project."** The Government of Alberta announced that three test wells will soon be drilled for a large-volume CO_2 sequestration project in Alberta, Canada, to support Alberta's Climate Change Strategy by examining the CO_2 injection capability and storage capacity in formations deep beneath the Earth's surface. Through the Alberta Energy Research Institute (AERI), the Government of Alberta is providing $6.6 million in funding for the three-year, $20-million project near Shell Canada's Scotford facility. According to Shell, the first well will be drilled at the Scotford upgrader site and two more wells would be located 10 and 60 kilometers away. Officials acknowledged the possibility that two more wells may have to be drilled to understand the geology of the area, as there are few cores available to study. Shell has already initiated the engineering and design work necessary for the bitumen upgraders to add carbon capture technology and officials project small amounts of CO_2, likely between 50 and 100 tonnes of CO_2 per year, could be captured and injected, eventually increasing to 1.2 million tonnes per year. The field test phase is expected to conclude by June 2010. The funding is independent of Alberta's $2 billion CCS fund, which seeks to reduce CO_2 emissions by up to 5 million tonnes per year by 2015 through the development of three to five commercial-scale CCS projects. For more information on AERI, visit: http://www.aeri.ab.ca/. October 16, 2008, http://www.alberta.ca//acn/200810/24549060A11EE-A487-6EAB-0BA6A4955D18D734.html, and October 17, 2008, http://www.canada.com/edmontonjournal/news/business/story.html?id=15c3deea-5975-42ed-aba0-21ddded11ce8.

***ScottishPower Press Release*, "ScottishPower Looks to North Sea Storage Potential for Carbon Emissions,"** and ***New Energy Focus*, "ScottishPower Group Investigates North Sea Carbon Storage Site."** Following its qualification as a participant in the United Kingdom's (UK) competition to develop the nation's first commercial-scale CCS project, a consortium led by ScottishPower is investigating whether a formation under the North Sea could store all of Europe's CO_2 emissions for the next 600 years. The plan calls for two of the four burner units at the Fife-based, 2.3-Gigawatt Longannet Power Station to utilize CCS technology designed by Aker that would strip CO_2 emissions using chemical solvents. The CO_2 would be liquefied for transportation to existing oil and gas pipelines for storage in a formation in the Firth of Forth. ScottishPower officials believe the Longannet Power Station could become a center to handle CO_2 emissions from all of Scotland and the North of England. The proposed activity is one of four entries in the UK Government's Department for Business, Enterprise, and Regulatory Reform (BERR) competition to test a "full chain" of CCS technologies by 2014. The demonstration project requires that 90 percent of CO_2 emissions from a 300- to 400-megawatt generating facility are captured. E.ON, BP Alternative Energy International Ltd, and Peel Power Ltd have also entered the competition. The Longannet Power Station is Europe's third largest coal-based power station. For more details about BERR's CCS demonstration competition, click: http://www.berr.gov.uk/whatwedo/energy/sources/sustainable/ccs/ccs-demo/page40961.html. September 16, 2008, http://www.scottishpower.com/PressReleases_1755.htm, and September 19, 2008, http://newenergyfocus.com/do/ecco.py/view_item?listid=1&listcatid=32&listitemid=1709&section.

***Alberta Saline Aquifer Project News Release*, "Alberta Saline Aquifer Project Awards Key Contracts to Launch Carbon Sequestration Pilot in Early 2009."** The Alberta Saline Aquifer Project

(ASAP) announced that five companies were awarded contracts for the engineering, design, and environmental-related work needed for Phase I of the initiative. Specifically, Norwest Engineering will identify three potential aquifers in Alberta, Canada, with the assistance of an Athabasca Basin data log donated by ConocoPhillips. Schlumberger Carbon Services will develop a set of monitoring, verification, and accounting (MVA) protocols. Colt WorleyParsons will produce a pre-Front End Engineering Design (FEED) study and cost estimate on the compression and pipeline system to carry the CO_2 in liquid form to the sequestration sites and conduct a preliminary study of any health and safety concerns that could affect the public, wildlife, or the environment. Hatch Energy will design and prepare a cost estimate for the facilities needed at the sequestration sites. Finally, Oxand Canada will develop risk and mitigation strategies associated with compressing, transporting, and sequestering CO_2. The contracts indicate that Phase I, which includes the identification of viable formation locations and applications for permitting, is on schedule for completion by the end of 2008. Several companies have agreed to donate a reservoir injection simulation and a report containing recommendations on several MVA approaches to achieve the project's Phase I goals. ASAP believes that Phase II, consisting of constructing the pilot project and initiating CO_2 injection, will begin in 2009 (dependant upon regulatory approval). The initiative's Phase III activities entail expanding the pilot-scale project to a large-scale, commercial operation. For more information about the 35-member ASAP, visit: http://www.albertaasap.com/. September 22, 2008, http://www.albertaasap.com/pdf/ASAP-News-Release-Sept17.pdf.

December 2008

***University of Wyoming News Release*, "GE Energy and the University of Wyoming Reach Joint Agreement to Advance Cleaner Coal."** GE Energy and the University of Wyoming (UW) reached an agreement for work to begin on a proposed development plan for the High Plains Gasification Advanced Technology Center. The center will enable researchers from both GE Energy and UW to develop advanced gasification and clean coal solutions for Powder River Basin and other coals. The agreement outlines the framework for the development, design, construction, engineering, and operation of the small-scale gasification facility. With the support of GE Energy, UW will perform a site selection and acquisition process that considers a number of factors, ranging from availability of land appropriate for the facility, availability of necessary utilities and waste disposal facilities, proximity to coal supply, and environmental permitting requirements. The cost of the center will be split by GE Energy and UW, with the state's contribution stemming from appropriations from the Federal Abandoned Mine Reclamation Fund. In 2008, Wyoming's initial state appropriation was $20 million; Governor Dave Freudenthal will seek an additional $30 million during the 2009 legislative session. While UW owns the facility and retains responsibility for its operation, the agreement calls for GE Energy to lease the facility from the university, with options to renew. For more detailed information about the High Plains Gasification Advanced Technology Center, click: http://www.uwyo.edu/ge/default.asp, or click: http://www.uwyo.edu/gesupport/docs/JDIA_Executive_Summary.pdf to view the Joint Development and Implementation Agreement. November 13, 2008, http://uwadmnweb.uwyo.edu/UW/research/showrelease.asp?id=26186.

***Reuters*, "Abu Dhabi $3 Bln Carbon Capture Project Set for 2013."** The Abu Dhabi government-owned Masdar Initiative signed an agreement with Hydrogen Energy, a venture between BP Alternative Energy and Rio Tinto, to design a commercial-scale, hydrogen-fired power generation project with CCS technology. The $3 billion project, located in Abu Dhabi, will be operational by early 2013, allowing for enhanced oil recovery (EOR) and providing alternative energy and transport, according to officials. Work on the project has already begun and is currently in the front-end engineering and design (FEED) stage, which is being undertaken by the United States' company Foster Wheeler. Under this project, natural gas would be processed to create hydrogen, which would be used to generate low-carbon electricity and CO_2; the CO_2 would then be transferred via pipelines to aging oilfields for EOR. The CO_2 would replace the natural gas that is currently being injected into the fields to maintain pressure. Officials anticipate approximately 20 million tonnes of CO_2 will be captured during the project's 25-year lifespan. The design of the project is expected to be completed by the end of 2008. To view Hydrogen Energy's press release,

go to: http://www.hydrogenenergy.com/MediaArticle.aspx?m=29&amid=41828. To view a video detailing the Abu Dhabi project, visit: http://www.hydrogenenergy.com/FullStory.aspx?m=51&amid=582. October 28, 2008, http://www.reuters.com/article/companyNews/idUKLS16612520081028?symbol=FWLT.O.

***Eni Press Release*, "Eni and Enel Sign Strategic Agreement on CO_2 Capture,"** and ***Reuters*, "Italy's Eni, Enel Agree CO_2 Capture Pilot Project."** Enel, Italy's main electricity provider, and Eni, an Italian oil and gas company, signed an agreement to develop Italy's first carbon sequestration project, including technologies for the capture, transport, and geological sequestration of CO_2. Under the agreement, Enel will trap CO_2 from a coal-fired, thermal power station at Brindisi in southern Italy and transport the CO_2 to the Eni-owned Stogit natural gas field at Cortemaggiore near Piacenza in northern Italy for injection. The project will also examine monitoring, verification, and accounting (MVA) techniques to observe the safety and stability of the injected CO_2. The pilot project stems from two independent projects launched by each company: Enel is currently completing Italy's first industrial CO_2 capture plant capable of removing 2.5 tonnes of gas per hour at the Brindisi power station, while Eni has initiated a project aimed at injecting about 8,000 tonnes of CO_2 per year at the Stogit field. Officials expect the pilot plant will be ready in Fall 2009 and underground injection is scheduled to begin sometime in Fall 2010; Enel and Eni will also build a pilot CO_2 pipeline at the Brindisi site. The agreement includes the preparation of a joint study to determine Italian CO_2 storage potential. In addition, Eni, Enel, and Italy's Environment Ministry signed a Memorandum of Understanding aimed at the verification of CO_2 capture techniques and the promotion of renewable sources. October 21, 2008, http://www.eni.it/en_IT/media/press-releases/2008/10/2008-10-21-accordo-Eni-Enel.shtml?menu2=media-archive&menu3=press-releases, and October 21, 2008, http://www.reuters.com/article/rbssEnergyNews/idUSLL51565620081021.

January 2009

***Washington University News Release*, "Washington University Research to Advance Clean Coal Technology,"** and ***Greenwire*, "Energy, University Consortium Could Make St. Louis Clean Coal Center."** On December 2, Washington University in St. Louis announced the establishment of the Consortium for Clean Coal Utilization, a partnership tasked with establishing the key priorities and laboratory facilities for clean coal research. The consortium will bring together university researchers, industries, foundations, and government organizations to research clean coal technology by examining the co-combustion of coal with biomass or the combustion of coal in pure oxygen, which can lead to reductions in CO_2 emissions. The consortium may develop pilot-scale facilities where scientists can perform fundamental research and develop new technology related to clean coal combustion and carbon capture and storage (CCS). Arch Coal and Peabody Energy will each contribute $5 million to the Consortium for Clean Coal Utilization and Ameren will contribute $2 million over a five-year period. The consortium will operate under the International Center for Advanced Renewable Energy and Sustainability (I-CARES), which Washington University established in June 2007 to advance education and research related to energy, environment, and sustainability. To view the Consortium for Clean Coal Utilization website, click: http://cleancoal.wustl.edu/. December 2, 2008, http://news-info.wustl.edu/news/page/normal/13050.html, and December 4, 2008, http://www.eenews.net/Greenwire/2008/12/04/7/.

***DNV Press Release*, "Developing a Unified Approach to Qualifying CO_2 Storage Sites."** DNV, a global provider of risk management services, is developing a standard methodology for characterizing, selecting, and qualifying offshore and onshore sites for the geological storage of CO_2 in collaboration with more than 10 of the world's oil, gas, and coal companies. The joint industry project (JIP) will provide guidance on establishing permanent, safe, and cost-effective storage of CO_2. The current JIP focuses on establishing a transparent, predictable, and cost-effective site selection approach by: (1) providing guidance on the proper management of risks and geological uncertainties; (2) providing guidance for best engineering practices; (3) providing open references to ensure the confidence of stakeholders and the public; (4) simplifying demonstrations of compliance with legal and regulatory requirements and

implementation; and (5) explaining how to obtain emission reduction credits. The framework developed by the JIP should also: (1) define the desired storage site attributes; (2) assign and rank risks based on the available data; (3) define an environmentally friendly and economically acceptable site operation procedure, including compliance with standards, legislation, and directives; (4) define requirements for a monitoring, mitigation, and accounting (MVA) program; and (5) provide guidance for managing storage sites with a transparent, consistent, and cost-effective process. For more information about DNV's initiative, click: http://www.dnv.com/press_area/press_releases/2008/developingaunifiedapproachtoqualifyingco2storagesites.asp#.

***Shell News Release*, "Essent and Shell Take First Step toward Low-CO_2 Power Plant."** Essent Business Development B.V. (Essent) and Shell Gas & Power Developments B.V. (Shell) signed a Memorandum of Understanding (MOU) to study the feasibility of a 1,000-megawatt (MW) power plant that would capture CO_2 emissions and store them underground. Essent and Shell will examine the viability of combining a high-efficiency gasifier, a power generation plant, and equipment to capture and store CO_2. Under this scenario, coal and solid biomass would be gasified to produce synthesis gas, which is used to make hydrogen; the hydrogen would then be used to generate electricity in turbines. A study will also be conducted to assess whether depleted oil and gas fields (both offshore and onshore) would be suitable for CO_2 storage. The companies are investigating potential plant locations in the southwestern portion of the Netherlands. The project supports the European Union's (EU) plan to reduce CO_2 emissions through the demonstration of 10 to 12 large-scale CCS projects starting between 2015 and 2020, and is in line with the vision of the Rotterdam Climate Initiative (details available at: http://www.rotterdamclimateinitiative.nl/NL/English/?cid=6). December 8, 2008, http://www.shell.com/home/content/media/news_and_library/press_releases/2008/essent_shell_lowco2_08122008.html.

***Alstom Press Release*, "Alstom Teams Up with PGE Elektrownia Belchatów to Reduce CO_2 Output in Poland."** Alstom and PGE Elektrownia Belchatów S.A. (PGE) have signed an MOU for the development and implementation of CCS technology at the Belchatów power plant in Poland. Under the first phase of the MOU, Alstom will design and construct a pilot carbon capture plant that will be operated by both Alstom and Elektrownia Belchatów at the existing unit 12 of the Belchatów Power Plant. By using advanced amines technology, the plant will capture approximately 100,000 tonnes of CO_2 per year and is expected to be operational by mid-2011. In the second phase, Alstom and PGE will build a larger CCS project to capture CO_2 produced by the new 858-MW lignite-fired unit currently being constructed by Alstom for Elektrownia Belchatów. The Belchatów CCS project plans to be in operation by 2015 and is expected to remove more than 1 million tonnes of CO_2 emissions per year. December 8, 2008, http://www.alstom.com/pr_corp_v2/2008/corp/53961.EN.php?languageId=EN&dir=/pr_corp_v2/2008/corp/&idRubriqueCourante=23132.

February 2009

***Power Engineering International*, "Tenaska's Coal-Fired IGCC Plant Moves Forward."** Tenaska's proposed Taylorville Energy Center, a coal gasification project with carbon capture and storage (CCS) technology, has obtained a final air permit from the Illinois Environmental Protection Agency (EPA) that allows it to become the "initial clean coal facility" under Illinois' Clean Coal Portfolio Standard Act (SB 1987). According to Tenaska officials, the emission levels at the Taylorville Energy Center are expected to be lower than any other type of fossil fuel plant. The plant will use Hybrid Integrated Gasification Combined-Cycle (IGCC) to generate as much as 525 megawatts of electricity. Current estimates of construction costs are approximately $2.5 billion and the project is expected to be completed by 2014. The Clean Coal Portfolio Standard Act provides a framework for the development of clean coal projects and would require project developers to capture and store more than 50 percent of CO_2 emissions. The Taylorville Energy Center project will now prepare to develop a Front-End Engineering and Design (FEED) study and facility cost report. The Clean Coal Portfolio Standard is available at:

http://www.ilga.gov/legislation/95/SB/09500SB1987lv.htm. January 12, 2009, http://pepei.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&SubSection=Display&PUBLICATION_ID=6&ARTICLE_ID=350019.

***Hattiesburg American*, "Mississippi Power Plans Cleaner, More Plentiful Fuel."** Mississippi Power announced plans to build a $2 billion, lignite-fired power plant in Kemper County, located north of Meridian in eastern Mississippi, which could become the first full-scale, clean coal generating plant in the United States. The plant would employ coal gasification technology to produce electricity and capture 50 percent of CO_2 emissions. The captured CO_2 would be compressed and sold to a company that would inject it into depleted oil wells around Mississippi for EOR. The plant is anticipated to open sometime between 2013 and 2015. Mississippi Power is currently negotiating with property owners in Kemper County for the mineral rights to approximately 12,000 acres. The proposed plant would use between 100 and 150 million tons of the Mississippi's 4 billion ton supply of lignite, a low grade of coal that gives off a smaller amount of heat. December 15, 2008, http://www.hattiesburgamerican.com/article/20081218/NEWS01/812180316&referrer=FRONTPAGECAROUSEL.

***TransAlta News Release*, "TransCanada to Participate in TransAlta's Carbon Capture and Storage (CCS) Project."** TransCanada Pipelines, Ltd. announced plans to participate with TransAlta Corporation in the development of Project Pioneer, Canada's first fully-integrated CCS plant. The project will employ Alstom Canada's chilled ammonia process and will be designed to capture one megatonne (Mt) of CO_2 emissions from an existing coal plant in the Wabamun area located in western Edmonton. The CO_2 will be used for EOR and injected into a permanent geological storage site. Preliminary FEED work has started on Project Pioneer and TransAlta hopes to receive funding commitments during 2009 that will allow for construction to begin in early 2010 and operations to commence in 2012. Project Pioneer is expected to deliver at least 20 percent of Alberta's 2015 target of five Mt in annual CO_2 reductions. December 18, 2008, http://www.transalta.com/transalta/webcms.nsf/AllDoc/1894680E80DB8BBC872575220063CC1C?OpenDocument.

***The Associated Press*, "Algerian Project Captures and Buries Carbon Dioxide,"** and ***International Herald Tribune*, "Algeria's Gas Fields Seek to Set Eco-Example."** Algerian and international oil firms invested $100 million in a joint venture to capture and sequester CO_2 at In Salah, one of Algeria's largest natural gas fields. Algeria's natural gas usually holds four to six percent CO_2, but its main customer, the European Union (EU), only accepts two percent. According to officials, 800,000 tons of CO_2 are buried each year at In Salah. Carbon dioxide represents seven percent of the 9 billion cubic meters (318 billion cubic feet) of gas extracted at In Salah each year. Over the anticipated 30-year life of the project, about 20 million tonnes of CO_2 will be captured and sequestered. The In Salah gas project includes Sonatrach of Algeria, BP of Britain, and Statoil of Norway. Algeria hopes other foreign drilling partners will include CCS plans in their investment projects. December 15, 2008, http://www.google.com/hostednews/afp/article/ALeqM5jRoddcZUKYkN4anwfycPz1XuQ_zQ, and December 16, 2008, http://www.iht.com/articles/ap/2008/12/16/africa/AF-Algeria-Green-Gas-Field.php.

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***Mid Columbia Tri City Herald*, "Wallula Project Aims to Trap Greenhouse Gases,"** and ***MSNBC*.com, "Carbon Dioxide Sequestration Project in Wallula Could Help Prevent Climate Change."** As part of the first phase of a joint, pilot-scale project headed by the Big Sky Carbon Sequestration Partnership (BSCSP), Boise Inc. and Battelle researchers have started drilling a layer of basalt approximately three-quarters of a mile underground near Wallula, Washington, to determine if the formation can store CO_2. If successful, the Pacific Northwest National Laboratory-based researchers will apply for a state permit to inject nearly 1,000 tons of CO_2 into the well, which they are building at Boise Inc. pulp and paper mill. The basalt formation, believed to be 13 million years old, is a result of 300 lava

flows and includes layers of rock abundant with sponge-like holes. According to researchers, the CO_2 will flow through the layers covered with holes, infusing itself with non-potable water that is trapped in the rock. The carbonated water would then react with the basalt elements and turn into calcium carbonate, allowing the top layer of hard basalt to serve as a caprock. January 22, 2009, http://www.tri-cityherald.com/kennewick_pasco_richland/story/453735.html, and January 22, 2009, http://www.msnbc.msn.com/id/28781701/.

***Montana State University News Release*, "MSU Shares in $1.4 Million Grant for Carbon Sequestration Research."** A $1.4 million DOE grant has been awarded to researchers at Montana State University, the University of Montana, and Montana Tech University to study the effects carbon sequestration sites may have on the surrounding environment. The researchers will study the effects of injecting large volumes of liquefied CO_2 into porous rocks deep underground for storage. The injections could affect the rock's pore structures, material properties, or microbial activity, all of which play a role in how well the CO_2 is sequestered. Project researchers will also monitor microbes and plants near the sequestration sites to determine whether a site is containing CO_2. The grant is derived from DOE's Experimental Program to Stimulate Competitive Research (EPSCoR). January 22, 2009, http://www.montana.edu/cpa/news/nwview.php?article=6730.

***EPRI News Release*, "EPRI to Study Adding Carbon Capture to Existing Coal Power Plants."** Electric Power Research Institute (EPRI) announced that five electric utilities will participate in a series of studies to determine the impact(s) of retrofitting amine-based, post-combustion CO_2 capture technology to existing coal-fired power plants. The five host companies and sites are Edison Mission Group's Powerton Station in Pekin, Illinois; Great River Energy's Coal Creek Station in Underwood, North Dakota; Nova Scotia Power's two units at its Lingan Generating Station in Lingan, Nova Scotia; Intermountain Power Agency's Intermountain Generation Station in Delta, Utah; and FirstEnergy's Bay Shore Plant's circulating fluidized bed boiler Unit 1 in Oregon, Ohio. The studies will examine challenges such as the limited space for new plant equipment, limited heat available for process integration, additional cooling water requirements, and potential steam turbine modifications. The sites were selected because they present a variety of unit sizes and ages, existing and planned emissions controls, fuel types, steam conditions, boilers, turbines, cooling systems, and options for CO_2 storage. A report for each site will: (1) assess the CO_2 capture efficiency configuration based on site constraints; (2) determine the space required for the CO_2 capture technology; (3) estimate performance and costs; and (4) assess the features of each plant that affect retrofit cost and feasibility. January 27, 2009, http://my.epri.com/portal/server.pt/gateway/PTARGS_0_2_317_205_776_43/http%3B/uspalecp604%3B7087/publishedcontent/publish/epri_to_study_adding_carbon_capture_to_existing_coal_power_plants_da_626651.html.

***Norway Post*, "ESA Approves Carbon Capture and Storage Project at Kaarstoe."** The European Free Trade Association (EFTA), through the EFTA Surveillance Authority (ESA) of Norway, authorized funding for establishing a carbon capture and storage (CCS) facility in Kaarstoe, Norway. The CCS facility, which will be owned and managed by the state-owned company Gassnova SF, will capture and store CO_2 emitted from the Naturkraft Power Plant. The goal of the Kaarstoe project is to reduce energy costs and contribute to the global deployment of CCS technologies. Gassnova SF will be the direct recipient of the state funding, which will cover operating costs of the CCS facility for 10 years. ESA believes that testing the technology and learning from the results is an essential step to cutting CCS operating costs. The Norwegian state hopes the Kaarstoe project will contribute to making CCS technology more cost effective. January 30, 2009, http://www.norwaypost.no/content/view/21561/1/.

***Times Online*, "National Grid to Pipe Carbon Dioxide Emissions under North Sea."** According to its Director of Network Operations, National Grid is planning to construct a $2.9 billion carbon transport and storage network near the Humber estuary of Northern England to pipe CO_2 emissions from power stations to geological formations beneath the North Sea. Under the proposed plan, the network would pipe CO_2 emitted from coal- and gas-fired stations such as Drax, Eggborough, Ferrybridge, and

Killingholme. The plan calls for the network to be operational within three years, which would aide Britain's goal to have its first commercial-scale, CCS-equipped power plant operational by 2012. The official also said National Grid would use existing pipes and other infrastructure formally used to transport natural gas when possible. February 11, 2009, http://www.timesonline.co.uk/tol/news/environment/article5705182.ece.

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***Fossil Energy Techline*, "DOE Seeks Applications for Tracking Carbon Dioxide Storage in Geologic Formations."** On February 19, 2009, DOE issued a Funding Opportunity Announcement (FOA) to enhance the capability to simulate, track, and evaluate the potential risks of CO_2 storage in geologic formations. Depending on Fiscal Year 2009 appropriations, up to $24 million may be available for multiple projects that would last up to four years. Some of the project objectives under this FOA are to: (1) develop tools and protocols for MVA of CO_2 stored in geologic formations; (2) improve simulation tools to predict the behavior of geologically stored CO_2; and (3) develop risk assessment models associated with geological CO_2 storage. The selected projects will be managed by NETL and will become part of the Carbon Sequestration Program's research portfolio. February 19, 2009, http://www.fossil.energy.gov/news/techlines/2009/09009-DOE_Issues_FOA.html.

***StatoilHydro Press Release*, "Greenhouse Store Staying Sealed."** New seismic data from the Utsira Formation in the North Sea shows that the CO_2 injected by StatoilHydro and partners Exxon Mobil and Total is spreading through the formation as expected. StatoilHydro, which extensively monitors and controls the CO_2 in the subsurface store to identify the behavior of the gas in the formation, collects four-dimensional seismic data every other year. The data from the 2008 survey confirms that the seven geophysical measurements conducted to date show a stable trend, with the CO_2 spreading upwards from the injection site and slowly through the rock; it is maintaining the same dispersion speed as it did in 2006, indicating the gas is remaining in the formation and not escaping to the surface. StatoilHydro extracts 2,600 tonnes of CO_2 from Sleipner West production and stores it 1,000 meters beneath the seabed, rather than releasing it into the atmosphere. Since Fall 1996, more than 10 million tonnes of CO_2 have been injected into the Utsira sandstone formation. The injected CO_2 covers approximately three square kilometers of the roughly 26,000 square kilometers available in the Utsira Formation. March 5, 2009, http://www.statoilhydro.com/en/NewsAndMedia/News/2009/Pages/03MarSleipner.aspx.

***Reuters*, "E.ON, Siemens to Build Pilot Carbon Capture Plant,"** and ***E.ON Kraftwerke Press Release*, "Siemens and E.ON Kraftwerke to Build Pilot CO_2 Capture Plant for Coal-Fired Power Plants."** German utility E.ON and the industrial group Siemens reached a joint agreement on February 19, 2009, to build a pilot plant to capture CO_2 emissions. The plant will be built at E.ON's Staudinger power station in Grosskrotzenburg near Hanau, east of Frankfurt, and will be tested in a coal-fired unit, Staudinger's Unit 5. Operations are slated to start in Summer 2009 for the pilot plant, which would have a capacity of one megawatt (MW); commercial-size plants would be required to have at least a 400-MW capacity. The pilot plant will be operated with part of the flue gas from Unit 5 and E.ON and Siemens intend to operate it on the Staudinger site until the end of 2010. The project is part of the 5th Energy Research Program, "Innovation and New Energy Technologies," and promotes R&D in the field of low-CO_2 power plant technologies. E.ON plans on using industrial-scale carbon capture and sequestration (CCS) starting in 2020, when the European Union (EU) requires coal plans to use the process. February 19, 2009, http://uk.reuters.com/article/oilRpt/idUKLJ41964320090219?sp=true, and February 18, 2009, http://www.eon-kraftwerke.com/pages/ekw_en/Media/Press_Releases/Latest_Press_Releases/Pressemitteilung.htm?id=1379437.

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***EPA News Release*, "ADEQ and EPA Issue Permits for Carbon Sequestration Injection Project Beneath APS Power Plant in Joseph City / Pilot Project First of its Kind in the Southwest."** The Arizona Department of Environmental Quality (ADEQ) and U.S. Environmental Protection Agency (EPA) issued permits to the West Coast Regional Carbon Sequestration Partnership (WESTCARB) that allow the partnership to inject 2,000 tons of CO_2 into an underground saline formation in Joseph City, Arizona. The injection will incur at an approximate depth of 3,500 feet on Arizona Public Service Company's Cholla Power Plant site in Navajo County. ADEQ also issued a temporary one-year Aquifer Protection Permit that requires the project to use the best available technology and meet Arizona's aquifer water quality standards. The injection wells will also be regulated under the EPA-administered Safe Drinking Water Act's (SDWA) Underground Injection Control (UIC) Program, which aims to prevent the contamination of underground sources of drinking water (USDWs) by regulating the permitting, construction, operation, and safe closure of injection wells that place fluids underground for storage, enhanced oil and gas recovery (EOR/EGR), or disposal. To view the WESTCARB website, visit: http://www.westcarb.org/. March 25, 2009, http://yosemite.epa.gov/opa/admpress.nsf/0/220b7b1e753178ee85257584005ef34a?OpenDocument.

***Power Engineering International*, "E.ON Announces Pipeline Survey Work for UK's Kingsnorth CCS Project."** E.ON has initiated field work to identify potential routes to pipe CO_2 from a newly-proposed coal-fired power plant at Kingsnorth Power Station in Kent, United Kingdom to the North Sea gas field for storage. The survey will investigate the area along the Grain Peninsula for potential pipeline routes. Once potential routes have been identified, the planning process will begin, which includes consultation with landowners, the public, and statutory organizations, such as the Medway Council and the Environmental Agency. E.ON also committed to add carbon capture and storage (CCS) technology to the proposed coal units at Kingsnorth Power Station if incentives are in place. The option of transporting the captured CO_2 by ship is also being considered. March 17, 2009, http://pepei.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&SubSection=Display&PUBLICATION_ID=6&ARTICLE_ID=356422.

***Reuters*, "S. Africa Plans Carbon Capture Storage Plant by 2020,"** and ***Engineering News*, "SA Launches Carbon Capture Storage Centre, Plans Plant by 2020."** On March 27, 2009, a government official said that South Africa expects to build its first pilot-scale CCS plant by 2020. The South African National Energy Research Institute (SANERI) has secured $27.2 million for the next five years to support the research and development (R&D) activities conducted by the South African Centre of Carbon Capture and Storage. The centre's main objectives are to ensure the development of South African CCS projects and to gain an understanding of how CO_2 would react with South African geology. South Africa plans to implement a CO_2 injection experiment by 2016, after which it would develop a demonstration plant by 2020. A CO_2 storage atlas, which will identify potential CO_2 storage capacity in South Africa, is expected to be completed by April 2010. Preliminary studies conducted by the Council of Geosciences show that South Africa has an available storage capacity of 100 gigatons. For more information about SANSERI, visit: http://www.saneri.org.za/index.html. March 27, 2009, http://af.reuters.com/article/investingNews/idAFJOE52Q0CR20090327, and March 27, 2009, http://www.engineeringnews.co.za/article/sa-launches-carbon-capture-storage-centre-plans-demonstration-plant-by-2020-2009-03-27.

June 2009

***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 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-CO2-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/.

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***Fossil Energy Techline*, "Implementation of the American Recovery and Reinvestment Act of 2009."** On behalf of DOE's Office of Fossil Energy (FE), NETL issued four Funding Opportunity Announcements (FOAs) as part of the American Recovery and Reinvestment Act of 2009. Two FOAs will provide grants to develop geologic sequestration training centers and support site characterization of promising geologic formations for CO_2 storage; two other FOAs will provide funding for CCS from industrial sources and innovative concepts for beneficial CO_2 use, and for Round III of the Clean Coal Power Initiative. FE received $3.4 billion from the American Recovery and Reinvestment Act of 2009 for initiatives that focus on the research, development, and deployment of technologies that use coal more cleanly and efficiently, such as gasification and techniques that clean or capture and store greenhouse gas (GHG) emissions from coal-fired power plants. More information regarding the FOA for industrial CCS projects can be found at: http://www.fossil.energy.gov/news/techlines/2009/09038-DOE_to_Fund_Industrial_CCS.html. June 9, 2009, http://www.fossil.energy.gov/aboutus/budget/stimulus.html.

***Fossil Energy Techline*, "DOE Establishes National Carbon Capture Center to Speed Deployment of CO_2 Capture Processes."** DOE announced the creation of the National Carbon Capture Center (NCCC) to aid in the development and testing of technologies to capture CO_2 from coal-based power plants. NCCC will serve as a test center for emerging carbon capture technologies at a scale large enough to provide meaningful data under real operating conditions. The center will be operated and managed by Southern Company Services, Inc. at the Power Systems Development Facility (PSDF) in Wilsonville, Alabama. PSDF offers multiple slipstream capabilities for testing processes and the ability to investigate different ranks of coal, biomass, and other fuels. The facility will test multiple pre- and post-combustion CO_2 capture technologies. To learn more about DOE's Carbon Sequestration Program, visit: http://www.fossil.energy.gov/programs/sequestration/index.html. May 27, 2009, http://www.fossil.energy.gov/news/techlines/2009/09034-National_Carbon_Capture_Center_Est.html.

***Southern Company News Release*, "Southern Company to Demonstrate Technology to Reduce Greenhouse Gas Emissions from Electric Generating Plant."** Southern Company announced plans to demonstrate CCS on a coal-fired power plant to support the development of technologies for reducing GHG emissions. In collaboration with DOE and other partners, a demonstration facility will be built by Southern Company to capture CO_2 emissions from an existing unit of Alabama Power's Plant Barry, which is located near Mobile, Alabama. Beginning in 2011, the facility will capture approximately 100,000 to 150,000 tons of CO_2 per year and supply it to the Southeast Regional Carbon Sequestration Partnership (SECARB), which will then transport it by pipeline to a site within the area of the Citronelle Oil Field for underground storage. The CO_2 capture technology planned for the project uses an advanced, amine-based solvent that reacts with CO_2 in flue gas before being separated and compressed for pipeline transport. For more information about SECARB, visit: http://www.secarbon.org/. May 21, 2009, http://southerncompany.mediaroom.com/index.php?s=43&item=1904.

***Casper Star-Tribune*, "Wyo Models CO_2 Pipeline Grid."** Wyoming state energy officials released a work-in-progress database that details potential pipeline investment and collaboration opportunities for CO_2 stakeholders. The database, which maps out where planned and speculative CO_2 sources could connect through the phased development of pipelines throughout Wyoming, was refined by the state's Pipeline Authority and the University of Wyoming's Enhanced Oil Recovery Institute (EORI). Wyoming's current CO_2 pipeline network stems from ExxonMobile's Shute Creek gas plant in southwest Wyoming to

the Lost Solider oilfield near Bairoil, Wyoming, and to the Salt Creek field 42 miles north of Casper, Wyoming. According to Wyoming officials, the next phases of the pipeline development will continue to connect CO_2 from natural gas processing plants to oilfields within the state. The database is available at: http://eori.gg.uwyo.edu/database.asp. May 19, 2009, http://casperstartribune.net/articles/2009/05/19/news/wyoming/e33d1ffac9b38b9c872575bb00828117.txt.

August 2009

***Business First of Louisville*, "Duke Energy Files Plans for Carbon Storage Study,"** and ***Duke Energy News Release*, "Duke Energy Files Plans for Carbon Storage Study in Southwest Indiana."** Duke Energy Corporation has filed plans with the Indiana Utility Regulatory Commission (IURC) for a proposed CO_2 storage project in southwest Indiana. Duke Energy will invest $121 million to store a portion of the CO_2 emissions from a coal-gasification power plant in Edwardsport, Indiana. The CO_2 will be stored underground in deep saline aquifers and depleted oil and gas fields. If the three-year site characterization is considered a success, Duke Energy will seek permission from IURC to permanently capture and store CO_2. Duke Energy applied for a DOE CCPI Round 3 grant in January, which could offset up to 50 percent of the CCS costs for the project. July 6, 2009, http://www.bizjournals.com/louisville/stories/2009/07/06/daily7.html, and July 6, 2009, http://www.duke-energy.com/news/releases/2009070603.asp.

***Reuters*, "Alberta to Back Three Carbon Capture Projects,"** and ***The Calgary Herald*, "Alberta Announces Three Winning Projects for Carbon Capture Funding."** Alberta government officials announced on June 30, 2009, that three CCS projects will be financed using a $1.7 billion fund set aside last year. Alberta expects to provide up to $92.5 million this year for design and engineering work on the three proposals. The three projects, which were selected after a year-long competition, include CCS at Royal Dutch Shell Plc's Scotford oil sands upgrader; a carbon capture facility at a power plant owned by EPCOR and backed by Enbridge, Inc.; and a project that takes CO_2 from an Agrium, Inc. fertilizer plant and a planned upgrader, and ships it by pipeline to oil fields, where it will be used to boost output. The first round of commercial-scale projects is expected to achieve annual CO_2 reductions by 2015. June 30, 2009, http://www.reuters.com/article/internal_ReutersNewsRoom_BehindTheScenes_MOLT/idUSTRE55T78220090630, and July 1, 2009, http://www.calgaryherald.com/Business/Alberta+announces+three+winning+projects+carbon+capture+funding/1747893/story.html.

***International Power Press Release*, "Hazelwood Carbon Capture Project Underway."** A $10 million CCS pilot project designed to initially capture up to 25 tonnes of CO_2 per day initiated operation in July 2009 at International Power Australia's (IPRA) Hazelwood Plant in the Latrobe Valley in Victoria, Australia. The plant has the potential to eventually capture up to 50 tonnes a day. The CO_2 from the power plant's flue gas is absorbed by a carbon capture technology using a solvent solution; the captured CO_2 is then used to reduce the pH of the power plant's ash water. The CO_2 reacts with the ash water to produce calcium carbonate ($CaCO_3$) – a commercially usable product. Officials said that the Hazelwood project will be assessed for its potential applicability to future large-scale projects. The carbon capture plant received technology support from the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC). July 8, 2009, https://www.ipplc.com.au/_modules/Uploader/_uploaderBin/jbrinkworth/eb82e902c881129d320544a947eb8c14nrInternationalPowermrCCSlaunch080709.pdf.

Science

September 2008

***Reuters*, "Untouched Forests Store 3 Times More Carbon: Study,"** and ***The Age*, "Trees Will Fight Climate Change: Report."** According to a study conducted by scientists at the Australian National University (ANU), Australia's untouched natural forests store three times more CO_2 than originally estimated and 60 percent more than plantation forests. The report, titled, "Green carbon: the role of natural forests in carbon storage," found that the effect of retaining the current carbon stock of 25.5 billion tonnes of CO_2 in the Eucalypt forests of southeast Australia is equivalent to avoiding 460 million tonnes of CO_2 emissions over the next 100 years. The Intergovernmental Panel on Climate Change (IPCC), which bases forest carbon storage on plantation estimates, defines a forest as trees taller than six feet and a canopy cover greater than 10 percent. However, in Australia a forest is defined as an area having trees taller than 33 feet and a canopy cover greater than 30 percent. IPCC originally estimated temperate forests held 217 tonnes of CO_2 per hectare, but the ANU report found Australia's forests stored an average of 640 tonnes per hectare, and in some areas with trees as high as 262 feet, the forests stored as much as 2,000 tonnes per hectare. Scientists believe that if the 14.5 million hectares of eucalypt forests in Australia are left undisturbed, some 9.3 billion tonnes of CO_2 could be stored; IPCC has estimated one-third of this potential capacity. Scientists believe natural forests store more carbon for a longer period of time than plantation forests because they are not cut down on a rotational basis. To read the complete ANU report, go to: http://epress.anu.edu.au/green_carbon/pdf/whole_book.pdf. August 4, 2008, http://www.reuters.com/article/environmentNews/idUSSP25595420080804, and August 4, 2008, http://news.theage.com.au/national/trees-will-fight-climate-change-report-20080805-3q1n.html.

***Science Daily*, "Some African Drought Linked To Warmer Indian Ocean, NASA Data Show."** A study co-funded by the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) identified a connection between a warming Indian Ocean and declining rainfall in eastern and southern Africa. Since the 1980s, rainfall in eastern Africa has fallen about 15 percent during the rainy season, which runs from March through May, due to abnormalities in the transfer of moisture between the ocean and land caused by rising Indian Ocean temperatures. By analyzing seasonal rainfall data from 1950 to 2005, NASA found the declines in rainfall in Ethiopia, Kenya, Tanzania, Zambia, Malawi, and Zimbabwe were linked to rainfall increases over the Indian Ocean. The researchers simulated future rainfall changes through the use of 11 climate models that showed the increased rainfall over the Indian Ocean would continue through 2050. The research team then developed a model to determine how the future rainfall conditions could affect malnutrition in eastern Africa. The models revealed that if the current trends of declining rainfall and agricultural capacity persist through 2030, the number of malnourished individuals could increase more than 50 percent in eastern Africa; even if agricultural capacity modestly increased, the researchers believe the number of malnourished individuals would increase 40 percent. The complete study, titled, "Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development," is available at: http://www.pnas.org/content/105/32/11081.abstract?sid=6c5ed07f-7b7f-4321-ac7b-2a67887cdd5e. August 7, 2008, http://www.sciencedaily.com/releases/2008/08/080805124005.htm.

October 2008

***Reuters*, "Australia Hit by More 'Extreme Waves,'"** and ***The Australian*, "Climate Change 'Causing Extreme Waves.'"** Scientists researching wave sizes on Australia's coastline over the past 45 years claim that the waves are becoming more frequent and destructive. According to a report prepared by Australia's national science agency, the Commonwealth Scientific and Industrial Research Organization (CSIRO), the increase in the intensity of waves 9.8 feet tall or higher is driven by possible climate change. As the world's driest inhabited continent, Australia is more susceptible to changes in temperature and rainfall because of its many arid and semi-arid areas. The United Nations (UN) has included Australia on a list of vulnerable climate shift "hot spots," because the country's average yearly temperatures are estimated to increase by as much as six percent by 2070. With most Australians populating the southeast coastal cities and towns, "extreme waves" represent a heightened threat in the form of coastal erosion and flooding. The report also found a correlation between an increase in wave

power in northern Australia and the length and strength of northern tropical monsoon seasons. Lastly, the report provides information to help coastal zone managers prepare for the potential impacts of climate change, such as developing a network of long-term coastal observation sites to improve the understanding of large waves. To view the CSIRO website, click: http://www.csiro.au/. September 10, 2008, http://www.reuters.com/article/environmentNews/idUSSYD21540420080910?pageNumber=1&virtualBrandChannel=10284, and September 10, 2008, http://www.theaustralian.news.com.au/story/0,25197,24325113-12377,00.html.

***Science Daily*, "Thawing Permafrost Likely To Boost Global Warming, New Assessment Concludes."** A new University of Florida study more than doubles previous estimates of the amount of carbon stored in permafrost and specifies that CO_2 emissions from the microbial decomposition of organic carbon found in thawing permafrost could amount to roughly half those resulting from global land-use change during this century. By mixing soil from different depths during the yearly melting and freezing of permafrost, the assessment concludes that more than 1 trillion metric tons of organic compounds have been buried in the world's permafrost regions. The scientists believe current conditions are returning organic material back into the ecosystem by turning over soil. Some effects of permafrost thawing are apparent in Arctic areas called thermokarst (the land surface that forms as permafrost melts). However, complexities exist in gathering data, as emissions are influenced by factors ranging from the amount of surface water, topography, wildfires, snow cover, and the difficulty in accurately modeling the thawing. The Arctic Region's warming-related trends, like the advancement of trees into tundra, may cause absorption of CO_2, which could counter some effects of permafrost thawing. Permafrost is frozen ground that contains soil organic matter; when permafrost thaws, bacteria and fungi breakdown the carbon contained in this organic matter more quickly, releasing CO_2 or methane (CH_4) into the atmosphere. The study, titled, "Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle," is available at: http://www.bioone.org/perlserv/?request=get-abstract&doi=10.1641%2FB580807. (Subscription required.) September 2, 2008, http://www.sciencedaily.com/releases/2008/09/080901084854.htm.

November 2008

***Science Daily*, "Tropical Rainforest And Mountain Species May Be Threatened By Global Warming,"** and ***Reuters*, "Climate Change May Threaten Biodiversity in Tropics."** According to a recent report by the University of Connecticut, tropical plant and animal species living in some of the warmest places on Earth may be threatened by potential climate change. The report claims that tropical climates have warmed more than three-fourths of a degree Celsius (1.4 degrees Fahrenheit) since 1975 and climate models predict an additional increase of more than three degrees Celsius (nearly six degrees Fahrenheit) over the next century in the tropical forests of Central and South America. This warming would cause temperature zones to shift approximately 2,000 feet above sea level. Data was analyzed on nearly 2,000 species of plants, insects, and fungi in Costa Rica and it was found that nearly half of the species would have to move to higher ground. As a result, since no other species are adapted to the climate, lowland populations in the tropics may experience decreases in biodiversity and species at higher elevations may run out of room to climb higher due to human land use. To view the report, titled, "Global Warming, Elevational Range Shifts, and Lowland Biotic Attrition in the Wet Tropics," go to: http://www.sciencemag.org/cgi/content/abstract/322/5899/258. (Subscription may be required). October 10, 2008, http://www.sciencedaily.com/releases/2008/10/081009143700.htm, and October 9, 2008, http://www.reuters.com/article/environmentNews/idUSTRE4989MY20081009?pageNumber=1&virtualBrandChannel=10279.

***ClimateWire*, "Temperature Spikes Cramp Plants' Ability to Absorb CO_2, Study Finds."** A new study has concluded that one year of warmth can reduce some plants' and soils' ability to capture CO_2 from the air for up to two years. The study, conducted by the Nevada-based Desert Research Institute, is based on a four-year experiment that involved placing 12 large chunks of a grassland ecosystem (plants,

soil, and soil microbes) in four climate-controlled containers. Computers were used to adjust the temperature and humidity to simulate days, nights, and seasons. After a year, the heat was turned up on half of the grassland chunks, warming them by approximately 7.2 degrees Fahrenheit, the high end of temperature rise the Intergovernmental Panel on Climate Change (IPCC) predicts could occur by the end of this century. The results showed that the heated plants absorbed two-thirds less CO_2 than the plants growing in normal conditions. When the temperatures returned to normal, the once-heated ecosystems still absorbed less CO_2 because the activity of CO_2-producing soil microbes increased. According to the report, the research suggests that an increase in the number of warm years could possibly create a new climate feedback loop at the extreme end, turning some ecosystems from carbon sinks into carbon sources. The study, titled, "Prolonged suppression of ecosystem carbon dioxide uptake after an anomalously warm year," can be accessed at: http://www.nature.com/nature/journal/v455/n7211/full/nature07296.html. (Subscription may be required). September 18, 2008, http://www.eenews.net/climatewire/2008/09/18/4/.

December 2008

***Reuters*, "Lemmings in Norway Hit by Global Warming: Study,"** and ***Science News*, "Climate Change Stifling Lemmings."** A recent study examining disruptions in snowfall caused by climate change and lemming populations revealed that the number of lemmings in Norway is falling, signifying a shift in the historic "boom-and-bust" cycle of the lemming population that has occurred over previous decades. Lemmings, which are famed for their population booms, typically undergo dramatic population booms every three to five years, as female lemmings can have litters of up to 12 as many as three times per year. Lemmings are about half the size of a guinea pig and live in nests beneath the snow during the winter months. However, warmer temperatures in recent years have resulted in wetter snow that melts and refreezes at ground level, making it difficult for lemmings to hide and reach food. When the snowpack is light and fluffy, warmth from the ground melts small spaces under the snow that the lemmings use to search for grass and moss without being exposed to predators. The study of lemmings since 1970 showed the last population boom was in 1994. The researchers noted that lemmings are still abundant and far from being labeled a threatened species, as temperatures in late winter and early spring in southeastern Norway in recent decades were the highest since recordkeeping began in 1756. To view the report, titled, "Linking climate change to lemming cycles," click: http://www.nature.com/nature/journal/v456/n7218/abs/nature07442.html. November 5, 2008, http://www.reuters.com/article/environmentNews/idUSTRE4A49MC20081105, and November 5, 2008, http://www.sciencenews.org/view/generic/id/38313/title/Climate_change_stifling_lemmings.

***Science Daily*, "Rocks Could Be Harnessed To Sponge Vast Amounts Of Carbon Dioxide From Air,"** and ***Reuters*, "Scientists Say a Rock Can Soak up Carbon Dioxide."** The most common rock found in the Earth's mantle, peridotite, may be capable of slowing down potential climate change by storing large amounts of CO_2, according to a recent study. The rock naturally reacts at high rates with CO_2 to form solid minerals, and scientists claim the process could be enhanced up to 1 million times or more through drilling and injection methods. It is estimated that the process could grow underground minerals that can permanently store 2 billion or more of the 30 billion tons of CO_2 emitted by human activities every year. The scientists state they could initiate the carbon storage process by injecting peridotite with heated water containing pressurized CO_2. In addition to being found directly below the Earth's crust, peridotite also appears on the surface in areas like the Middle Eastern nation of Oman, where scientists say 4 to 5 billion tons of greenhouse gases (GHGs) could be stored per year. However, the rock is not found in GHG-emitting areas such as the United States, India, and China. The study, titled, "In situ carbonation of peridotite for CO_2 storage," can be found at: http://www.pnas.org/content/early/2008/10/31/0805794105. November 6, 2008, http://www.sciencedaily.com/releases/2008/11/081105180813.htm, and November 7. 2008, http://www.reuters.com/article/environmentNews/idUSTRE4A59IB20081107.

January 2009

***USGS Newsroom*, "Getting Warmer? Prehistoric Climate Can Help Forecast Future Changes."** The first comprehensive reconstruction of an extreme warm period has shown the climate system's sensitivity to changes in CO_2 levels, as well as the influence of ocean temperatures, heat transport from equatorial regions, and GHGs on Earth's temperature. Led by the U.S. Geological Survey (USGS), research conducted by the Pliocene Research, Interpretation, and Synoptic Mapping (PRISM) group has allowed for more accurate predictions of future climate changes. PRISM scientists examined fossils from the mid-Pliocene warm period, which ranges from three to 3.3 million years ago. The mid-Pliocene experienced the most extreme warming over the past 3.3 million years. Global temperatures at that time were 4.5°F greater than today and within the Intergovernmental Panel on Climate Change's (IPCC) projection for the 21st century, which led PRISM researchers to suggest that a slight increase in the world's current CO_2 level could have a large impact on temperature change. Research also shows warming as much as 32.4°F in the high latitudes of the North Atlantic and Arctic Oceans during the mid-Pliocene, which raises temperatures from 28.4°F to 60.8°F. Data suggests the likely cause of mid-Pliocene warmth was a combination of several factors, including increased heat transport from equatorial regions to the poles and increased GHGs. To listen to a podcast interview with USGS scientists, go to: http://www.usgs.gov/corecast/details.asp?ep=77. November 24, 2008, http://www.usgs.gov/newsroom/article.asp?ID=2080.

***The Courier Mail*, "White Possum Said to be First Victim of Global Warming,"** and ***ClimateWire*, "White Possum may be First Victim of Climate Change."** The white lemuroid possum, a rare creature native to Australia's Daintree forest, may be the first mammal to become extinct due to climate change, according to scientists. Found only above 3,281 feet in the mountain forests of north Queensland, Australia, this tree-dwelling species has not been seen since 2005; the species had been labeled as highly vulnerable five years ago. Experts believe the disappearance is a result of a 1.4°F rise in temperature. Scientists say the record high temperatures in the summer of 2005 could have caused a massive die-off, as the white possum has not been seen in any nighttime spotlight expeditions since then. Researchers will undertake a mission early next year to find the white possum in the untouched "cloud forests" three hours north of Cairns. Scientists believe some frog, bug, and insect species have already been killed off by climate change, but this would be the first known loss of a mammal and the most significant since the extinction of the Dodo and the Tasmanian Tiger. December 2, 2008, http://www.news.com.au/couriermail/story/0,23739,24742053-952,00.html, and December 3, 2008, http://www.eenews.net/climatewire/2008/12/03/10/. (Subscription may be required.)

***Science Daily*, "Climate Change Set Back For Acidified Rivers."** According to a study by Cardiff University, warmer, wetter winters brought on by climate change is interfering with the long-term recovery of rivers from the effects of acid rain. The research, which took place over a 25-year period around Llyn Brianna and mid-Wales, was carried out in 14 streams and involved assessing the number and variety of stream insects present each year; measuring concentrations of acid and other aspects of stream chemistry; and documenting climatic variation, such as warmer, wetter winters. Due to improvements in the levels of acid rain, average acidity in rivers has fallen and researchers expected that as many as 29 insect species should have re-populated the streams as they improved. However, their findings showed that the biological recovery has been slowed, with just four new species added to the recovering rivers that were sampled. To view the Cardiff School of Biosciences study, entitled, "Restoration and recovery from acidification in upland Welsh streams over 25 years," go to: http://www3.interscience.wiley.com/journal/121543652/abstract?CRETRY=1&SRETRY=0. December 5, 2008, http://www.sciencedaily.com/releases/2008/12/081202190859.htm.

February 2009

***MSNBC.com*, "2 Trillion Tons of Ice Gone Since '03,"** and ***CNN.com*, "Ice Melting Across Globe at Accelerating Rate, NASA Says."** According to National Aeronautics and Space Administration (NASA) satellite data showing the latest signs of potential climate change, more than 2 trillion tons of land ice in Greenland, Antarctica, and Alaska have melted since 2003. NASA's Gravity Recovery and Climate Experiment (GRACE) showed that more than half of the loss of landlocked ice over the past five years has occurred in Greenland. Since 2003, when the NASA satellite started taking measurements, Alaska has lost 400 billion tons of land ice. However, after dropping in 2005, land ice in Alaska showed a slight increase in 2008 due to large winter snow falls. According to NASA scientists, the melting of land ice slightly increases sea levels, which has led to Greenland adding approximately half a millimeter to the world's sea level each year. Over the past five years, melting land ice in Greenland, Antarctica, and Alaska has raised global sea levels approximately one-fifth of an inch. Sea levels can also rise from water expanding as it warms; according to scientists, parts of the Arctic north of Alaska were nine to 10 degrees warmer this past fall. The Arctic waters absorb more heat in the summer as sea ice melts due to the loss of reflective powers. The absorbed heat is then released into the air in the fall, which according to researchers, has led to autumn temperatures being six to 10 degrees warmer than in the 1980s. December 16, 2008, http://www.msnbc.msn.com/id/28249708/, and December 17, 2008, http://www.cnn.com/2008/TECH/science/12/16/melting.ice/index.html.

***Los Angeles Times*, "Moose are Roaming Right out of Existence."** A recent study shows that climate change has caused the number of moose in northwest Minnesota to decrease from 4,000 to less than 100 in two decades. There are approximately 7,700 moose in all of Minnesota – a 50 percent decrease from 20 years ago. Over the past 40 years in northwestern Minnesota, the average winter temperature has risen 12 degrees and the average summer temperature has risen four degrees. The moose is not endangered in the United States, but it is in danger of disappearing from the Midwest, the far southern fringe of its range. Minnesota and Michigan wildlife biologists say that heat, water, and parasites play important roles in the diminishing of the species, but they believe that warmer temperatures are the main source. Unlike other local animals who have adapted to warmer temperatures, such as deer, wolves, and bears, moose have suffered because they require shade, water, and cool weather to survive – all of which are dwindling in northwestern Minnesota. When temperatures rise, the moose work harder to find places to stay cool, which affects their immune system and prevents them from gaining enough fat for the winter, leaving them vulnerable to parasites. In northeastern Minnesota, which offers more shade and, thus, more opportunities to cool off, the moose population is declining approximately 10 percent a year. December 29, 2008, http://www.latimes.com/news/science/environment/la-na-minnesota-moose29-2008dec29,0,3445902.story.

March 2009

***Science Daily*, "All Earth's Seasons Now Arrive Two Days Earlier, Researchers Report."** According to a study conducted by scientists from the University of California, Berkley and Harvard University, the hottest day of the year has shifted forward nearly two days, which opposes current Intergovernmental Panel on Climate Change (IPCC) models that predict the annual temperature cycle. While the researchers are unclear of the cause, they believe that GHGs may be responsible for this shift in the cycle of seasons. The study reveals that a pattern of winds has also changed over the same time period. This pattern of atmospheric circulation, known as the Northern Annular Mode, is important for controlling why one winter in the Northern Hemisphere is different from another. However, researchers have found that the mode is also important when it comes to controlling the arrival of the seasons each year. As temperatures can be different on land compared to the ocean, a change in wind strength and direction can move heat from the ocean onto land, which could affect the timing of the seasons. Researchers also found that during the same 50-year period that was used to study the seasons, summer and winter land temperatures have decreased, with winter temperatures warming more than summer temperatures. January 22, 2009, http://www.sciencedaily.com/releases/2009/01/090121144053.htm.

***Science Daily*, "Global Warming: Tree Deaths Have Doubled Across the Western U.S."** Tree deaths in the Western United States have more than doubled in recent decades, according to a study led by the U.S. Geological Survey (USGS). The study documented the tree deaths, which researchers believe is a cause of regional warming and related drought conditions, in all sizes and at varying elevations in the interior west, including Colorado and Arizona, and northwest regions, such as northern California, Oregon, Washington, and Southern British Columbia. The study speculates that the high level of tree deaths could lead to ecological and wildlife population changes in the west. According to USGS researchers, climate records of Colorado's subalpine forests, which are roughly 8,500 feet to 10,000 feet in elevation, show an increase in temperatures during all seasons of the year over the past 50 years. The 76 western forest plots used for the study contained nearly 59,000 living trees, which researchers studied during two periods – from 1955 to 1994 and from 1998 to 2007. Researchers also believe that the tree deaths could lead to potential increases in atmospheric CO_2 levels, which could be the result of lower CO_2 storage from smaller trees and increased CO_2 emissions from dead trees. To read the study, titled, "Widespread Increase of Tree Mortality Rates in the Western United States," go to: http://www.sciencemag.org/cgi/content/abstract/323/5913/521. January 25, 2009, http://www.sciencedaily.com/releases/2009/01/090122141222.htm.

April 2009

***Reuters*, "Scientists Map U.S. Rocks that Soak up CO_2,"** and ***Earth Institute at Columbia University Press Release*, "Geologists Map Rocks to Soak CO_2 From Air."** According to a study conducted by scientists at Columbia University's Earth Institute and the U.S. Geological Survey (USGS), certain rocks abundant on the East and West Coasts of the United States may someday absorb CO_2 emissions at a rate capable of slowing potential climate change. The study reports that approximately 6,000 square miles of ultramafic rocks that could be supercharged to absorb CO_2 lie on or near the surface of California, Oregon, Washington, and the Appalachian belt of eastern North America, spanning from Alabama to Newfoundland. These rocks originate deep in the earth and contain minerals that react with CO_2 to form solid minerals. Over thousands of years, rocks naturally absorb CO_2 by binding it with minerals to form solids such as calcium carbonate, a substance found in rocks and the main component of snail shells and eggshells. When their surfaces dissolve due to weathering or natural cycles, the CO_2 re-crystallizes, at which point it is absorbed by rocks. Scientists say the U.S. rocks could potentially absorb 500 years worth of U.S. CO_2 emissions. The report, titled, "Mapping the Mineral Resource Base for Mineral Carbon-Dioxide Sequestration in the Conterminous United States," is available at: http://pubs.usgs.gov/ds/414/. March 6, 2009, http://www.reuters.com/article/environmentNews/idUSTRE52552W20090306, and March 5, 2009, http://www.earth.columbia.edu/articles/view/2393.

***Reuters*, "Forests Absorb 20 Percent of Fossil Fuel Emissions: Study,"** and ***Guardian News*, "Fifth of World Carbon Emissions Soaked Up by Extra Forest Growth, Scientists Find."** Over the past 40 years, tropical trees have grown larger and now absorb 20 percent of fossil fuel emissions, according to British researchers. The researchers used data collected from nearly 250,000 trees in the world's tropical forests over the last 40 years, and found that the tropical forests across the world remove approximately 4.8 billion metric tons of CO_2 emissions each year. Data also showed that the average total mass of the trees, which is mostly in their trunks, is increasing. Researchers are unsure why the trees are becoming larger and absorbing more CO_2, but offer the hypothesis that the extra CO_2 in the atmosphere may be acting like a fertilizer. However, they have concluded that tropical forests now make up more than half of the world's land carbon sink. The Intergovernmental Panel on Climate Change (IPCC) estimates that human activity produces approximately 32 billion tons of CO_2 each year, with 15 billion tons released into the atmosphere. February 18, 2009, http://www.reuters.com/article/environmentNews/idUSTRE51H5KE20090218, and February 18, 2009, http://www.cbc.ca/technology/story/2009/02/18/tropical-forests.html.

May 2009

***U.S. Geological Survey News Release*, "New Science Gauges Potential to Store CO_2."** The U.S. Geological Survey (USGS) released a report, titled, "Development of a Probabilistic Assessment Methodology for Evaluation of Carbon Dioxide Storage," describing its new methodology to assess the potential for carbon sequestration in the United States. The new USGS methodology identifies methods to assess the volume of pore space in subsurface rocks and characterize the storage potential of saline formations and oil and gas reservoirs in the United States. The methodology depends upon constructing geologic models of the areas to be assessed; statistical methods are used to integrate uncertainty and natural geologic variability on the ranges of potential storage resources within a storage assessment unit. DOE, NETL, EPA, and the Bureau of Land Management contributed to the research. USGS will begin accepting technical comments on the methodology from the public in the near future. (**See Recent Publications section in this newsletter to view a portion of the Introduction and a link to USGS's "Development of a Probabilistic Assessment Methodology for Evaluation of Carbon Dioxide Storage."**) For more information on this methodology and other USGS carbon sequestration efforts, visit: http://energy.er.usgs.gov/health_environment/co2_sequestration/. March 16, 2009, http://www.usgs.gov/newsroom/article.asp?ID=2163&from=rss_home.

***Science Daily,* "Carbon Dioxide in Atmosphere Can Now Be Measured From Space."** INESC Porto and the European Space Agency (ESA) have developed a technology that will measure atmospheric gases more effectively than currently used technologies. The new technology, which is an optical fiber filter capable of measuring CO_2 levels from space, can also measure other greenhouse gases (GHGs), such as methane (CH_4), nitrous oxide (NO_X), and ozone. The system is developed by INESC Porto's Optoelectronics and Electronic System Unit (UOSE) and has a high potential of applicability in satellites due to its efficiency, compactness, and reduced volume and mass. Those satellites equipped with the system, which will be able to detect GHGs in the Earth's atmosphere in concentrations less than one kilometer high and at an altitude of 400 kilometers, also will be able to three-dimensionally map the atmosphere from a single position and with a higher resolution; currently used technologies consist of atmospheric balloons and airplanes. The technology is based on optical fiber technology that can monitor the atmosphere with the reflection of laser impulses. April 12, 2009, http://www.sciencedaily.com/releases/2009/04/090401204201.htm.

June 2009

***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.

July 2009

***Science Daily*, "Climate Change Threatens Endangered Honeycreeper Birds of Hawaii."** United States Geological Survey (USGS) researchers claim that deadly, non-native bird diseases will become more prevalent and invade most of the disease-free sanctuaries of Hawaii's native bird, the honeycreeper, as temperatures increase in Hawaii's mountains due to climate change. The researchers examined the present altitudinal range of avian malaria and pox, honeycreeper distribution, and the future, projected range of diseases and honeycreeper habitat with potential climate change to arrive at their conclusion. Prior to the late 1880s, the Hawaiian Islands did not have any mosquitoes or mosquito-born diseases; shortly thereafter, mosquitoes made their way to the islands, bringing with them diseases that are dependent on seasonal changes in temperature, such as avian malaria and pox. Having no natural resistance against these diseases, honeycreepers significantly declined in numbers and geographic range. Honeycreepers refuge in high-elevation mountains (above 4,000 feet) provided a habitat in which mosquitoes could not thrive. However, climate change could allow mosquitoes to survive in this habitat, which researchers believe could be catastrophic for the honeycreeper population. The journal article, titled, "Introduced Avian Diseases, Climate Change, and the Future of Hawaiian Honeycreepers," is available at: http://www.bioone.org/doi/abs/10.1647/2008-059.1. May 27, 2009, http://www.sciencedaily.com/releases/2009/05/090526140840.htm.

***Science Daily*, "Global Warming Increasing The Dispersal Of Flora In Northern Forests."** Researchers from the University of Helsinki have found that stronger winds caused by climate change, combined with a slight increase in temperature, could potentially increase the dispersal of plants in Northern forests by spreading plant species into forest clearings. According to the researchers, seeds and pollen are being carried over longer distances due to an increase in wind strength. This dispersal is believed to significantly affect the dynamics and the genetic variation of plant populations. When spread throughout more favorable areas, seeds and pollen have a greater likelihood of surviving in the potentially warming climate. Researchers also discovered that the dispersal of seeds, and the speed at which populations spread throughout the growth season, increased after a rise in temperature of 5.4 degrees Fahrenheit. Based on these results, researchers concluded that warmer temperatures may accelerate the spread of plants, but will not be solely sufficient to aid plant populations in relocating to new vegetation zones. The journal article, titled, "Increases in air temperature can promote wind-driven dispersal and spread of plants," is available at: http://rspb.royalsocietypublishing.org/content/early/2009/06/05/rspb.2009.0693. June 12, 2009, http://www.sciencedaily.com/releases/2009/06/090611065853.htm.

August 2009

***MSNBC.com*, "Study: Tropical Rain Band is Shifting North."** Authors of a recent study state that the Earth's most prominent rain band, which they believe bordered the equator 350 years ago during the

planet's Little Ice Age from approximately 1400 to 1850, has shifted north at an average rate of approximately one mile a year for three centuries due to climate change. The band supplies freshwater to almost 1 billion people and if the northern migration continues, the scientists asserted that some Pacific islands near the equator may no longer receive freshwater by midcentury or sooner. While the scientists noted there is no global water shortage, humans are placing additional pressure on water resources. According to the scientists, the band of tropical rainfall stems from the "intertropical convergence zone," where winds from the northern and southern hemispheres meet and heat enters into the atmosphere from the tropical sun. To arrive at their conclusions, the authors analyzed rainfall records from annual layers of lake and lagoon sediments on four Pacific islands at or near the equator. The researchers found that areas like Washington Island, which sits at the southern edge of the intertropical convergence zone, and the island of Palau, which lies about in the heart of the modern convergence zone, receive an ample supply of rainfall. Researchers also found evidence that areas located on the equator in the Eastern Pacific like the Galapagos Islands possessed a wet climate during the Little Ice Age and currently have an arid climate. The study, titled, "Southward movement of the Pacific intertropical convergence zone AD 1400-1850," is available at: http://www.nature.com/ngeo/journal/v2/n7/abs/ngeo554.html. July 2, 2009, http://www.msnbc.msn.com/id/31709811/ns/us_news-environment/.

***Science Daily*, "Climate Change May Spell Demise of Key Salt Marsh Constituent."** New research shows that a component of salt marshes known as pannes could be affected by climate change. Pannes, which are waterlogged, low-oxygen zones of salt marshes, are considered "plant diversity hotspots," as at least a dozen species of plants called forbs inhabit them, including *Limonium nashii* (sea lavender), *Salicornia europaea* (pickleweed), and *Triglochin maritima*. To arrive at their conclusions, the researchers subjected plots of forb pannes to air about six degrees Fahrenheit warmer than the surrounding area; they found that plant growth initially increased, but the plants began a rapid die-off and were replaced by the salt marsh grass *Spartina patens*. In tests that spanned from 2004 to 2006, the forbs pannes cover dropped from 50 percent to less than 10 percent at two sites – Nag Creek (Prudence Island, Rhode Island) and Little River (Maine). At the third test site, Drakes Island (Maine), the forb pannes cover decreased from 50 percent to 44 percent in Summer 2007. The researchers believe the forbs disappeared due to changes in the plant-water balance, meaning the warmer air caused the forbs to take in more water, making the area less waterlogged and more welcoming for *Spartina patens*, which prefers less water-soaked environments. In the New England region, pannes span from Connecticut, where they make up less than 10 percent of a salt marsh's area, to Maine, where they can consist of about 40 percent of the salt marsh ecosystem. The study, titled, "Experimental warming causes rapid loss of plant diversity in New England salt marshes," is available at: http://www3.interscience.wiley.com/journal/122473116/abstract. July 15, 2009, http://www.sciencedaily.com/releases/2009/07/090713085016.htm.

Policy

September 2008

***Bloomberg*, "Japan Power Exchange to Start Carbon-Credit Trading in October."** Following Japanese Prime Minister Yasuo Fukuda's announcement before a Group of Eight (G-8) meeting in early July to reduce Japan's greenhouse gases (GHGs) by more than half and the subsequent endorsement by the Prime Minister's cabinet, the Japan Electric Power Exchange will begin trading carbon credits on a trial basis in October 2008 and increase research on carbon capture technology. The trade ministry has directed the 39-member stock exchange in Tokyo to design an experimental, web-based trading platform with the credits being traded in yen per metric ton. Under this plan, the stock exchange will match the bids and offers placed on the trading platform. Tokyo Electric Power Co., Merrill Lynch & Co., and Mitsubishi Corp. are among those who are expected to use the trading platform. The United Nations' (UN) Clean Development Mechanism (CDM) allows rich, polluting countries to buy credits from projects

that cut emissions in the poorer nations; the credits are tradable on the European Climate Exchange (ECX). The Japanese government will monitor the trial trading process to determine if any adjustments are needed before full-fledged trading can proceed. August 11, 2008, http://www.bloomberg.com/apps/news?pid=20601101&sid=aTfts8D4pzN0&refer=japan.

"Modeling the Price Dynamics of CO_2 Emission Allowances." In this paper [the authors] analyze the short-term spot price behavior of carbon dioxide (CO_2) emission allowances of the new EU-wide CO_2 emissions trading system (EU ETS). After reviewing the stylized facts of this new class of assets [the authors] investigate several approaches for modeling the returns of emission allowances. Due to different phases of price and volatility behavior in the returns, [the authors] suggest the use of Markov switching and AR-GARCH models for stochastic modeling. [The authors] examine the approaches by conducting an in-sample and out-of-sample forecasting analysis and by comparing the results to alternative approaches. [The authors'] findings strongly support the adequacy of the models capturing characteristics like skewness, excess kurtosis and in particular different phases of volatility behavior in the returns. **Eva Benz and Stefan Trück**, *Energy Economics*, Available online July 16, 2008, doi:10.1016/j.eneco.2008.07.003, http://www.sciencedirect.com/science/article/B6V7G-4T0MMJH-1/2/991161593335051c51f268dd12ee5024. (Subscription may be required.)

October 2008

***Reuters*, "New Zealand Parliament Passes Carbon Trading Bill,"** and ***Bloomberg*, "New Zealand Parliament Passes Law to Curb Greenhouse Gases."** New Zealand passed an emissions trading bill on September 10, 2008, that will set up the first national GHG cap-and-trade scheme outside of Europe. The climate change bill, which passed with a 63-57 vote, will eventually bring all sectors of the economy under a regime that will set limits on emitted carbon. If the limit is breached, the credits will have to be purchased from users who produced emissions below their limit. New Zealand is joining the 27 European Union (EU) nations that adopted an emissions trading scheme in 2005; the passing of the bill could also help New Zealand meet its Kyoto Protocol obligations. The percentage of the country's emissions to be captured is not expected to surpass 40 percent of the total, covering 25 million tonnes of CO_2 per year. The New Zealand trading scheme will include all forestry emissions from 2008, stationary energy by 2010, transport fuels from 2011, and agricultural waste by 2013. New Zealand is also currently in discussions to possibly combine carbon schemes with Australia. The trading of carbon credits is set to begin in 2009. **The "New Zealand Energy Greenhouse Gas Emissions 1990-2007" report is available in the Recent Publications section**. September 10, 2008, http://uk.reuters.com/article/oilRpt/idUKLA22139820080910?pageNumber=2&virtualBrandChannel=0&sp=true, and September 10, 2008, http://www.bloomberg.com/apps/news?pid=20601081&sid=apIsG4Shwdh4&refer=australia.

"Public risk perspectives on the geologic storage of carbon dioxide." The following is the abstract of this article: "CCS technology has the potential to enable large reductions in global GHG emissions, but one of the unanswered questions about CCS is to what extent it will be accepted by the public. To provide insight regarding risk perception as an important component that will influence the public acceptance of CCS, this study discusses different notions of risk and their varying uses by the public, who generally use a social constructivist risk perspective, and risk experts, who generally use a realist perspective. Previous studies discussing the public acceptance of CCS have relied on survey response data and/or focus groups. This study instead uses the psychometric theory of public risk perception to postulate how the public is likely to respond to efforts to use geologic storage of CO_2, a component of the CCS architecture. Additionally this paper proposes further actions that could favorably impact the public's perception of risk from geologic storage projects. Through the psychometric analysis this study concludes that the risks of geologic storage are likely to eventually be considered no worse than existing fossil fuel energy technologies. However, since geologic storage of CO_2 is a new technology with little operational experience, additional field tests and a demonstrated ability to mitigate problems should they arise will be necessary to improve the public's perception of risk from CCS technologies." **Gregory**

Singletona, Howard Herzoga, and Stephen Ansolabehere, *International Journal of Greenhouse Gas Control*, Available online September 2, 2008, doi:10.1016/j.ijggc.2008.07.006, http://www.sciencedirect.com/science/article/B83WP-4TBVR08-1/2/21a4d8b7d4bef16a66311a9aa0c705d4. (Subscription may be required.)

November 2008

***Norwegian Ministry of Petroleum and Energy Press Release*, "Nearly Two Billion NOK for Carbon Capture and Storage in 2009,"** and ***Reuters*, "Norway Earmarks $309 Mln for Carbon Storage in '09."** As part of its 2009 draft budget, the Norwegian government proposed spending ~$287 million on CCS technology in order to capture CO_2 emissions from power plants and other industrial sources and to bury the emissions underground or below the North Sea. In terms of domestic CCS projects, ~$139 million would be allocated to a CCS test center at the Mongstad power plant located on Norway's North Sea coastline and ~$29 million would finance another carbon capture project at the Kårstø gas-processing unit before an investment decision anticipated by the end of 2009, according to ministry officials. In addition, the draft budget calls for ~$86 million dedicated to the "planning and preparations of the transportation and storage of captured [CO_2]." Norway's national program to fund research, development, and demonstration (RD&D) of CCS technologies, CLIMIT, would receive approximately $23 million in 2009. Most of the remaining funds, estimated at $3 million, would be spent on an action plan for international research and on the promotion of Norway's goal to encourage the acceptance of CCS as a viable tool to reduce CO_2 emissions. More information about Norway's CCS-related initiatives can be found at: http://www.regjeringen.no/en/dep/oed/Subject/Carbon-capture-and-storage.html?id=86982. October 7, 2008, http://www.regjeringen.no/en/dep/oed/press-center/Press-releases/2008/nearly-two-billion-nok-for-carbon-captur.html?id=528880, and October 7, 2008, http://www.reuters.com/article/rbssEnergyNews/idUSL76861120081007.

"Regional abatement action and costs under allocation schemes for emission allowances for achieving low CO_2-equivalent concentrations." The following is the abstract of this article: "This paper assesses regional abatement action and costs for two scenarios in which atmospheric [GHG] concentrations stabilize at 450 and 550 ppm CO_2-equivalent. It evaluates two allocation schemes: Multi-Stage and Contraction [and] Convergence. It was found that abatement costs as percentages of GDP vary significantly by region, with high costs for the Middle East and the former Soviet Union, medium costs for the OECD regions and low costs or even gains for (other) developing regions. In addition to the abatement costs they incur, fossil-fuel-exporting regions are also likely to be affected by losses of coal and oil exports while the former Soviet Union and South America could experience increased bio-energy exports. Especially in the former Soviet Union and Asia, non-CO_2 abatement options are important in the short term in reducing their emissions. [CCS], energy efficiency improvements, bio-energy use, and the use of renewables dominate reductions in the long term in all regions. It was found that the regional costs are influenced more by the assumed stabilization level and baseline scenario than by the allocation regimes explored or the assumptions for different technologies." **Michel G. J. den Elzen, Paul L. Lucas, and Detlef P. van Vuuren**, *Earth and Environmental Science*, Available online September 3, 2008, doi:10.1007/s10584-008-9466-1, http://www.springerlink.com/content/q14328j1822q4723/?p=e3df9ac86e184d70b71eae53812d5575&pi=4. (Subscription required.)

December 2008

***Latrobe Valley Express*, "CCS Bill Gets the Nod,"** and ***Oil & Gas Journal*, "Aussie Bill Sets Up CO_2 Sequestration Framework."** Two pieces of legislation were passed in Australia for the advancement of CCS technologies. Victoria became the first Australian state to pass CCS legislation with the State Government's "Greenhouse Gas Geological Sequestration Bill," which is expected to take effect on January 1, 2010. The bill will enable the onshore injection and permanent storage of CO_2 and other

GHGs. The announcement of the bill follows the Australian Federal Treasury's release of detailed cost modeling and opportunities to meet the challenge of potential climate change. Australia's "Offshore Petroleum Amendment Bill," which was also recently approved by the Australian Petroleum Production and Exploration Association (APPEA), establishes the world's first regulatory framework for CCS. The bill ensures that after project completion, companies can transfer long-term liability to the government. The transfer of liability will not begin until a minimum of 20 years after CO_2 injection operations are complete. The new legislation also establishes access and property rights in Australia for geosequestration and forms the key component of the government's response to possible climate change. November 10, 2008, http://latrobevalley.yourguide.com.au/news/local/news/general/ccs-bill-gets-the-nod/1356258.aspx, and November 13, 2008, http://www.ogj.com/display_article/345336/7/ONART/none/DriPr/1/Aussie-bill-sets-up-CO-2--sequestration-framework/.

"The performance of the Norwegian carbon dioxide, capture and storage innovation system." The following is the abstract of this article: "In order to take up Norway's twin challenge of reducing CO_2 emissions, while meeting its growing energy demand with domestic resources, the deployment of CCS plays an important role in Norwegian energy policies. This study uses the Functions of Innovation Systems approach to identify key policy issues that need to be addressed in order to prolong Norway's international leadership position in the development of CCS. The analysis shows that Norway has been successful in building an innovation system around CCS technology. The key determinants for this achievement are pinpointed in this article. However, the evolution of the innovation system seems to have entered a critical phase that is decisive for a further thriving development of CCS in Norway. The results provide a clear understanding of the current impediments in the CCS innovation system and stress the need to direct policy initiatives at the identified weak system functions – i.e. entrepreneurial activity and market formation – to improve the performance of the system. [The authors] discuss how policymakers can use these insights to develop a coherent set of policy instruments that would foster the deployment of CCS concepts related to power production and EOR in Norway." **Klaas van Alphen, Jochem van Ruijven, Sjur Kasa, Marko Hekkert, and Wim Turkenburg**, *Energy Policy*, Available online September 18, 2008, doi:10.1016/j.enpol.2008.07.029, http://www.sciencedirect.com/science/article/B6V2W-4TG8P50-2/2/6983d0e068693e162cb449e1f93b3db6. (Subscription may be required.)

"A climate protection strategy for Germany – 40 percent reduction of CO_2 emissions by 2020 compared to 1990." The following is the abstract of this article: "This paper presents measures and instruments for Germany to achieve the goal of 40 [percent] CO_2-emission reduction until 2020 by reducing energy-related emissions by 224 million tonne (Mt). The most important measures in this regard are cuts in electricity generation (savings of 40 Mt), fuel switching and increased energy conversion efficiency (30 Mt) and an augmented 26 [percent] share of renewable energies in the provision of electrical energy (44 Mt). Average cost of the measures are at 50 euro per tonne avoided CO_2, which corresponds to an additional monthly expenditure per household of less than 25 euro." **Christoph Erdmenger, Harry Lehmann, Klaus Müschen, Jens Tambke, Sebastian Mayr, and Kai Kuhnhenn**, *Energy Policy*, Available online September 25, 2008, doi:10.1016/j.enpol.2008.07.031, http://www.sciencedirect.com/science/article/B6V2W-4THS3MT-1/2/61cbfa991facbfc4397f9188050a62d3. (Subscription may be required.)

January 2009

***Reuters*, "Mexico Says to Set Climate Targets, Cap and Trade,"** and ***The Associated* Press, "Mexico Pledges 50 Percent Cut in Greenhouse Gases."** Mexico plans to adopt caps on GHG emissions next year according to an announcement at the United Nation (UN) climate talks in Poznań, Poland, where 190 countries met to develop a new climate treaty to replace the Kyoto Protocol, which expires in 2012. In February 2009, Mexican President Felipe Calderon will rule on a binding CO_2 emissions cap from cement and oil refining, with a goal to halve national GHGs by 2050. Subject to presidential approval, a cap-and-trade carbon market would be launched by 2012. Companies that

reduce their emissions below the limits could sell their unused allowances on the international carbon market. Although Mexico is a member of the Organization for Economic Cooperation and Development (OECD), it is classified as a "developing country" under the Kyoto Protocol. Therefore, it does not have to cap its carbon emissions until at least 2012. The plan would make Mexico the only developing country to set a voluntary national target below current levels. December 11, 2008, http://www.reuters.com/article/GCA-GreenBusiness/idUSTRE4BA55T20081211, and December 11, 2008, http://www.google.com/hostednews/ap/article/ALeqM5jpOWN_kr_fbB4qOx_hrA34eg67LgD950L4580.

"Risk Analysis for Future CO_2 Sequestration Projects Based on over 35 years of CO_2 Enhanced Oil Recovery in the U.S." The following is the abstract of this article: "This paper is the first of a series that attempts to assess the possible health and safety risks associated with large scale CO_2 sequestration in deep brine reservoirs. The approach is based on analysis of available data on the operational track record from CO_2 transportation and injection associated with CO_2-EOR in the [United States]. This paper is particularly concerned with identification of the main business risks facing a company engaged in geological sequestration. Such risks include both the operational risks of capturing, compressing, transporting and injecting CO_2, as well as the risk of accidental, rapid CO_2 release from wells (including an analysis of blow out data from CO_2 injection wells, worked over wells as well as abandoned wells). Observations of the outcomes from accidents in real pipelines and CO_2 injection wells in CO_2-EOR projects provide the most concrete basis to predict the future safety of the above ground operations of CO_2 sequestration in deep brine reservoirs." **Ian J. Duncan, Jean-Philippe Nicot, and Jong-Won Choi**, Presented at the 9th International Conference on Greenhouse Gas Control Technologies (GHGT-9), held November 16-20, 2008, at the Omni Shoreham Hotel in Washington DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00647%2Epdf.

February 2009

***Energy Business Review*, "CCS: Technology's Prospects Boosted by Dutch Government."** The Dutch Government granted Shell and a consortium led by GDF-Suez approximately $39.5 million for the development of CCS schemes that are expected to capture a combined 2 million tonnes of CO_2 over the next 10 years at two new sites in Holland. Shell will capture CO_2 from its Pernis oil refinery in Rotterdam and sequester it in depleted gas fields. The consortium headed by GDF-Suez will capture CO_2 from DSM Agro's ammonia plant and store it in a depleted coal mine in the southeastern Limburg region. In addition, the GDF-Suez led consortium has already identified other sites that may be suitable for the geological CO_2 storage, because the conversion of the coal mine to a CCS capable facility may be contingent upon the local geography. January 9, 2009, http://www.energy-business-review.com/article_feature.asp?guid=D8543B83-3E75-412D-BF67-DCE9CAB0E091.

"A Multi-Level Approach to Outreach for Geologic Sequestration Projects." The following is the abstract of this article: "Public perception of CCS projects represents a potential barrier to commercialization. Outreach to stakeholders at the local, regional, and national level is needed to create familiarity with and potential acceptance of CCS projects. This paper highlights the Midwest Geological Sequestration Consortium (MGSC) multi-level outreach approach which interacts with multiple stakeholders. The MGSC approach focuses on external and internal communication. External communication has resulted in building regional public understanding of CCS. Internal communication, through a project Risk Assessment process, has resulted in enhanced team communication and preparation of team members for outreach roles." **Sallie E. Greenberg, Hannes E. Leetaru, Ivan G. Krapac, Ken Hnottavange-Telleen, and Robert J. Finley**, Presented at the 9th International Conference on Greenhouse Gas Control Technologies (GHGT-9), held November 16-20, 2008, at the Omni Shoreham Hotel in Washington, DC, United States,

https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00647%2Epdf.

"Case studies of the application of the Certification Framework to two geologic carbon sequestration sites." The following is the abstract of this article: "[The authors] have developed a certification framework (CF) for certifying that the risks of geologic carbon sequestration (GCS) sites are below agreed-upon thresholds. The CF is based on effective trapping of CO_2, the proposed concept that takes into account both the probability and impact of CO_2 leakage. The CF uses probability estimates of the intersection of conductive faults and wells with the CO_2 plume along with modeled fluxes or concentrations of CO_2 as proxies for impacts to compartments (such as potable groundwater) to calculate CO_2 leakage risk. In order to test and refine the approach, [the authors] applied the CF to (1) a hypothetical large-scale GCS project in the Texas Gulf Coast, and (2) [West Coast Carbon Sequestration Partnership's (WESTCARB)] Phase III GCS pilot in the southern San Joaquin Valley, California." **Curtis M. Oldenburg, Jean-Philippe Nicot, and Steven L. Bryant**, Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington, DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00687%2Epdf.

March 2009

***Zurich Financial Services Group News Release*, "Zurich Creates Two New Insurance Policies to Support Greenhouse Gas Mitigation Technologies, Addressing the Unique Needs of Carbon Capture and Sequestration."** Zurich Financial Services Group announced the availability of CCS Liability Insurance and Geologic Sequestration Financial Assurance (GSFA), which are intended to facilitate future CCS usage. The products cover the long-term liabilities posed by CCS technology, ranging from geologic storage site design, operational phases, site closure, and post-closure. Zurich's CCS Liability Insurance covers pollution events, business interruption, control of the well, liabilities related to carbon transmission, and geomechanical liabilities during the operational life of the CO_2 storage facilities. GSFA is intended to cover the decades after the closure of the facility, including funding to close the covered well(s) and to monitor CO_2 storage after site closure. Officials believe these products can be applied to clean coal operations and a variety of onshore and offshore industrial processes. Zurich officials also said the coverages were developed in collaboration with customers, academic experts, and government officials. January 19, 2009, http://www.zurichna.com/zna/media/news_releases/current_releases/releases011909.htm.

***Reuters*, "Norway Plans $750 Mln Carbon Technology Centre."** On January 30, the Norwegian government proposed spending $750 million to build a center for the development of CCS technology at StatoilHydro's Mongstad refinery. Under the proposal, Norway and StatoilHydro would have stakes of 80 percent and 20 percent respectively, although industrial partners could enter into the project and reduce Norway's portion. Norwegian officials expect that the center will take approximately 2.5 years to build. StatoilHydro has been burying 1 million tonnes of CO_2 per year at the Sleipner field in the North Sea since 1996; however, the CO_2 is stripped from a natural gas well stream, not captured from an industrial plant. More information about the Mongstad facility can be found at: http://www.statoilhydro.com/en/ouroperations/terminalsrefining/prodfacilitiesmongstad/pages/default.aspx. January 30, 2009, http://www.reuters.com/article/rbssEnergyNews/idUSLU62914620090130.

"Evaluating CO_2 reduction strategies in the US." The following is the abstract of this article: "[The authors] constructed a model to simulate emissions of CO_2 from electricity generation in the [United States] and, using the model, [the authors] developed 20-year projections of emissions under various regulatory scenarios. [The authors] concluded that the State renewable portfolio standards (RPS) adopted by 23 States will decrease emissions by a mere 4.5 [percent] relative to [business-as-usual (BaU)] conditions. By comparison, possible national GHG control strategies such as applying the

California standards to the entire [United States] or imposing a 2000-level cap on CO_2 emissions would result in a reduction of 34 [percent] relative to BaU. Finally, imposing a 1990-level cap on CO_2 emissions would result in a reduction of 49 [percent] relative to BaU. Notwithstanding these findings, [the authors] demonstrate that, even the most ambitious GHG reduction strategies being contemplated in the [United States] for the energy generating sector will not reach the 60 [percent] reduction, generally regarded as necessary, on a global scale and from all CO_2-emitting sectors to prevent an atmospheric warming of about 2 [degrees]. [The authors] conclude that efforts now need to focus, not only on reducing GHG emissions, but equally on preparing for the inevitable climate change. Beyond the scenarios evaluated in this research, the model can serve as a flexible tool for determining whether a given strategy will achieve the desired CO_2 emission reduction goal." **Joseph I. Arar and Douglas Southgate**, *Ecological Modelling*, Available online January 20, 2009, doi:10.1016/j.ecolmodel.2008.12.005, http://www.sciencedirect.com/science/article/B6VBS-4VDS47T-4/2/e650234a0d9d37206a110162023b7e81. (Subscription may be required.)

April 2009

***Greenwire*, "EPA Proposes Greenhouse Gas Reporting Rule,"** and ***Reuters*, "EPA Offers First Carbon Reporting Plan."** On March 10, 2009, the U.S. Environmental Protection Agency (EPA), proposed a new rule that requires industries to report their GHG emissions. Covering any upstream suppliers of fuels or direct emitters that emit at least 25,000 metric tons of GHGs per year, the rule would affect a range of industrial plants and operations, such as power plants, refineries, coal mines, and auto and engine makers – approximately 13,000 facilities, or 85 to 90 percent of all U.S. emissions. The rule is expected to cost industries $160 million for the first year, and $127 million annually in the following years. EPA plans for the new reporting requirements to go into effect by 2010, with the first annual report submitted in 2011 for the 2010 calendar year, with the exception of the vehicle and engine makers, who would begin reporting with model year 2011. According to a draft EPA presentation, the agency also plans to issue an "endangerment finding" in mid-April that will address the relation between GHG emissions and human health. After public hearings, EPA could be allowed to regulate GHG emissions under the Clean Air Act, which mandates the collecting of data on emissions from power plants. Information sheets for each of the source categories covered in the proposed EPA rule are available at: http://www.epa.gov/climatechange/emissions/ghg_infosheets.html. To read EPA's proposed rule, click: http://www.epa.gov/climatechange/emissions/downloads/MRR-Rule.pdf. March 10, 2009, http://www.eenews.net/Greenwire/2009/03/10/2/, and March 11, 2009, http://www.reuters.com/article/environmentNews/idUSTRE5294M920090311.

***Reuters*, "U.S., Canada to Agree on Energy Pact: Official,"** and ***The Toronto Star*, "Canada, U.S. to Open Clean Energy 'Dialogue'."** According to a White House official, the United States and Canada announced plans to work together on clean energy technology, including CCS, as a way to meet their goal of cutting emissions from within their countries. As part of the agreement, both countries will advance technologies and collaborate on a Smart Grid. The focus of the plan is to mitigate emissions from existing energy sources, specifically from Alberta's oil sands and America's vast coal deposits. Funding will come from both governments' respective stimulus packages, which have a portion set up for clean energy. The agreement is viewed as the first step towards bringing together Canadian and American environmental regulations to limit GHGs. February 19, 2009, http://www.reuters.com/article/GCA-BusinessofGreen/idUSTRE51I4X520090219, and February 19, 2009, http://www.thestar.com/News/Canada/article/590043.

"Economic and Environmental Costs of Regulatory Uncertainty for Coal-Fired Power Plants." The following is the Abstract of this article: "Uncertainty about the extent and timing of CO_2 emissions regulations for the electricity-generating sector exacerbates the difficulty of selecting investment strategies for retrofitting or alternatively replacing existent coal-fired power plants. This may result in inefficient investments imposing economic and environmental costs to society. In this paper, [the authors] construct a multiperiod decision model with an embedded multistage stochastic dynamic program

minimizing the expected total costs of plant operation, installations, and pollution allowances. [The authors] use the model to forecast optimal sequential investment decisions of a power plant operator with and without uncertainty about future CO_2 allowance prices. The comparison of the two cases demonstrates that uncertainty on future CO_2 emissions regulations might cause significant economic costs and higher air emissions." **Dalia Patiño-Echeverri, Paul Fischbeck, and Elmar Kriegler**, *Environmental Science & Technology*, Available online January 12, 2009, doi: 10.1021/es800094h, http://pubs.acs.org/doi/pdf/10.1021/es800094h. (Subscription may be required.)

May 2009

***U.S. Environmental Protection Agency News Release*, "EPA Finds Greenhouse Gases Pose Threat to Public Health, Welfare / Proposed Finding Comes in Response to 2007 Supreme Court Ruling."** Following a thorough scientific review ordered in 2007 by the U.S. Supreme Court, EPA issued a proposed finding on April 17, 2009, that GHGs contribute to air pollution that may endanger public health or welfare. The proposed finding identifies six GHGs that may pose a threat – CO_2, CH_4, NO_X, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). In addition, the finding states that the concentrations of these GHGs are at unprecedented levels in the atmosphere due to human emissions and that the EPA believes they serve as the likely cause of increased average temperatures. The analysis also reveals that climate change could present national security implications. The proposed endangerment finding, which does not include any proposed regulations, will now enter a public comment period. For more information about the proposed finding, visit: http://www.epa.gov/climatechange/endangerment.html. (**See the Recent Publications section in this newsletter to view a portion of the Summary and a link to EPA's "Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act."**) April 17, 2009, http://yosemite.epa.gov/opa/admpress.nsf/0/0EF7DF675805295D8525759B00566924.

***Financial Times*, "Berlin Agrees Carbon Capture Rules."** German ministers have agreed on draft legislation that creates a regulatory and technical framework for trial CCS projects and provides utilities with planning and investment guidelines and environmental and public safety rules. The draft legislation covers the separation, transportation, and underground storage of CO_2 and states that German-based utilities will not be allowed to transfer responsibility for their CO_2 repositories to the state until 30 years after the plant that produced the gas has closed. Officials said the first CCS trials will be reviewed in 2015 and a decision will be made on whether to revise the environment standards. Three pilot-scale CCS projects are currently underway in Germany, including the world's first operating CCS power plant owned by Vattenfall. April 1, 2009, http://www.ft.com/cms/s/0/e44194ee-1ee4-11de-a748-00144feabdc0.html?nclick_check=1. (Subscription required.)

"Regulating Geologic Sequestration in the United States: Early Rules Take Divergent Approaches." The following is the Abstract of this article: "Regulations for geological sequestration (GS) of CO_2 have been adopted in the state of Washington and proposed by the state of Kansas and the EPA UIC Program. These three sets of rules take significantly different approaches to regulating GS of CO_2. This paper compares these rules, focusing on elements where their differences highlight the choices that must be made to create a regulatory framework for GS in the United States. Consensus is emerging in some areas, but there is still substantial disagreement regarding the allowable composition of the CO_2 stream, the size of the area of review, reservoir performance goals, and management of risks other than those to groundwater. Gaps include issues related to ownership of subsurface pore space, [GHG] accounting, and long-term stewardship. The divergent approaches of these rules raise two overarching questions: (1) Should policymakers create GS regulations by modifying and supplementing UIC rules or through new enabling legislation? (2) What should be the relative roles of state and federal governments in GS regulation? [The authors] outline trade-offs between the consistency and coordination that federal involvement could offer and the reality that states need to be heavily involved with implementation of GS regulations. [The authors] conclude that federal involvement above and beyond the proposed EPA Class VI rules is needed to create effective GS regulation in the United States." **Melisa F. Pollak and**

Elizabeth J, **Wilson**, *Environmental Science and Technology*, Available online March 30, 2009, doi:10.1021/es803094f, http://pubs.acs.org/doi/abs/10.1021/es803094f. (Subscription may be required.)

"Global learning on carbon capture and storage: A call for strong international cooperation on CCS demonstration." The following is the Abstract of this article: "CCS rhetoric and technical progress is critically important to global climate mitigation efforts. Developing strong international cooperation on CCS demonstration with global coordination, transparency, cost-sharing and communication as guiding principles would facilitate efficient and cost-effective collaborative global learning on CCS, would allow for improved understanding of the global capacity and applicability of CCS, and would strengthen global trust, awareness and public confidence in the technology." **Heleen de Coninck, Jennie C. Stephens, and Bert Metz**, *Energy Policy*, Available online March 12, 2009, doi:10.1016/j.enpol.2009.01.020, http://www.sciencedirect.com/science/article/B6V2W-4VTK5RT-1/2/2503c41caf0d85100136da818a9b0d3e. (Subscription may be required.)

June 2009

***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 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.)

July 2009

***Natural Resources Canada News Release*, "Harper Government Launches $1-Billion Clean Energy Fund, Invests in New Technology, Creates Jobs,"** and ***Reuters*, "Canada Details Fund for Carbon Capture, Clean Energy."** On June 19, 2009, the Canadian Government announced the launch of an $885 million Clean Energy Fund that will be used to develop and advance clean energy technologies. According to officials, the majority of the fund will be used to support the development of large-scale CCS demonstration projects. The remaining funds will be used to research clean energy technologies, as well as pay for small-scale renewable and alternative energy projects. Investment in the Clean Energy Fund will also support Canada's work with the United States in building a cleaner energy economy for North America through the Canada-United States Clean Energy Dialogue. The Clean Energy Fund is part of the Government of Canada's Economic Action Plan (2009), which includes nearly $2.1 billion for the support of a cleaner and more sustainable environment. May 19, 2009, http://www.nrcan-rncan.gc.ca/media/newcom/2009/200943-eng.php, May 19, 2009, http://www.reuters.com/article/GCA-GreenBusiness/idUSTRE54I5K420090520.

"The consequences of failure should be considered in siting geologic carbon sequestration projects." The following is the Abstract of this article: "Geologic carbon sequestration is the injection of anthropogenic CO_2 into deep geologic formations where the CO_2 is intended to remain indefinitely. If successfully implemented, geologic carbon sequestration will have little or no impact on terrestrial ecosystems aside from the mitigation of climate change. However, failure of a geologic carbon sequestration site, such as large-scale leakage of CO_2 into a potable groundwater aquifer, could cause impacts that would require costly remediation measures. Governments are attempting to develop regulations for permitting geologic carbon sequestration sites to ensure their safety and effectiveness. At present, these regulations focus largely on decreasing the probability of failure. In this paper [the authors] propose that regulations for the siting of early geologic carbon sequestration projects should emphasize limiting the consequences of failure because consequences are easier to quantify than failure probability." **Phillip N. Price and Curtis M. Oldenburg**, *International Journal of Greenhouse Gas Control*, Available online May 21, 2009, doi:10.1016/j.ijggc.2009.03.002, http://www.sciencedirect.com/science/article/B83WP-4WBH5HS-1/2/48f43bac03adcee48d45e2cfbf2eeeab. (Subscription may be required.)

August 2009

***UK Department of Energy and Climate Change*, "Clean Coal to Support Up to 60,000 UK Jobs,"** and ***UK Department of Energy and Climate Change*, "Clean Coal Funding Bill Announced."** The United Kingdom (UK) proposed a new energy bill for the upcoming Parliamentary session as part of an effort to advance clean coal technologies. The bill would enable the Secretary of State for Energy and Climate Change to fund up to four commercial-scale CCS demonstration plants; the first of these could be in operation by the middle of the next decade. The bill follows the publication of a consultation document, titled, "A Framework for the Development of Clean Coal," (available at: http://www.decc.gov.uk/Media/viewfile.ashx?FilePath=Consultations\A framework for the development of clean coal\1_20090617164456_e_@@_cleancoalcondoc2.pdf&filetype=4) on June 17, 2009, which lays the foundation for how the UK Government proposes integrating emissions reducing technologies into future coal-fired power plants. Specifically, the proposals under consultation in the document include: providing funding for up to four commercial-scale CCS demonstrations; requiring new coal-fired power plants to demonstrate CCS; and requiring new coal-fired power plants to retrofit CCS within five years of CCS being independently judged technically and economically proven. The consultation also contains proposals for the design of the financial support mechanism introduced in the bill. June 29, 2009,

http://www.decc.gov.uk/en/content/cms/news/pn068/pn068.aspx, and June 17, 2009, http://www.decc.gov.uk/en/content/cms/news/pn061/pn061.aspx.

"A survey on the public perception of CCS in France." The following is the Abstract of this article: "An awareness and opinion survey on CCS was conducted on a representative sample of French residents aged 15 years and above. About [six percent] of respondents were able to provide a satisfactory definition of the technology. The key question about 'approval of or opposition to' the use of CCS in France was asked twice, first after presenting the technology, then after explaining its potential adverse consequences. The approval rates, which were 59 [percent] and 38 [percent], respectively, show that there is no a priori rejection of the technology. The sample was split in two to test for a semantic effect: half of the questionnaires used 'stockage' (English: storage), the other half 'Sequestration.' Manipulating the vocabulary had no statistically significant effect on approval rates. Stockage is more meaningful, but does not convey the idea of permanent monitoring." **Minh Ha-Duong, Alain Nadaï, and Ana Sofía Campos,** *International Journal of Greenhouse Gas Control*, Available online June 23, 2009, doi:10.1016/j.ijggc.2009.05.003, http://www.sciencedirect.com/science/article/B83WP-4WKJ5MD-3/2/bc6a8c7e9e404ca4ea4498a5ca1e1037. (Subscription may be required.)

Geology

September 2008

"Comparison of adsorption models in reservoir simulation of enhanced coalbed methane recovery and CO_2 sequestration in coal." The following is the abstract of this article: "Coalbed methane is an important resource of energy. Meanwhile CO_2 sequestration in coal is a potential management option for greenhouse gas emissions. An attractive aspect to this process is that CO_2 is adsorbed to the coal, reducing the risk of CO_2 migration to the surface. Another aspect to this is that the injected CO_2 could displace adsorbed methane leading to enhanced coalbed methane recovery. Therefore, in order to understand gas migration within the reservoir, mixed-gas adsorption models are required. Moreover, coal reservoir permeability will be significantly affected by adsorption-induced coal swelling during CO_2 injection. Coal swelling is directly related to reservoir pressure and gas content which is calculated by adsorption models in reservoir simulation. Various models have been studied to describe the pure- and mixed-gas adsorption on coal. Nevertheless, only the Langmuir and Extended Langmuir models are usually applied in coal reservoir simulations. This paper presents simulation work using several approaches to representing gas adsorption, implemented into the coal seam gas reservoir simulator SIMED II. The adsorption models are the Extended Langmuir model (ELM), the Ideal Adsorbed Solution (IAS) model and the Two-Dimensional Equation of State (2-D EOS). The simulations based on one Australian and one American coal sample demonstrated that (1) the Ideal Adsorbed Solution model, in conjunction with Langmuir model as single-component isotherm, shows similar simulation results as the ELM for both coals, with the IAS model representing the experimental adsorption data more accurately than the ELM for one coal and identically with the ELM for the other coal; (2) simulation results using the 2-D EOS, however, are significantly different to the ELM or IAS model for both coal samples. The magnitude of the difference is also dependent on coal swelling and the well operating conditions, such as injection pressure." **Zhejun Pan and Luke D. Connella**, *International Journal of Greenhouse Gas Control*, Available online July 11, 2008, doi:10.1016/j.ijggc.2008.05.004, http://www.sciencedirect.com/science/article/B83WP-4SYKM4C-1/1/78c694dce5925cb10b8b8afede7ab848. (Subscription may be required.)

October 2008

"Shrinkage and Swelling of Coal Induced by Desorption and Sorption Of Fluids: Theoretical Model and Interpretation of a Field Project." The following is the abstract of this article: "Geologic

sequestration in deep unmineable coal seams and enhanced coalbed methane [ECBM] production is a promising choice, economically and environmentally, to reduce anthropogenic gases such as CO_2 in the atmosphere. Unmineable coal seams are typically known to adsorb large amounts of CO_2 in comparison to the sizeable amounts of sorbed CH_4, which raises the potential for large scale sequestration projects. During the process of sequestration, CO_2 is injected into the coalbed and desorbed CH_4 is produced. The coal matrix is believed to shrink when a gas is desorbed and swell when a gas is sorbed, sometimes causing profound changes in the cleat porosity and permeability of the coal seam. These changes may have significant impact on the reservoir performance. Therefore, it is necessary to understand the combined influence of swelling and shrinkage, and geomechanical properties including elastic modulus, cleat porosity, and permeability of the reservoir. The present paper deals with the influence of swelling and shrinkage on the reservoir performance, and the geomechanical response of the reservoir system during the process of geologic sequestration of CO_2 and ECBM production in an actual field project located in northern New Mexico. A 3-D swelling and shrinkage model was developed and implemented into an existing reservoir model to understand the influence of geomechanical parameters, as well as swelling and shrinkage properties, on the reservoir performance. Numerical results obtained from the modified simulator were compared to available measured values from that site and previous studies. Results show that swelling and shrinkage, and the combination of geomechanical and operational parameters, have a significant influence on the performance of the reservoir system." **Hema J. Siriwardane, Raj K. Gondle, and Duane H. Smith**, *International Journal of Coal Geology*, Available online August 16, 2008, doi:10.1016/j.coal.2008.08.005, http://www.sciencedirect.com/science/article/B6V8C-4T77G1W-1/2/1c1ce97c960863b9f726dd4b87655dfb. (Subscription may be required.)

"Long-term variations of CO_2 trapped in different mechanisms in deep saline formations: A case study of the Songliao Basin, China." The following is the abstract of this article: "The geological storage of CO_2 in deep saline formations is increasingly seen as a viable strategy to reduce the release of GHGs to the atmosphere. There are numerous sedimentary basins in China, in which a number of suitable CO_2 geologic reservoirs are potentially available. To identify the multi-phase processes, geochemical changes and mineral alteration, and CO_2 trapping mechanisms after CO_2 injection, reactive geochemical transport simulations using a simple 2-D model were performed. Mineralogical composition and water chemistry from a deep saline formation of Songliao Basin were used. Results indicate that different storage forms of CO_2 vary with time. In the CO_2 injection period, a large amount of CO_2 remains as a free supercritical phase (gas trapping), and the amount dissolved in the formation water (solubility trapping) gradually increases. Later, gas trapping decrease, solubility trapping increases significantly due to the migration and diffusion of CO_2 plume and the convective mixing between CO_2-saturated water and unsaturated water, and the amount trapped by carbonate minerals increases gradually with time. The residual CO_2 gas keeps dissolving into groundwater and precipitating carbonate minerals. For the Songliao Basin sandstone, variations in the reaction rate and abundance of chlorite, and plagioclase composition affect significantly the estimates of mineral alteration and CO_2 storage in different trapping mechanisms. The effect of vertical permeability and residual gas saturation on the overall storage is smaller compared to the geochemical factors. However, they can affect the spatial distribution of the injected CO_2 in the formations. The CO_2 mineral trapping capacity could be in the order of 10 kg/m^3 medium for the Songliao Basin sandstone, and may be higher depending on the composition of primary aluminosilicate minerals especially the content of [calcium (Ca), magnesium (Mg), and iron (Fe)]." **Wei Zhang, Yilian Li, Tianfu Xu, Huilin Cheng, Yan Zheng, and Peng Xiong**, *International Journal of Greenhouse Gas Control*, Available online September 4, 2008, doi:10.1016/j.ijggc.2008.07.007, http://www.sciencedirect.com/science/article/B83WP-4TC8J70-1/2/ff21d85bfa76edf5046ee0db7088520d. (Subscription may be required.)

November 2008

"Gravity Currents with Residual Trapping." The following is the abstract of this article: "Motivated by geological CO_2 storage, [the authors] present a vertical-equilibrium sharp-interface model for the

migration of immiscible gravity currents with constant residual trapping in a two-dimensional confined aquifer. The residual acts as a loss term that reduces the current volume continuously. In the limit of a horizontal aquifer, the interface shape is self-similar at early and at late times. The spreading of the current and the decay of its volume are governed by power-laws. At early times the exponent of the scaling law is independent of the residual, but at late times it decreases with increasing loss. Owing to the self-similar nature of the current the volume does not become zero, and the current continues to spread. In the hyperbolic limit, the leading edge of the current is given by a rarefaction and the trailing edge by a shock. In the presence of residual trapping, the current volume is reduced to zero in finite time. Expressions for the up-dip migration distance and the final migration time are obtained. Comparison with numerical results shows that the hyperbolic limit is a good approximation for currents with large mobility ratios even far from the hyperbolic limit. In gently sloping aquifers, the current evolution is divided into an initial near-parabolic stage, with power-law decrease of volume, and a later near-hyperbolic stage, characterized by a rapid decay of the plume volume. [The authors'] results suggest that the efficient residual trapping in dipping aquifers may allow CO_2 storage in aquifers lacking structural closure, if CO_2 is injected far enough from the outcrop of the aquifer." **M. A. Hesse, F. M. Orr Jr., and H. A. Tchelepi**, *Journal of Fluid Mechanics*, Available online August 26, 2008, doi:10.1017/S002211200800219X, http://pangea.stanford.edu/~mhesse/papers/TrappingJFM.pdf. (Subscription may be required.)

"Large-scale impact of CO_2 storage in deep saline aquifers: A sensitivity study on pressure response in stratified systems." The following is the abstract of this article: "Large volumes of CO_2 captured from carbon emitters (such as coal-fired power plants) may be stored in deep saline aquifers as a means of mitigating climate change. Storing these additional fluids may cause pressure changes and displacement of native brines, affecting subsurface volumes that can be significantly larger than the CO_2 plume itself. This study aimed at determining the three-dimensional region of influence during/after injection of CO_2 and evaluating the possible implications for shallow groundwater resources, with particular focus on the effects of interlayer communication through low-permeability seals. To address these issues quantitatively, [the authors] conducted numerical simulations that provide a basic understanding of the large-scale flow and pressure conditions in response to industrial-scale CO_2 injection into a laterally open saline aquifer. The model domain included an idealized multilayered groundwater system, with a sequence of aquifers and aquitards (sealing units) extending from the deep saline storage formation to the uppermost freshwater aquifer. Both the local CO_2-brine flow around the single injection site and the single-phase water flow (with salinity changes) in the region away from the CO_2 plume were simulated. [The authors'] simulation results indicate considerable pressure buildup in the storage formation more than 100 km away from the injection zone, whereas the lateral distance migration of brine is rather small. In the vertical direction, the pressure perturbation from CO_2 storage may reach shallow groundwater resources only if the deep storage formation communicates with the shallow aquifers through sealing units of relatively high permeabilities (higher than 10^{-18} m^2). Vertical brine migration through a sequence of layers into shallow groundwater bodies is extremely unlikely. Overall, large-scale pressure changes appear to be of more concern to groundwater resources than changes in water quality caused by the migration of displaced saline water." **Jens T. Birkholzer, Quanlin Zhou, and Chin-Fu Tsang**, *International Journal of Greenhouse Gas Control*, Available online October 8, 2008, doi:10.1016/j.ijggc.2008.08.002, http://www.sciencedirect.com/science/article/B83WP-4TMHM10-1/2/838188a7dcb1a98bf8cd9edb74ae8c5c. (Subscription may be required.)

December 2008

"Coupled Flow and Geomechanical Processes during Enhanced Coal Seam Methane Recovery through CO_2 Sequestration." The following is the abstract of this article: "The sensitivity of coal permeability to the effective stress means that changes in stress as well as pore pressure within a coal seam lead to changes in permeability. In addition coal swells with gas adsorption and shrinks with desorption; these sorption strains impact on the coal stress state and thus the permeability. Therefore the consideration of gas migration in coal requires an appreciation of the coupled geomechanical behavior. A number of approaches to representing coal permeability incorporate the geomechanical

response and have found widespread use in reservoir simulation. However these approaches are based on two simplifying assumptions; uniaxial strain (i.e. zero strain in the horizontal plane) and constant vertical stress. This paper investigates the accuracy of these assumptions for reservoir simulation of enhanced coalbed methane through CO_2 sequestration. A coupled simulation approach is used where the coalbed methane simulator SIMED II is coupled with the geomechanical model FLAC3D. This model is applied to three simulation case studies assembled from information presented in the literature. Two of these are for 100 [percent] CO_2 injection, while the final example is where a flue gas (12.5 [percent] CO_2 and 87.5 [percent] N_2) is injected. It was found that the horizontal contrast in sorption strain within the coal seam caused by spatial differences in the total gas content leads to vertical stress variation. Thus the permeability calculated from the coupled simulation and that using an existing coal permeability model, the ShiDurucan model, are significantly different; for the region in the vicinity of the production well the coupled permeability is greater than the ShiDurucan model. In the vicinity of the injection well the permeability is less than that calculated using the ShiDurucan model. This response is a function of the magnitude of the strain contrast within the seam and dissipates as these contrasts diminish." **L.D. Connell**, *International Journal of Coal Geology*, Available online October 13, 2008, doi:10.1016/j.coal.2008.09.013, http://www.sciencedirect.com/science/article/B6V8C-4TNKH0M-1/2/9f62281ef0f61fa02341354924ecbd46. (Subscription may be required.)

"CO_2 Injection in Geological Formations: Determining Macroscale Coefficients from Pore Scale Processes." The following is the abstract of this article: "CO_2 injections in geological formations are usually performed for enhanced hydrocarbon recovery in oil and gas reservoirs and storage and sequestration in saline aquifers. Once CO_2 is injected into the formation, it propagates in the porous rock by dispersion and convection. Chemical reactions between brine ions and CO_2 molecules and consequent reactions with mineral grains are also important processes. The dynamics of CO_2 molecules in random porous media are modeled with a set of differential equations corresponding to pore scale and continuum macroscale. On the pore scale, convective-dispersive equation is solved considering reactions on the inner boundaries in a unit cell. A unit cell is the smallest portion of a porous media that can reproduce the porous media by repetition. Inner boundaries in a unit cell are the surfaces of the mineral grains. Dispersion process at the pore scale is transformed into continuum macroscale by adopting periodic boundary conditions for contiguous unit cells and applying Taylor-Aris dispersion theory known as macrotransport theory. Using this theory, the discrete porous system changes into a continuum system within which the propagation and interaction of CO_2 molecules with fluid and solid matrix of the porous media are characterized by three position-independent macroscopic coefficients: the mean velocity vector, dispersivity dyadic, and mean volumetric CO_2 depletion coefficient." **F. Javadpour**, *Transport in Porous Media*, Available online October 4, 2008, doi: 10.1007/s11242-008-9289-6, http://www.springerlink.com/content/m927615304048728/?p=cfef5a9335004d63b2ebebab4c8e6145&pi=11. (Subscription required.)

January 2009

"Integrated modeling and experimental approach for caprock integrity, risk analysis, and long term safety assessment." The following is the abstract of this article: "A global safety assessment of geological storage of CO_2 involves looking both at the direct protection of the populations with respect to health and sanitary risks, and at the mitigation of CO_2 with respect to global warming. A set of safety criteria can be defined in order to assess the impact on human and environment of CO_2 leaking from the reservoir. These criteria have to take into account the fact that CO_2 can either take the form of gas and cause a threat in case of inhalation or affect the global climate; or it can be dissolved in the water and cause a direct threat to health measurable according to drinking water criteria ([potential hydrogen (pH)], dissolved elements). The nature and amount of potential leakage are calculated by modeling the evolution of the reservoir-caprock system which has to include the most important physico chemical phenomena and which can be organized according to (1) a reference case scenario for the performance assessment, and (2) to different scenarios in altered conditions for the safety assessment. In this

exercise, exhaustiveness is often not possible because of the complexity of the system, the coupling between the different phenomena, or the lack of value for some parameters. Dedicated experiments are needed to determine the most critical parameters but simplifying hypotheses may still be required. In this case, they have to be justified in terms of their conservative character, especially with respect to uncertainties and heterogeneities. Such an approach is illustrated by looking at a crucial element of the performance of CO_2 storage: the integrity of the caprock overlying the reservoir. The safety function of the caprock is to oppose the migration of CO_2 by stopping, limiting, or delaying the fluxes towards the geosphere, relying on adequate petrophysical, geochemical, and geomechanical properties. Even if the caprock initially presents the expected confinement properties of a continuous barrier, it may also contain natural heterogeneity to some degree (in composition and/or in properties, i.e. the presence of fractures) and will also evolve in time due to perturbations such as mechanical stress and aggressive fluids. The different leakage scenarios that are identified result from a phenomenological analysis of the situations encountered in the evolution of the global system. They involve the diffusion of dissolved CO_2, the migration of a CO_2 gas bubble through the matrix of the caprock or through fractures. A first series of calculations is shown which intends to assess the flux of CO_2 out of the storage system in the nominal, or reference situation. These results are then compared with calculations in degraded conditions including data from geochemical experiments in order to investigate the effect of the CO_2 reactivity with the caprock on transport and geomechanical properties." **Olivier Bildstein, Michel Jullien, Anthony Crédoz, and Jocelyne Garnier**, Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00241%2Epdf.

"Real-Time Assessment of CO_2 Migration Direction during Geologic Storage." The following is the abstract of this article: "Minimizing the cost of large-scale geologic storage of CO_2 is a paramount concern, and consequently many aquifer storage projects may be implemented without a detailed characterization of the target formation. On the other hand, CO_2 migration beyond the volume designed for effective trapping is a paramount risk. Thus, inexpensive methods of monitoring the plume movement will be valuable for operators and regulators alike. Unanticipated heterogeneities within the target formation, whether high-permeability channels or low permeability barriers, are one of the most likely causes of migration beyond the design volume. [The authors] propose that routine measurements of injection rate and injection pressure in each well can be used to infer the existence of heterogeneities large enough to affect the plume path. [The authors] do not seek from these measurements a detailed spatial distribution of permeability in the formation, but merely an indication of features that affect the overall migration path. The advantage of this approach is that these measurements will be acquired routinely, frequently and cheaply in all projects, whereas methods yielding higher resolution (time-lapse seismic surveys, electromagnetic surveys, cross-well seismic, monitoring wells, etc.) are specialized and expensive. [The authors] have implemented this idea by combining (i) previously developed research software (Pro-HMS) which carries out geologically consistent parameter estimation from injection and production data and (ii) a commercial compositional simulator (GEM from CMG) as a forward model which has been tuned to the full physics and phase behavior of the CO_2/brine/rock system. In this paper [the authors] test the approach on model aquifers that exhibit permeability heterogeneity prescribed by a spatial correlation model. The permeability estimation process is performed within a fully probabilistic framework. [The authors] include the noise typical of pressure/rate data from real wells and find that signal of large heterogeneities can still be discerned." **Cesar A. Matilla, YagnaDeepika Oruganti, Steven L. Bryant, and Sanjay Srinivasan,** Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00465%2Epdf.

February 2009

"Impact of Injected CO_2 on Reservoir Mineralogy During CO_2-EOR." The following is the abstract of this article: "An investigation of the impact of injected CO_2 on reservoir mineralogy was completed as part of the geochemical monitoring and modeling of the Pembina Cardium CO_2 Monitoring Project southwest of Drayton Valley, Alberta, Canada. Oil production at the pilot is primarily from the upper two of three stacked sandstone units of the Cardium Formation in the Pembina field. Core analyzed included samples from each of the three sandstone units, and encompassed three distinct time periods: pre-water flood (1955), pre-CO_2 flood (2005), and post-CO_2 flood (2007). The results of whole rock analysis (XRF, ICP, and XRD), and microscopy (polarizing and electron microprobe) suggest the three separate sandstone units are both texturally and compositionally similar regardless of when the core was recovered. Framework grains are predominately sub-angular to sub-rounded quartz/chert (up to 90.0 wt%), and include smaller amounts of lithic fragments (shale), feldspar (k-feldspar, and albite), mica (muscovite and chlorite), and fluor-apatite. Authigenic pyrite is found as finely disseminated rhombs throughout the formation. Clay minerals present are predominantly kaolinite and illite. Kaolinite appears as fine discrete pore filling books, and is considered to be authigenic. Illite occurs as a major constituent of shale fragments, as well as fine pore bridging strands. The sandstone's irregular pores are cemented to varying degrees by silica and/or carbonate minerals (calcite and siderite). Dissolution features associated with formation diagenesis, including the degradation of detrital grains (quartz and feldspar), the partial and/or complete removal of carbonate cements, and the presence of residual clays, are found in core from each of the three time periods. Attributing dissolution features in post-CO_2 flood core to the interaction of minerals and carbonic acid is difficult due to the geologic history of the formation." **M. Nightingale, G. Johnson, M. Shevalier, I. Hutcheon, E. Perkins, and B. Mayer**, Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington, DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00696%2Epdf.

"Geological Factors Affecting CO_2 Plume Distribution." The following is the abstract of this article: "Understanding the lateral extent of a CO_2 plume has important implications with regards to buying/leasing pore volume rights, defining the area of review for an injection permit, determining the extent of an [monitoring, verification, and accounting (MVA)] plan, and managing basin-scale sequestration from multiple injection sites. The vertical and lateral distribution of CO_2 has implications with regards to estimating CO_2 storage volume at a specific site and the pore pressure below the caprock. Geologic and flow characteristics such as effective permeability and porosity, capillary pressure, lateral and vertical permeability anisotropy, geologic structure, and thickness all influence and affect the plume distribution to varying degrees. Depending on the variations in these parameters one may dominate the shape and size of the plume. Additionally, these parameters do not necessarily act independently. A comparison of viscous and gravity forces will determine the degree of vertical and lateral flow. However, this is dependent on formation thickness. For example in a thick zone with injection near the base, the CO_2 moves radially from the well but will slow at greater radii and vertical movement will dominate. Generally the CO_2 plume will not appreciably move laterally until the caprock or a relatively low permeability interval is contacted by the CO_2. Conversely, in a relatively thin zone with the injection interval over nearly the entire zone, near the wellbore the CO_2 will be distributed over the entire vertical component and will move laterally much further with minimal vertical movement. Assuming no geologic structure, injecting into a thin zone or into a thick zone immediately under a caprock will result in a larger plume size. With a geologic structure such as an anticline, CO_2 plume size may be restricted and injection immediately below the caprock may have less lateral plume growth because the structure will induce downward vertical movement of the CO_2 until the outer edge of the plume reaches a spill point within the structure." **Scott M. Frailey and Hannes Leetaru**, Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington, DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00673%2Epdf.

March 2009

"The hydromagnesite playas of Atlin, British Columbia, Canada: A biogeochemical model for CO_2 sequestration." The following is the abstract of this article: "Anthropogenic [GHG] emissions may be offset by sequestering CO_2 through the carbonation of magnesium silicate minerals to form magnesium carbonate minerals. The hydromagnesite [$Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$] playas of Atlin, British Columbia, Canada provide a natural model to examine mineral carbonation on a watershed scale. At near surface conditions, CO_2 is biogeochemically sequestered by microorganisms that are involved in weathering of bedrock and precipitation of carbonate minerals. The purpose of this study was to characterize the weathering regime in a groundwater recharge zone and the depositional environments in the playas in the context of a biogeochemical model for CO_2 sequestration with emphasis on microbial processes that accelerate mineral carbonation. Regions with ultramafic bedrock, such as Atlin, represent the best potential sources of feedstocks for mineral carbonation. Elemental compositions of a soil profile show significant depletion of MgO and enrichment of SiO_2 in comparison to underlying ultramafic parent material. Polished serpentinite cubes were placed in the organic horizon of a coniferous forest soil in a groundwater recharge zone for three years. Upon retrieval, the cube surfaces, as seen using scanning electron microscopy, had been colonized by bacteria that were associated with surface pitting. Degradation of organic matter in the soil produced chelating agents and acids that contributed to the chemical weathering of the serpentinite and would be expected to have a similar effect on the magnesium-rich bedrock at Atlin. Stable carbon isotopes of groundwater from a well, situated near a wetland in the southeastern playa, indicate that ~12 percent of the dissolved inorganic carbon has a modern origin from soil CO_2. The mineralogy and isotope geochemistry of the hydromagnesite playas suggest that there are three distinct depositional environments: (1) the wetland, characterized by biologically-aided precipitation of carbonate minerals from waters concentrated by evaporation, (2) isolated wetland sections that lead to the formation of consolidated aragonite sediments, and (3) the emerged grassland environment where evaporation produces mounds of hydromagnesite. Examination of sediments within the southeastern playa-wetland suggests that cyanobacteria, sulphate reducing bacteria, and diatoms aid in producing favorable geochemical conditions for precipitation of carbonate minerals. The Atlin site, as a biogeochemical model, has implications for creating carbon sinks that utilize passive microbial, geochemical and physical processes that aid in mineral carbonation of magnesium silicates. These processes could be exploited for the purposes of CO_2 sequestration by creating conditions similar to those of the Atlin site in environments, artificial or natural, where the precipitation of magnesium carbonates would be suitable. Given the vast quantities of Mg-rich bedrock that exist throughout the world, this study has significant implications for reducing atmospheric CO_2 concentrations and combating global climate change." **Ian M. Power, Siobhan A. Wilson, James M. Thom, Gregory M. Dipple, Janet E. Gabites, and Gordon Southam**, *Chemical Geology*, Available online January 24, 2009, doi:10.1016/j.chemgeo.2009.01.012, http://www.sciencedirect.com/science/article/B6V5Y-4VFK7YX-3/2/82a3d4a55a01e47ba6845982a9aceb2d. (Subscription may be required.)

"Water-rock-CO_2 interactions in saline aquifers aimed for carbon dioxide storage: experimental and numerical modeling studies of the Rio Bonito Formation (Permian), southern Brazil." The following is the abstract of this article: "Mineral trapping is one of the safest ways to store CO_2 underground as [carbon] will be immobilized in a solid phase. Carbon dioxide will be, therefore, sequestered for geological periods of time, helping to diminish greenhouse gas emissions and mitigate global warming. Although mineral trapping is considered a fairly long process, owing to the existence of kinetic barriers for mineral precipitation, it has been demonstrated both experimentally and by numerical modeling. Here the results of experimental and numerical modeling studies performed in sandstones of the saline aquifer of the Rio Bonito Formation, Paraná Basin, are presented. The Rio Bonito Formation consists of paralic sandstones deposited in the intracratonic Paraná Basin, southern Brazil, during the Permian (Artinskian-Kungurian). These rocks have the largest potential for CO_2 storage because of their appropriated reservoir quality, depth and proximity to the most important stationary CO_2 sources in Brazil. Here it is suggested that CO_2 can be permanently stored as carbonates as CO_2 reacts with rocks of the Rio Bonito Formation and forms [calcium carbonate ($CaCO_3$)] at temperatures and pressures similar to those encountered for CO_2 storage in geological formations. Results of this work will be useful for studies of partitioning mechanisms for [carbon] trapping in CO_2 storage programs." **J.M. Ketzer, R.**

Iglesias, S. Einloft, J. Dullius, R. Ligabue, and V. de Lima, *Applied Geochemistry*, Available online January 14, 2009, doi:10.1016/j.apgeochem.2009.01.001, http://www.sciencedirect.com/science/article/B6VDG-4VCH6VV-1/2/086dca8c49236e594d034f96d9ab0742. (Subscription may be required.)

April 2009

"Potential environmental issues of CO_2 storage in deep saline aquifers: Geochemical results from the Frio-I Brine Pilot test, Texas, USA." The following is from the Abstract of this article: "Sedimentary basins in general, and deep saline aquifers in particular, are being investigated as possible repositories for large volumes of anthropogenic CO_2 that must be sequestered to mitigate global warming and related climate changes. To investigate the potential for the long-term storage of CO_2 in such aquifers, 1600 t of CO_2 were injected at 1500 m depth into a 24-m-thick "C" sandstone unit of the Frio Formation, a regional aquifer in the U.S. Gulf Coast. Fluid samples obtained before CO_2 injection from the injection well and an observation well 30 m updip showed a Na-Ca-Cl type brine with ~93,000 mg/L TDS at saturation with [methane (CH_4)] at reservoir conditions; gas analyses showed that CH_4 comprised ~95 [percent] of dissolved gas, but CO_2 was low at 0.3 [percent]. Following CO_2 breakthrough, 51 h after injection, samples showed sharp drops in pH (6.5 to 5.7), pronounced increases in alkalinity (100 to 3000 mg/L as HCO_3) and in Fe (30 to 1100 mg/L), a slug of very high DOC values, and significant shifts in the isotopic compositions of H_2O, DIC, and CH_4. These data, coupled with geochemical modeling, indicate corrosion of pipe and well casing as well as rapid dissolution of minerals, especially calcite and iron oxyhydroxides, both caused by lowered pH (initially ~3.0 at subsurface conditions) of the brine in contact with supercritical CO_2." **Yousif K. Kharaka, James J. Thordsen, Susan D. Hovorka, H. Seay Nance, David R. Cole, Tommy J. Phelps, and Kevin G. Knauss**, *Applied Geochemistry*, Available online February 20, 2009, doi: 10.1016/j.apgeochem.2009.02.010, http://www.sciencedirect.com/science/article/B6VDG-4VNH3WD-2/2/45c11e8c8082c8f8e508e10ce103068b. (Subscription may be required.)

"Dissolution of Columbia River Basalt under mildly acidic conditions as a function of temperature: experimental results relevant to the geological sequestration of carbon dioxide." The following is the Abstract of this article: "Increasing attention is being focused on the rapid rise of CO_2 levels in the atmosphere, which many believe to be the major contributing factor to global climate change. Sequestering CO_2 in deep geological formations has been proposed as a long-term solution to help stabilize CO_2 levels. However, before such technology can be developed and implemented, a basic understanding of H_2O-CO_2 systems and the chemical interactions of these fluids with the host formation must be obtained. Important issues concerning mineral stability, reaction rates, and carbonate formation are all controlled or at least significantly impacted by the kinetics of rock-water reactions in mildly acidic, CO_2-saturated solutions. Basalt has recently been identified as a potentially important host formation for geological sequestration. Dissolution kinetics of the Columbia River Basalt (CRB) were measured for a range of temperatures (25° to 90°C) under mildly acidic to neutral pH conditions using the single-pass flow-through test method. Under anaerobic conditions, the normalized dissolution rates for CRB decrease with increasing pH ($3 \leq pH \leq 7$) with a slope, η, of -0.15 ± 0.01. Activation energy, Ea, has been estimated at 32.0 ± 2.4 kJ mol-1. Dissolution kinetics measurements like these are essential for modeling the rate at which CO_2-saturated fluids react with basalt and ultimately drive conversion rates to carbonate minerals in situ." **H. Todd Schaef and B. Peter McGrail**, *Applied Geochemistry*, Available online March 5, 2009, doi: 10.1016/j.apgeochem.2009.02.025, http://www.sciencedirect.com/science/article/B6VDG-4VS405T-1/2/b63d927b86505bfcd32ce192220e716b. (Subscription may be required.)

May 2009

"Effect of Moisture on Adsorption Isotherms and Adsorption Capacities of CO_2 on Coals." The following is the Abstract of this article: "The effect of moisture on the adsorption isotherms and adsorption capacities of CO_2 on Argonne Premium coals has been investigated. In some experiments a small hysteresis was observed between the adsorption and desorption isotherms. The hysteresis was absent or negligible for high-rank and as-received coals but was discernible for lower rank and dried coals. An equation that accounted for the volumetric changes when an adsorbate alters the structure of an adsorbent was employed to interpret the data. The best-fit solutions indicate that the coal volume decreases upon drying. The microscopic shrinkage estimated using helium expansion was greater than the shrinkage reported using the bed-height technique. The microscopic shrinkage was 5-10 [percent] for low-moisture medium and high-rank coals and up to 40 [percent] for low-rank coals having higher moisture contents. The CO_2 swelling of coals during adsorption isotherm measurements was estimated to be about the same as the shrinkage that occurred during the moisture loss. The adsorption capacity, isosteric heat of adsorption, average pore size, and surface area of the as-received (moist) and dried Argonne coals were estimated after accounting for the volume changes. The isosteric heat of adsorption of CO_2 was found to be between 23 and 25 kJ/mol for as-received coals and between 25 and 27 kJ/mol for dried coals, regardless of the rank. The degree of drying was shown to affect the adsorption capacity and the calculated surface area. For dried coals, the adsorption capacity showed the typical 'U-shape' dependence on rank whereas the as-received coals displayed a more linear dependence. A relationship is proposed to quantify the effect of moisture on the adsorption capacity. The mechanism of CO_2 adsorption on moist coals and the implications of the lower adsorption capacity of wet coals to coal seam sequestration of CO_2 are presented." **Ekrem Ozdemir and Karl Schroeder**, *Energy Fuels*, Available online April 1, 2009, doi:10.1021/ef801126a, http://pubs.acs.org/doi/abs/10.1021/ef801126a. (Subscription may be required.)

"Carbon sequestration in coal-beds with structural deformation effects." The following is the Abstract of this article: "[CO_2] sequestration in a coal-bed is a profitable method to reduce the concentration of [GHG] in the atmosphere and to recover byproduct methane from the coal seam. The important factor to be considered is the stability of the coal-bed with the increased [CO_2] injection. It is crucial to avoid [CO_2] escaping from the coal seam caused by structural deformation. Meanwhile, structural deformation also depends on such properties of the geological coal basin as fracture state and phase equilibrium, especially the porosity, permeability and saturation of the coal seam. In this study, a structural deformation effect was simulated with the purpose of predicting [CO_2] storage in the environment of a typical unmineable coal seam. As an example, Appalachian Basin is considered in the deformation analysis of [CO_2] sequestration based on the variable saturation model. Moreover, the comparison between simulations with and without the account of structural deformation is given. The results indicate that modeling of structural deformation in carbon sequestration is feasible by directly coupling structure terms to a variable saturated model. Moreover, introducing structural deformation effects into carbon sequestration modeling is important because it affects the fluid flow and leads to a faster drop of the resulting capillary pressure and relative permeability of the gas phase. This faster drop directly results in the diminished [CO_2] storage capacity in a coal bed basin. In addition, structural deformation modeling in carbon sequestration simulations can provide important insights into how to avoid carbon leakage and seepage by monitoring the effective stress and displacement of coal-bed basin during [CO_2] injection." **Guoxiang Liu and Andrei V. Smirnov**, *Energy Conversion and Management*, Available online March 27, 2009, doi: 10.1016/j.enconman.2009.02.012, http://www.sciencedirect.com/science/article/B6V2P-4VXT0NH-2/2/d94313b8143e7d3c6084884af7a70755. (Subscription may be required.)

June 2009

"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 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.)

July 2009

"Analytical solution to evaluate salt precipitation during CO_2 injection in saline aquifers." The following is the Abstract of this article: "Carbon dioxide sequestration in deep saline aquifers is a means of reducing anthropogenic atmospheric emissions of CO_2. Among various mechanisms, CO_2 can be trapped in saline aquifers by dissolution in the formation water. Vaporization of water occurs along with the dissolution of CO_2. Vaporization can cause salt precipitation, which reduces porosity and impairs permeability of the reservoir in the vicinity of the wellbore, and can lead to reduction in injectivity. The amount of salt precipitation and the region in which it occurs may be important in CO_2 storage operations if salt precipitation significantly reduces injectivity. Here [the authors] develop an analytical model, as a simple and efficient tool to predict the amount of salt precipitation over time and space. This model is particularly useful at high injection velocities, when viscous forces dominate. First, [the authors] develop a model which treats the vaporization of water and dissolution of CO_2 in radial geometry. Next, the model is used to predict salt precipitation. The combined model is then extended to evaluate the effect of salt precipitation on permeability in terms of a time-dependent skin factor. Finally, the analytical model is corroborated by application to a specific problem with an available numerical solution, where a close agreement between the solutions is observed. [The authors] use the results to examine the effect of assumptions and approximations made in the development of the analytical solution. For cases studied, salt saturation was a few percent. The loss in injectivity depends on the degree of reduction of formation permeability with increased salt saturation. For permeability-reduction models considered in this work, the loss in injectivity was not severe. However, one limitation of the model is that it neglects capillary and gravity forces, and these forces might increase salt precipitation at the bottom of formation particularly when injection rate is low." **Mehdi Zeidouni, Mehran Pooladi-Darvish, and David Keith**, *International Journal of Greenhouse Gas Control*, Available online May 22, 2009, doi:10.1016/j.ijggc.2009.04.004, http://www.sciencedirect.com/science/article/B83WP-4WBR6R2-1/2/5cde03c04b69c08a23db98a0764195fa. (Subscription may be required.)

"The Footprint of the CO_2 Plume during Carbon Dioxide Storage in Saline Aquifers: Storage Efficiency for Capillary Trapping at the Basin Scale." The following is the Abstract of this article: "[The authors studied] a sharp-interface mathematical model of CO_2 migration in deep saline aquifers, which accounts for gravity override, capillary trapping, natural groundwater flow, and the shape of the plume during the injection period. The model leads to a nonlinear advection-diffusion equation, where the diffusive term is due to buoyancy forces, not physical diffusion. For the case of interest in geological CO_2 storage, in which the mobility ratio is very unfavorable, the mathematical model can be simplified to a hyperbolic equation. [The authors] present a complete analytical solution to the hyperbolic model. The main outcome is a closed-form expression that predicts the ultimate footprint on the CO_2 plume, and the time scale required for complete trapping. The capillary trapping coefficient and the mobility ratio between CO_2 and brine emerge as the key parameters in the assessment of CO_2 storage in saline aquifers. Despite the many approximations, the model captures the essence of the flow dynamics and therefore reflects proper dependencies on the mobility ratio and the capillary trapping coefficient, which are basin-specific. The expressions derived here have applicability to capacity estimates by capillary

trapping at the basin scale." **Ruben Juanes, Christopher W. MacMinn, and Michael L. Szulczewski**, *Transport in Porous Media*, Available online June 9, 2009, doi:10.1007/s11242-009-9420-3, http://www.springerlink.com/content/x572tx728pnh2t88/?p=60372d7184a94345a11c658b8be90809&pi=6. (Subscription may be required.)

August 2009

"Optimizing geologic CO_2 sequestration by injection in deep saline formations below oil reservoirs." The following is the Abstract of this article: "The purpose of this research is to present a best-case paradigm for geologic CO_2 storage: CO_2 injection and sequestration in saline formations below oil reservoirs. This includes the saline-only section below the oil-water contact (OWC) in oil reservoirs, a storage target neglected in many current storage capacity assessments. This also includes saline aquifers (high porosity and permeability formations) immediately below oil-bearing formations. While this is a very specific injection target, [the authors] contend that most, if not all, oil-bearing basins in the [United States] contain a great volume of such strata, and represent a rather large CO_2 storage capacity option. [The authors] hypothesize that these are the best storage targets in those basins. The purpose of this research is to evaluate this hypothesis. [The authors] quantitatively compared CO_2 behavior in oil reservoirs and brine formations by examining the thermophysical properties of CO_2, CO_2-brine, and CO_2-oil in various pressure, temperature, and salinity conditions. In addition, [the authors] compared the distribution of gravity number (*N*), which characterizes a tendency towards buoyancy-driven CO_2 migration, and mobility ratio (*M*), which characterizes the impeded CO_2 migration, in oil reservoirs and brine formations. [The authors] research suggests competing advantages and disadvantages of CO_2 injection in oil reservoirs vs. brine formations: (1) CO_2 solubility in oil is significantly greater than in brine (over 30 times); (2) the tendency of buoyancy-driven CO_2 migration is smaller in oil reservoirs because density contrast between oil and CO_2 is smaller than it between brine and oil (the approximate density contrast between CO_2 and crude oil is ~100 kg/m^3 and between CO_2 and brine is ~350 kg/m^3); (3) the increased density of oil and brine due to the CO_2 dissolution is not significant (about 7–15 kg/m^3); (4) the viscosity reduction of oil due to CO_2 dissolution is significant (from 5790 to 98 mPa s). [The authors] compared these competing properties and processes by performing numerical simulations. Results suggest that deep saline CO_2 injection immediately below oil formations reduces buoyancy-driven CO_2 migration and, at the same time, minimizes the amount of mobile CO_2 compared to conventional deep saline CO_2 injection (i.e., CO_2 injection into brine formations not below oil-bearing strata). Finally, to investigate practical aspects and field applications of this injection paradigm, [the authors] characterized oil-bearing formations and their thickness (capacity) as a component of the Southwest Regional Partnership on Carbon Sequestration (SWP) field deployments. The field-testing program includes specific sites in Utah, New Mexico, Wyoming, and western Texas of the United States." **Weon Shik Han and Brian J. McPherson**, *Energy Conversion and Management*, Available online July 12, 2009, http://dx.doi.org/10.1016/j.enconman.2009.06.008, http://www.sciencedirect.com/science/article/B6V2P-4WRKF58-3/2/b40c9bdede3002b3ec95edd7e93fdb45. (Subscription may be required.)

"Oil Recovery and Sequestration Potential of Naturally Fractured Reservoirs During CO_2 Injection." The following is the Abstract of this article: "With urgent need of [GHG] sequestration and booming oil prices, underground oil/gas reservoirs seem the only value-added choice. A great portion of current CO_2 injection projects in the world is in naturally fractured reservoirs. The matrix part of these reservoirs constitutes the major oil storage unit and this oil is targeted during CO_2 injection. It is [the authors'] intention to show that this media could also be used as permanent CO_2 storage unit while recovering oil from it. These reservoirs, however, are complex in nature and the physics of the matrix−fracture interaction process during CO_2 injection is still not known to a great extent. To ease the complex nature of the problems, experiments were performed on fractured sandstone cores (single fracture) saturated with n-decane and carbonate cores saturated with dead crude oil. CO_2 was injected at constant rates into the fracture while maintaining the high pressure into the core and the system. Injection and production data were monitored and collected using continuous data logging system. After

continuous injection, diffusion of CO_2 was allowed to occur by shutting down the system for a specific period of time and followed by a blowdown period to recover oil that diffused from matrix to fracture. At different pressure steps, produced liquid was analyzed using gas chromatography while the produced gas was measured using a flow meter. The CO_2 storage capacity of the rock with change in the pressure and the amount of oil recovered during blow down period were analyzed. The results of the continuous injection experiments were used to obtain diffusion coefficients by matching the simulation results. Using dimensionless analysis and matrix−fracture diffusion groups, [the authors] obtained a critical number for optimal recovery/sequestration. The pressure decay behavior during the shutdown was analyzed in conjunction with the gas chromatograph analysis of produced oil sample collected during blowdown after the quasiequilibrium reached during pressure decay. This led to insights into the governing mechanism of extraction/condensation and miscibility for recovering lighter to heavier hydrocarbons during pressure depletion from fractured reservoirs." **J. J. Trivedi and T. Babadagli,** *Energy Fuels*, Available online July 8, 2009, DOI:10.1021/ef900361n, http://pubs.acs.org/doi/abs/10.1021/ef900361n. (Subscription may be required.)

"Coal energy conversion with carbon sequestration via combustion in supercritical saline aquifer water." The following is the Abstract of this article: "The standard idea for deep saline aquifer sequestration is to separate [CO_2] from a process stream, compress it, and inject it underground. However, since [CO_2] is less dense than water, even at the high pressures found in aquifers, it is buoyant and will move towards the surface unless trapped by an impermeable seal. Also, significant energy expenditure is required to separate and compress [CO_2], even though neat [CO_2] is not a desired product. These issues may be addressed by combining the idea of fast dissolution at the surface with supercritical water oxidation (SCWO). By burning coal at high pressure in supercritical water drawn from an aquifer, and then sequestering the entire pre-equilibrated effluent, all carbon from the fuel is captured, as well as all non-mineral coal combustion products including sulfur and metals. A possible block diagram of an SCWO-based electric power plant is proposed, including processes to handle salts from the aquifer brine and minerals from coal. The plant is thermodynamically modeled, using an indirectly fired combined cycle to convert energy from hot combustion products to work. This model estimates the overall thermal efficiency that can be achieved, and reveals unanticipated interactions within the plant that have significant effects on efficiency. The assumptions and results of the model highlight design challenges for an actual system." **J.R. Heberle and C.F. Edwards**, *International Journal of Greenhouse Gas Control*, Available online June 23, 2009,

Technology

September 2008

"Biofilm enhanced geologic sequestration of supercritical CO_2." In order to develop subsurface CO_2 storage as a viable engineered mechanism to reduce the emission of CO_2 into the atmosphere, any potential leakage of injected supercritical CO_2 (SC-CO_2) from the deep subsurface to the atmosphere must be reduced. Here, [the authors] investigate the utility of biofilms, which are microorganism assemblages firmly attached to a surface, as a means of reducing the permeability of deep subsurface porous geological matrices under high pressure and in the presence of SC-CO_2, using a unique high pressure (8.9 [millipascals]), moderate temperature (32 [degrees Celsius]) flow reactor containing 40 millidarcy Berea sandstone cores. The flow reactor containing the sandstone core was inoculated with the biofilm forming organism *Shewanella fridgidimarina*. Electron microscopy of the rock core revealed substantial biofilm growth and accumulation under high-pressure conditions in the rock pore space which caused >95 [percent] reduction in core permeability. Permeability increased only slightly in response to SC-CO_2 challenges of up to 71 [hours (h)] and starvation for up to 363 h in length. Viable population assays of microorganisms in the effluent indicated survival of the cells following SC-CO_2 challenges and starvation, although *S. fridgidimarina* was succeeded by *Bacillus mojavensis* and *Citrobacter* sp. which were native in the core. These observations suggest that engineered biofilm barriers may be used to

enhance the geologic sequestration of atmospheric CO_2. **Andrew C. Mitchella, Adrienne J. Phillips, Randy Hiebert, Robin Gerlach, Lee H. Spangler and Alfred B. Cunningham**, *International Journal of Greenhouse Gas Control*, Available online July 18, 2008, doi:10.1016/j.ijggc.2008.05.002, http://www.sciencedirect.com/science/article/B83WP-4T13JHJ-1/1/ad165c642805a7faf9bb7ce1c95f4c44. (Subscription may be required.)

"Life cycle assessment of a pulverized coal power plant with post-combustion capture, transport and storage of CO_2." In this study the methodology of life cycle assessment has been used to assess the environmental impacts of three pulverized coal-fired electricity supply chains with and without carbon capture and storage (CCS) on a cradle to grave basis. The chain with CCS comprises post-combustion CO_2 capture with monoethanolamine, compression, and transport by pipeline and storage in a geological reservoir. The two reference chains represent sub-critical and state-of-the-art ultra supercritical pulverized coal fired electricity generation. For the three chains [the authors] have constructed a detailed greenhouse gas (GHG) balance, and disclosed environmental trade-offs and co-benefits due to CO_2 capture, transport, and storage. Results show that, due to CCS, the GHG emissions per kilowatt (kWh) are reduced substantially to 243 [gram (g)]/kWh. This is a reduction of 78 and 71 [percent] compared to the sub-critical and state-of-the-art power plant, respectively. The removal of CO_2 is partially offset by increased GHG emissions in up- and downstream processes, to a small extent (0.7 g/kWh) caused by the CCS infrastructure. An environmental co-benefit is expected following from the deeper reduction of hydrogen fluoride and hydrogen chloride emissions. Most notable environmental trade-offs are the increase in human toxicity, ozone layer depletion and fresh water ecotoxicity potential for which the CCS chain is outperformed by both other chains. The state-of-the-art power plant without CCS also shows a better score for the eutrophication, acidification, and photochemical oxidation potential despite the deeper reduction of SO_x and NO_x in the CCS power plant. These reductions are offset by increased emissions in the life cycle due to the energy penalty and a factor five increase in [ammonia (NH_3)] emissions. **Joris Koornneef, Tim van Keulen, André Faaij and Wim Turkenburg**, *International Journal of Greenhouse Gas Control*, Available online July 23, 2008, doi:10.1016/j.ijggc.2008.06.008, http://www.sciencedirect.com/science/article/B83WP-4T24FXP-2/1/366b12c51cc4b5824ab80be4e7e141c2. (Subscription may be required.)

"Evaluating cubic equations of state for calculation of vapor–liquid equilibrium of CO_2 and CO_2-mixtures for CO_2 capture and storage processes." Proper solution of vapor liquid equilibrium (VLE) is essential to the design and operation of CO_2 capture and storage system (CCS). According to the requirements of engineering applications, cubic equations of state (EOS) are preferable to predict VLE properties. This paper evaluates the reliabilities of five cubic EOSs, including [Peng-Robinson (PR), Patel-Teja (PT), Redlich-Kwong (RK), Soave-Redlich-Kwong (SRK) and 3P1T] for predicting VLE of CO_2 and binary CO_2-mixtures containing [methane (CH_4), hydrogen sulfide (H_2S), sulfur dioxide (SO_2), argon (Ar), nitrogen (N_2) or oxygen (O_2)], based on the comparisons with the collected experimental data. Results show that SRK is superior in the calculations about the saturated pressure of pure CO_2; while for the VLE properties of binary CO_2-mixtures, PR, PT and SRK are generally superior to RK and 3P1T. The impacts of binary interaction parameter k_{ij} were also analyzed. k_{ij} has clear effects on the calculating accuracy of an EOS in the property calculations of CO_2-mixtures. In order to improve the calculation accuracy, the binary interaction parameter was calibrated for all of the studied EOSs regarding every binary CO_2-mixture. **H. Li and J. Yan**, *Applied Energy*, Available online July 24, 2008**,** doi:10.1016/j.apenergy.2008.05.018, http://www.sciencedirect.com/science/article/B6V1T-4T29WNV-1/1/192bceb4888df25879f5cf767418b3a0. (Subscription may be required.)

October 2008

"Life cycle assessment of carbon dioxide capture and storage from lignite power plants." The following is the abstract of this article: "In this article, [the authors] present a life cycle assessment (LCA) of CCS for several lignite power plant technologies. The LCA includes post-combustion, pre-combustion and oxyfuel capture processes as well as subsequent pipeline transport and storage of the separated

CO_2 in a depleted gas field. The results show an increase in cumulative energy demand and a substantial decrease in GHG emissions for all CO_2 capture approaches in comparison with power plants without CCS, assuming negligible leakage within the time horizon under consideration. Leakage will, however, not be zero. Due to the energy penalty, CCS leads to additional production of CO_2. However, the CO_2 emissions occur at a much lower rate and are significantly delayed, thus leading to different, and most likely smaller, impacts compared to the no-sequestration case. In addition, a certain share of the CO_2 will be captured permanently due to chemical reactions and physical trapping. For other environmental impact categories, the results depend strongly on the chosen technology and the details of the process. The post-combustion approach, which is closest to commercial application, leads to sharp increases in many categories of impacts, with the impacts in only one category, acidification, reduced. In comparison with a conventional power plant, the pre-combustion approach results in decreased impact in all categories. This is mainly due to the different power generation process (IGCC) which is coupled with the pre-combustion technology. In the case of the oxyfuel approach, the outcome of the LCA depends highly on two uncertain parameters: the energy demand for air separation and the feasibility of co-capture of pollutants other than CO_2. If co-capture were possible, oxyfuel could lead to a near-zero emission power plant." **Martin Pehnta and Johannes Henke**, *International Journal of Greenhouse Gas Control*, Available online August 15, 2008, doi:10.1016/j.ijggc.2008.07.001, http://www.sciencedirect.com/science/article/B83WP-4T72K6K-1/2/98dc4f678050645d3752da6a8f069507. (Subscription may be required.)

November 2008

"Electrolysis and heat pretreatment methods to promote CO_2 sequestration by mineral carbonation." The following is the abstract of this article: "As a new mineral carbonation process for CO_2 sequestration, electrolysis of NaCl solution and serpentine as the source of Mg^{2+} to adsorb CO_2 in the simulating flue gas is introduced, which used the electrolyze NaCl solution to produce the HCl solution and NaOH solution. The HCl solution was used to dissolve Mg^{2+} from serpentine, and the NaOH solution was used to adsorb CO_2 in simulation smoke, then these two solutions were mixed to form $MgCO_3$ deposition at 358 K, which could be processed at relative low temperature and pressure. In order to further increase the solubility of Mg^{2+} from serpentine, the heat pretreatment of serpentine under nitrogen was investigated. The results indicated that the heat activation dramatically enhanced serpentine carbonation. [X-ray diffraction (XRD), thermogravimetric analysis (TGA), Fourier transform infrared (FT-IR), and inductively coupled plasma atomic emission spectroscopy (ICP-AES)] analyses indicated that the best activation temperature was 650°C, at which the crystalline features were changed from lizardite to amorphous followed the decomposition of hydroxyl groups. The dissolved capacity decreased with further increasing heat activation temperature, which might be related to the formation of a new crystalline feature. The XRD and TGA analyses showed that the solid product was mainly pure basic magnesium carbonate." **Wenzhi Li, Wen Li, Baoqing Li, and Zongqing Bai**, *Chemical Engineering Research and Design*, Available online September 17, 2008, doi:10.1016/j.cherd.2008.08.001, http://www.sciencedirect.com/science/article/B8JGF-4TG2963-1/2/69596194c91bb0af07c65d068807958c. (Subscription may be required.)

"Modeling of Coal Bed Methane (CBM) Production and CO_2 Sequestration in Coal Seams." The following is the abstract of this article: "A mathematical model was developed to predict the coalbed methane (CBM) production and CO_2 sequestration in a coal seam accounting for the coal seam properties. The model predictions showed that, for a CBM production and dewatering process, the pressure could be reduced from 15.17 MPa to 1.56 MPa and the gas saturation increased up to 50 [percent] in 30 years for a $5.4x10^5$ m^2 of coal formation. For the CO_2 sequestration process, the model prediction showed that the CO_2 injection rate was first reduced and then slightly recovered over [three] to 13 years of injection, which was also evidenced by the actual in seam data. The model predictions indicated that the sweeping of the water in front of the CO_2 flood in the cleat porosity could be important on the loss of injectivity. Further model predictions suggested that the injection rate of CO_2 could be about $11x10^3$ m^3 per day; the injected CO_2 would reach the production well, which was separated from

the injection well by 826 m, in about 30 years. During this period, about $160x10^6$ m^3 of CO_2 could be stored within a $21.4x10^5$ m^2 of coal seam with a thickness of 3 meters." **Ekrem Ozdemir**, *International Journal of Coal Geology*, Available online September 16, 2008, doi:10.1016/j.coal.2008.09.003, http://www.sciencedirect.com/science/article/B6V8C-4TFW960-2/2/dc8fa31f2b545cc74f82f3f8c5afb720. (Subscription may be required.)

December 2008

"Application of crosswell seismic tomography using difference analysis with data normalization to monitor CO_2 flooding in an aquifer." The following is the abstract of this article: "A pilot-scale experiment for CO_2 sequestration was undertaken at the Nagaoka test field in Japan. Time-lapse crosswell seismic tomography was conducted to detect and monitor the movement of CO_2 injected into an aquifer. [The authors] applied difference analysis with data normalization (DADN) to the time-lapse data to eliminate false images that were apparent in a conventionally processed difference section. Conventional difference analysis calculates travel-time delays after inversion, whereas the DADN method calculates them from raw travel-time records before inversion. Thus, fewer errors are generated with the DADN method compared to a conventional inversion analysis. [The authors] applied the DADN method to time-lapse tomography data recorded before and after the injection of CO_2 and computed the velocity variation in a subsurface section, which clearly showed the distribution of CO_2 flooding within a high permeability zone in the aquifer and showed no CO_2 leakage into the caprock. Our results also show the maximum velocity decrease as a result of CO_2 injection was about 9 [percent], which is close to the results obtained in laboratory experiments. Finally, numerical simulations were inverted to test the effectiveness of the conventional and DADN methods in dealing with noise. These tests showed that the DADN method effectively reduces unique coherent noise for particular receiver and source combinations. [The authors] concluded that the DADN method provides useful data for monitoring the flow of CO_2 sequestered in underground aquifers." **Kyosuke Onishi, Tetsuyuki Ueyama, Toshifumi Matsuoka, Dai Nobuoka, Hideki Saito, Hiroyuki Azuma and Ziqiu Xue**, *International Journal of Greenhouse Gas Control*, Available online October 9, 2008, doi:10.1016/j.ijggc.2008.08.003, http://www.sciencedirect.com/science/article/B83WP-4TMRK76-2/2/536f901e050d3fb89315c099f863e394. (Subscription may be required.)

"Numerical Modeling of Pressure and Temperature Profiles Including Phase Transitions in Carbon Dioxide Wells." The following is the abstract of this article: "Geological storage of CO_2 will usually be at condition above the critical temperature and pressure, so the CO_2 will exist as a single dense phase. However, conditions in the upper part of the CO_2 well with surface temperatures below the critical point of 31 degrees Celsius can lead to boiling and condensation in the well. The consequences of this are most apparent when flow rate changes, for example when a well is hut-in or if there is a well blowout. [The authors] have calculated density profiles for wells experiencing different thermal conditions to determine how bottom-hole pressures are related to wellhead pressures. There are two limiting cases, one when the fluid is in thermal equilibrium with the rock at the same horizon, there other when there is no heat exchange with the casing or the rock. [The authors] find that in deeper will static columns can exist in a stable state with liquid to the surface, but for shallower wells or wells in depleted reservoirs that a static column can be initially unstable with two-phase conditions near the surface. In producing wells, as the flow rate increases from static conditions, the pressure and temperature at the wellhead increases until high production rates are reached when the wellhead temperature then decreases, which can be to very low values. For injection wells, bottom-hole conditions are confined between the wellhead and the reservoir temperature. In general, phase change does not prevent CO_2 injection. Nevertheless care is needed in shallower or depleted reservoirs for the interpretation of reservoir pressure, the use of pressure for monitoring, and in all reservoirs for the management of blowouts." **L. Paterson, M. Lu, L. Connell, and J. Ennis-King**, *In: Proceedings of the 2008 SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA, September 21-24, 2008*, Available online September 21, 2008, https://extra.co2crc.com.au/modules/pts2/download.php?file_id=2624&rec_id=1058.

January 2009

"Comparing Existing Pipeline Networks with the Potential Scale of Future U.S. CO_2 Pipeline Networks." The following is the abstract of this article: "Interest is growing regarding the potential size of a future U.S.-dedicated CO_2 pipeline infrastructure if CCS technologies are commercially deployed on a large scale within the United States. This paper assesses the potential scale of the CO_2 pipeline system needed under two hypothetical climate policies (WRE450 and WRE550 stabilization scenarios); a comparison is then made to the extant U.S. pipeline infrastructures used to deliver CO_2 for enhanced oil recovery and to move natural gas and liquid hydrocarbons from areas of production and importation to markets. The analysis reveals that between 11,000 and 23,000 additional miles of dedicated CO_2 pipeline might be needed in the United States before 2050 across these two cases. While either case represents a significant increase over the 3900 miles that comprise the existing national CO_2 pipeline infrastructure, it is important to realize that the demand for additional CO_2 pipeline capacity will unfold relatively slowly and in a geographically dispersed manner as new dedicated CCS-enabled power plants and industrial facilities are brought online. During the period 2010-2030, this analysis indicates growth in the CO_2 pipeline system on the order of a few hundred to less than 1000 miles per year. By comparison, during the period 1950-2000, the U.S. natural gas pipeline distribution system grew at rates that far exceed these growth projections for a future CO_2 pipeline network in the United States. This analysis indicates that the need to increase the size of the existing dedicated CO_2 pipeline system should not be seen as a major obstacle for the commercial deployment of CCS technologies in the United States. While there could be issues associated with siting specific segments of a larger national CO_2 pipeline infrastructure, the sheer scale of the required infrastructure should not be seen as representing a significant impediment to U.S. deployment of CCS technologies." **JJ Dooley, RT Dahowski, and CL Davidson**, Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=\\serenity\EP11%24\Eventwin\Pool\office27\docs\pdf\ghgt_9Final00612.pdf.

"Validation of CO_2 Injection Simulations with Monitoring Well Data." The following is the abstract of this article: "The multiphase flow and solute transport simulator STOMP has been used to assess potential CO_2 injection rates into saline formations at several sites for the Midwest Regional Carbon Sequestration Partnership (MRCSP). An injection test of approximately 10,000 metric tons into the Bass Islands Dolomite with CO_2 injection rates from 250-500 tons per day, was performed in the test well at the MRCSP geologic field test site in Otsego County, Michigan, U.S.A. Reservoir simulations were performed to estimate injection parameters, such as bottom hole pressures and pressure response over time in the storage formation, and compared to measurements taken during the test." **Diana H. Bacon, Joel R. Sminchak, Jacqueline L. Gerst, and Neeraj Gupta**, Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5CGHGT%5F9pdfdocument00402%2Epdf.

February 2009

"Mitigation planning for large-scale storage projects: multiple injection zones and reservoir pressure reduction engineering design." The following is the abstract of this article: "Effective mitigation plans are an absolutely critical component of mitigation plans for commercial-scale geologic carbon sequestration. One fundamental component of mitigation engineering design is immediate reduction of reservoir pressure. The Southwest Regional Partnership on Carbon Sequestration (SWP) is employing immediate reservoir pressure reduction as a primary mitigation tool in our geologic sequestration field projects. [The authors] are also employing multiple injection zones at the SWP deep saline injection site, both to maximize capacity and optimize mitigation plans. [The authors] developed models for each of our test sites to forecast optimum density and placement of injection and observation

wells. Likewise, [the authors] designate certain observation wells as 'observation-pressure reduction,' or 'OPR' wells. These are wells that serve as observation wells, but are engineered for quick conversion to production (pumping) wells to facilitate immediate pressure reduction, if needed. Results of our reservoir models suggest that immediate pressure reduction may stem geomechanical deformation, stem and/or close crack/fracture growths, shut down 'piston-flow' displacement of brines into unintended reservoirs, slow leakage through wellbores, slow leakage of CO_2 through faults, and even induce closure of faults. Much like the injection wells, the distribution of such OPR wells is critical. For example, in ongoing Partnership field-testing, observation wells are being drilled that will serve as OPR wells, and [the authors] are using reservoir models to identify well locations that optimize both monitoring and mitigation potential. Reservoir model results also suggest that OPR wells can be converted to injection wells to maximize capacity and control reservoir pressure. For example, as one portion of the reservoir 'fills' or if pressure control becomes problematic, the injection well can be converted to OPR mode, and the next well in the series (whether linear or in a grid design) can become an injection well. Simulation results suggest that if pressure reduction wells are used to 'make space' for CO_2 by removing brine ahead of the CO_2 front, this pumping will also increase residual gas trapping by promoting horizontal migration. Additional results of our reservoir models suggest several caveats and potential problematic processes: (1) rapid reduction of reservoir pressure decreases CO_2 density, potentially leading to accelerated buoyancy effects, (2) premature CO_2 breakthrough may occur in pressure reduction wells, (3) pressure reduction decreases solubility of CO_2 in the formation water, potentially leading to exsolution and undesired phase changes, and (4) finally, a detailed cost analysis must accompany such an engineering approach, because reservoir pressures directly affect compression and injection costs, e.g., it is possible that pressure reduction wells may reduce or increase net costs of injection, depending on costs associated with water production and handling at the pressure reduction wells. [The authors] will show results of this sequestration field engineering approach for specific field tests, including ongoing geologic sequestration field-testing in several U.S. sites, including projects in Utah, New Mexico, and Texas." **Brian J. McPherson, Weon Shik Han, Si-Yong Lee, Chuan Lu, and Richard P. Esser**, Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington, DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00905%2Epdf.

"A coupled reservoir-geomechanical simulation study of CO_2 storage in a nearly depleted natural gas reservoir." The following is the abstract of this article: "Atzbach-Schwanenstadt natural gas field located in Upper Austria Molasse Foreland basin was one of the four European sites selected for subsurface CO_2 storage feasibility/performance evaluation in the recently completed EU-funded research project CASTOR. The objectives of the coupled reservoir-geomechanical modeling effort at Atzbach-Schwanenstadt gas field were: 1) evaluation of the hydro-mechanical response of the reservoir rock and overburden formations to historical and current gas production rates, different CO_2 injection scenarios and its long-term storage; and 2) assessment of the potential for shear failure and/or re-activation of pre-existing faults as a result of changes in the reservoir pressure due to natural gas production and CO_2 injection. The simulation results in terms of changes in the reservoir stresses and associated reservoir compaction/uplifting are presented and their likely impact on reservoir integrity discussed. The widely used Mohr-Coulomb shear failure analysis was carried out for the gas reservoir undergoing reservoir pressure depletion and then re-pressurization due to CO_2 injection, in particular under the regional strike-slip fault stress regime relevant to the gas field. An equation was derived to estimate the maximum sustainable pore pressure under different horizontal/vertical stress ratios and rock strength properties, with reference to the stress path hysteresis during reservoir re-pressurization." **Ji-Quan Shi and Sevket Durucan**, Presented at GHGT-9, held November 16-20, 2008, at the Omni Shoreham Hotel in Washington, DC, United States, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270005&file=%5C%5Cserenity%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%5F9Final00100%2Epdf.

March 2009

"CO_2 Sequestration Through Enhanced Oil Recovery In A Mature Oil Field." The following is the abstract of this article: "Recent advances in [enhanced oil recovery (EOR)] technology create new opportunities for CO_2 sequestration. This paper proposes a technical-economic model for underground storage of CO_2 emitted by a fertilizer industry in the Northeast of Brazil, in a hypothetical mature oil reservoir through EOR operation. Simulations based on mass, energy and entropy balances, as well as economic analysis, were assessed for the process of CO_2 Sequestration combined with EOR. This model takes into account the energy requirements for the whole CO_2 sequestration process, as well as the emissions inherent to the process. Additionally, a breakdown cost methodology is proposed to estimate the main financial determinants of the integrated EOR with CO_2 sequestration (costs of CO_2 purchase, compression, transportation and storage). Project evaluation is derived from a cash flow model, regarding reservoir production profile, price and costs, capital expenditures (CAPEX), operating expenditures (OPEX), carbon credits, depreciation time, fiscal assumptions etc. A sensitivity analysis study is carried out to identify the most critical variables. Project feasibility, as expected, is found to be very sensitive to oil price, oil production, and CAPEX. Moreover, there is the contribution from the mitigation of the GHG by storing a significant amount of CO_2 in the reservoir where it can remain for thousands of years." **A.T.F.S. Gaspar Ravagnani, E.L. Ligero, and S.B. Suslick,** *Journal of Petroleum Science and Engineering***,** Available January 10, 2009, doi:10.1016/j.petrol.2008.12.015, http://www.sciencedirect.com/science/article/B6VDW-4VBMNGN-1/2/9f1ad8ee9341c9ce0e31933d7a4c6e73. (Subscription may be required.)

"Modeling vertical stratification of CO_2 injected into a deep layered aquifer." The following is the abstract of this article: "The vertical stratification of CO_2 injected into a deep layered aquifer made up of high-permeability and low-permeability layers, such as Utsira aquifer at Sleipner site in Norway, is investigated with a Buckley-Leverett equation including gravity effects. In a first step, [the authors] study both by theory and simulation the application of this equation to the vertical migration of a light phase (CO_2), in a denser phase (water), in 1-D vertical columns filled with different types of porous media: homogeneous, piecewise homogeneous, layered periodic and finally heterogeneous. For each case, [the authors] solve the associated Riemann problems and propose semi-analytical solutions describing the spatial and temporal evolution of the light phase saturation. These solutions agree well with simulation results. [The authors] show that the flux continuity condition at interfaces between high-permeability and low-permeability layers leads to CO_2 saturation discontinuities at these interfaces and, in particular, to a saturation increase beneath low-permeability layers. In a second step, [the authors] analyze the vertical migration of a CO_2 plume injected into a 2-D layered aquifer. [The authors] show that the CO_2 vertical stratification under each low-permeability layer is induced, as in 1-D columns, by the flux continuity condition at interfaces. As the injection takes place at the bottom of the aquifer the velocity and the flux function decrease with elevation and this phenomenon is proposed to explain the stratification under each mudstone layer as observed at Sleipner site." **Mohamed Hayek, Emmanuel Mouche, and Claude Mügler**, *Advances in Water Resources***,** Available online January 14, 2009, doi:10.1016/j.advwatres.2008.12.009, http://www.sciencedirect.com/science/article/B6VCF-4VCH71J-1/2/b9d3a371370d84fcb8ca77dac756b8f4. (Subscription may be required.)

April 2009

"Design and off-design analyses of a pre-combustion CO_2 capture process in a natural gas combined cycle power plant." The following is the Abstract of this article: "In this study, a cycle designed for capturing the [GHG] CO_2 in a natural gas combined cycle power plant has been analyzed. The process is a pre-combustion CO_2 capture cycle utilizing reforming of natural gas and removal of the carbon in the fuel prior to combustion in the gas turbine. The power cycle consists of a H_2-fired gas turbine and a triple pressure steam cycle. Nitrogen is used as fuel diluent and steam is injected into the flame for additional [nitrogen oxide (NO_X)] control. The heat recovery steam generator includes pre-heating for the various process streams. The pre-combustion cycle consists of an air-blown auto-thermal reformer, water-gas shift reactors, an amine absorption system to separate out the CO_2, as well as a

CO_2 compression block. Included in the thermodynamic analysis are design calculations, as well as steady-state off-design calculations. Even though the aim is to operate a plant, as the one in this study, at full load there is also a need to be able to operate at part load, meaning off-design analysis is important. A reference case which excludes the pre-combustion cycle and only consists of the power cycle without CO_2 capture was analyzed at both design and off-design conditions for comparison. A high degree of process integration is present in the cycle studied. This can be advantageous from an efficiency stand-point but the complexity of the plant increases. The part load calculations is one way of investigating how flexible the plant is to off-design conditions. In the analysis performed, part load behavior is rather good with efficiency reductions from base load operation comparable to the reference combined cycle plant." **Lars Olof Nord, Rahul Anantharaman, and Olav Bolland**, *International Journal of Greenhouse Gas Control*, Available online March 17, 2009, doi: 10.1016/j.ijggc.2009.02.001, http://www.sciencedirect.com/science/article/B83WP-4VVN50Y-1/2/2657cfd3e9a9d13ad57291da6c6dad0c. (Subscription may be required.)

May 2009

"Progress and New Developments in Carbon Capture and Storage." The following is from the Abstract of this article: "Growing concern over the impact on global climate change of the buildup of GHGs in the atmosphere has resulted in proposals to capture CO_2 at large point sources and store it in geologic formations, such as oil and gas reservoirs, unmineable coal seams, and saline formations, referred to as CCS. There are three options for capturing CO_2 from point sources: post-combustion capture, pre-combustion capture, and oxy-combustion. Several processes are available to capture CO_2, and new or improved processes are under development. However, CO_2 capture is the most expensive part of CCS, typically accounting for 75 [percent] of overall cost. CCS will benefit significantly from the development of a lower cost post-combustion CO_2 capture process that can be retrofitted to existing power plants. Once captured, the CO_2 is compressed to about 150 atm and pipelined at supercritical conditions to a suitable storage site. Oil and gas reservoirs, because they have assured seals and are well characterized, are promising early opportunity sites. Saline formations are much more extensive and have a huge potential storage capacity, but are much less characterized. Several commercial and a number of pilot CCS projects are underway around the world. Information from these projects will form the basis for the development of CCS as a climate change mitigation strategy. These projects are contributing to the development of suitable regulations, determining best operating practices, improving mathematical models, and providing information to the public and other stakeholders. Based on current knowledge, CCS appears to be a promising option for reducing GHG emissions." **S.I. Plasynski, J.T. Litynski, H.G. McIlvried, R.D. Srivastava**, *Critical Reviews in Plant Sciences*, Available online May 1, 2009, doi: 10.1080/07352680902776440, http://www.informaworld.com/10.1080/07352680902776440. (Subscription may be required.)

"Certification framework based on effective trapping for geologic carbon sequestration." The following is the Abstract of this article: "[The authors] have developed a certification framework (CF) for certifying the safety and effectiveness of geologic carbon sequestration (GCS) sites. Safety and effectiveness are achieved if CO_2 and displaced brine have no significant impact on humans, other living things, resources, or the environment. In the CF, [the authors] relate effective trapping to CO_2 leakage risk which takes into account both the impact and probability of leakage. [The authors] achieve simplicity in the CF by using (1) wells and faults as the potential leakage pathways, (2) compartments to represent environmental resources that may be impacted by leakage, (3) CO_2 fluxes and concentrations in the compartments as proxies for impact to vulnerable entities, (4) broad ranges of storage formation properties to generate a catalog of simulated plume movements, and (5) probabilities of intersection of the CO_2 plume with the conduits and compartments. [The authors] demonstrate the approach on a hypothetical GCS site in a Texas Gulf Coast saline formation. Through its generality and flexibility, the CF can contribute to the assessment of risk of CO_2 and brine leakage as part of the certification process for licensing and permitting of GCS sites around the world regardless of the specific regulations in place in any given country." **Curtis M. Oldenburg, Steven L. Bryant, and Jean-Philippe Nicot**. *International*

Journal of Greenhouse Gas Control, Available online April 3, 2009, doi: 10.1016/j.ijggc.2009.02.009, http://www.sciencedirect.com/science/article/B83WP-4W09GSM-1/2/34f13d55c513ef08db0fcdfaeebad114. (Subscription may be required.)

June 2009

"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.)

July 2009

"Numerical investigation concerning the impact of CO_2 geologic storage on regional groundwater flow." The following is the Abstract of this article: "Large-scale storage of [CO_2] in saline aquifers may cause considerable pressure perturbation and brine migration in deep rock formations, which may have a significant influence on the regional groundwater system. With the help of parallel computing techniques, [the authors] conducted a comprehensive, large-scale numerical simulation of CO_2 geologic storage that predicts not only CO_2 migration, but also its impact on regional groundwater flow. As a case study, a hypothetical industrial-scale CO_2 injection in Tokyo Bay, which is surrounded by the most heavily industrialized area in Japan, was considered, and the impact of CO_2 injection on near-surface aquifers was investigated, assuming relatively high seal-layer permeability (higher than 10 microdarcy). A regional hydrogeological model with an area of about 60 km×70 km around Tokyo Bay was discretized into about 10 million gridblocks. To solve the high-resolution model efficiently, [the authors] used a parallelized multiphase flow simulator TOUGH2-MP/ECO2N on a world-class high performance supercomputer in Japan, the Earth Simulator. In this simulation, CO_2 was injected into a storage aquifer at about 1 km depth under Tokyo Bay from 10 wells, at a total rate of 10 million tons/year for 100 years. Through the model, [the authors] can examine regional groundwater pressure buildup and groundwater migration to the land surface. The results suggest that even if containment of CO_2 plume is ensured, pressure buildup on the order of a few bars can occur in the shallow confined aquifers over extensive regions, including urban inlands." **Hajime Yamamoto, Keni Zhang, Kenzi Karasaki, Atsunao Marui, Hitoshi Uehara, and Noriaki Nishikawa**, *International Journal of Greenhouse Gas Control*, Available online May

29, 2009, doi:10.1016/j.ijggc.2009.04.007, http://www.sciencedirect.com/science/article/B83WP-4WD6Y39-2/2/09ce1d619736522944aef2cf57f51309. (Subscription may be required.)

"Coal and energy security for India: Role of carbon dioxide (CO_2) capture and storage (CCS)." The following is from the Abstract of this article: "Coal is the abundant domestic energy resource in India and is projected to remain so in future under a business-as-usual scenario. Using domestic coal mitigates national energy security risks. However coal use exacerbates global climate change. Under a strict climate change regime, coal use is projected to decline in future. However this would increase imports of energy sources like natural gas (NG) and nuclear and consequent energy security risks for India. The paper shows that CCS can mitigate CO_2 emissions from coal-based large point source (LPS) clusters and therefore would play a key role in mitigating both energy security risks for India and global climate change risks. This paper estimates future CO_2 emission projections from LPS in India, identifies the potential CO_2 storage types at aggregate level and matches the two into the future using Asia-Pacific Integrated Model (AIM/Local model) with a Geographical Information System (GIS) interface. The paper argues that clustering LPS that are close to potential storage sites could provide reasonable economic opportunities for CCS in future if storage sites of different types are further explored and found to have adequate capacity. The paper also indicates possible LPS locations to utilize CCS opportunities economically in future, especially since India is projected to add over 220,000 MW of thermal power generation capacity by 2030." **Amit Garg and P.R. Shukla**, *Energy*, Available online May 2, 2009, doi: 10.1016/j.energy.2009.01.005, http://www.sciencedirect.com/science/article/B6V2S-4W6N2PS-1/2/7c4caeeccd9cf56d7527ce41de8d95c8. (Subscription may be required.)

August 2009

"Screening and selection of sites for CO_2 sequestration based on pressure buildup." The following is the Abstract of this article: "This paper presents a simple methodology for estimating pressure buildup due to the injection of supercritical CO_2 into a saline formation, and the limiting pressure at which the formation starts to fracture. Pressure buildup is calculated using the approximate solution of Mathias et al., which accounts for two-phase Forchheimer flow (of supercritical CO_2 and brine) in a compressible porous medium. Compressibility of the rock formation and both fluid phases are also accounted for. Injection pressure is assumed to be limited by the pressure required to fracture the rock formation. Fracture development is assumed to occur when pore pressures exceed the minimum principal stress, which in turn is related to the Poisson's ratio of the rock formation. Detailed guidance is also offered concerning the estimation of viscosity, density, and compressibility for the brine and CO_2. Example calculations are presented in the context of data from the Plains CO_2 Reduction (PCOR) Partnership. Such a methodology will be useful for screening analysis of potential CO_2 injection sites to identify which are worthy of further investigation." **Simon A. Mathias, Paul E. Hardisty, Mark R. Trudell, and Robert W. Zimmerman**, *International Journal of Greenhouse Gas Control*, Available online June 23, 2009, doi:10.1016/j.ijggc.2009.05.002, http://www.sciencedirect.com/science/article/B83WP-4WKJ5MD-2/2/b556fae8e190d1512aa0c9aeb46979f7. (Subscription may be required.)

Terrestrial/Ocean

September 2008

"Cover crops enhance soil organic matter, carbon dynamics and microbiological function in a vineyard agroecosystem." Impacts of soil tillage and cover crops on soil carbon dynamics and microbiological function were investigated in a vineyard grown in California's mediterranean climate. [The authors] (1) compared soil organic matter (SOM), carbon dynamics and microbiological activity of two cover crops [Trios 102 (*Triticale* × *Triosecale*) ('Trios'), Merced Rye (*Secale cereale*) ('Rye')] with cultivation ('Cultivation') and (2) evaluated seasonal effects of soil temperature, water content, and precipitation on soil carbon dynamics (0 to 15 cm depth). From treatments established in November

2001, soils were sampled every 2 to 3 weeks from November 2005 to November 2006. Gravimetric water content (GWC) reflected winter and spring rainfall. Soil temperature did not differ among treatments, reflecting typical seasonal patterns. Few differences in carbon dynamics between cover crops existed, but microbial biomass carbon (MBC), dissolved organic carbon (DOC), and carbon dioxide (CO_2) efflux in 'Trios' and 'Rye' were consistently 1.5 to 4-fold greater than 'Cultivation'. Cover crops were more effective at adding soil carbon than 'Cultivation'. Seasonal patterns in DOC, and CO_2 efflux reflected changes in soil water content, but MBC displayed no temporal response. Decreases in DOC and potential microbial respiration ($RESP_{mic}$) (i.e., microbially available carbon) also corresponded to or were preceded by increases in CO_2 efflux, suggesting that DOC provided carbon for microbial respiration. Despite similar MBC, DOC, $RESP_{mic}$, annual CO_2 efflux and aboveground carbon content between the two cover crops, greater aboveground net primary productivity and SOM in 'Trios' indicated that 'Trios' provided more soil carbon than 'Rye.' **Kerri Steenwerth and K.M. Belina**, *Applied Soil Ecology*, Available online July 26, 2008, doi:10.1016/j.apsoil.2008.06.006, http://www.sciencedirect.com/science/article/B6T4B-4T2RYSF-1/2/086cf7562cb2b80d9729555e13773daf. (Subscription may be required.)

October 2008

"Tillage and residue management effects on soil carbon and CO_2 emission in a wheat-corn double-cropping system." The following is the abstract of this article: "The mitigation of CO_2 emission into the atmosphere is important and any information on how to implement adjustments to agricultural practices and improve soil organic matter (SOM) stock would be helpful. [The authors] studied the effect of tillage and residue management on soil carbon sequestration and CO_2 emissions in loam soil cropped in a winter wheat-corn rotation in northern China. There were five treatments: mouldboard ploughing, rotary tillage and no-tillage with chopped residues (MC, RC and NC), additional no-tillage with whole residue (NW) and mouldboard ploughing without residue (CK). After [five] years of each tillage system, MC and RC had higher annual CO_2 efflux from soil. The CO_2 effluxes were correlated with the ratio of dissolved organic carbon to soil microbial biomass (DOC/MBC) among treatments. This effect may be due to less immobilization of soil carbon by microorganisms under long-time intensive tillage. Although both MBC and DOC showed seasonal variability, when averaged across the sampling period only MBC discriminated between treatments. After [five] years of tillage, all treatments except CK increased SOM (0.16-0.99 Mg [carbon] ha^{-1} $year^{-1}$) at 0-30 cm depth and NC was the greatest, resulting from historical SOM depletion and large [carbon] return from recent residues. Despite the lowest CO_2 flux being from the NW treatment, lower input residue from decreased biomass may have lowered [carbon] sequestration. To improve soil [carbon] sequestration in rotations, the input of residue and the CO_2 emission should be balanced by adopting appropriate tillage and residue management." **Wenxu Dong, Chunsheng Hu, Suying Chen, and Yuming Zhang**, *Nutrient Cycling in Agroecosystems*, Available online August 15, 2008, DOI: 10.1007/s10705-008-9195-x, http://www.springerlink.com/content/q37t8t37416423j4/?p=9a776e82ce334c30baa165f053c10d44&pi=0. (Subscription may be required.)

November 2008

"Soil organic carbon sequestration in relation to organic and inorganic fertilization in rice–wheat and maize–wheat systems." The following is the abstract of this article: "Soil organic carbon (SOC) pool is the largest among the terrestrial pools. The restoration of SOC pool in arable lands represents a potential sink for atmospheric CO_2. The management and enhancement of SOC is important for sustainable agriculture. The cropping system and soil type influence crop biomass under different fertilization. Data from two long-term field experiments on rice-wheat and maize-wheat systems in progress since 1971 were analyzed to assess the impact of fertilization practices on SOC stocks in sandy loam soils (typic ustipsament). The treatments in rice-wheat included (i) farmyard manure (FYM alone [at] 20 t ha^{-1}, applied at the time of pre-puddling tillage), (ii) $N_{120}P_{30}K_{30}$ (120 kg N, 30 kg P_2O_5 and

30 kg K_2O ha^{-1}), (iii) $N_{120}P_{30}$ (same as in (ii) except that K application was omitted), (iv) N_{120} (same as in (ii) except that P and K application was omitted) and (v) control (without any FYM or inorganic fertilizer). Similar treatments were studied in maize-wheat except that the amounts of N, P_2O_5 and K_2O were 100, 50 and 50 kg ha^{-1}, respectively. In rice-wheat system, the SOC concentration at different depths in 0–60 cm soil profile was higher (1.8–6.2 g kg^{-1}) in FYM-treated plots followed by 1.7–5.3 g kg^{-1} in NPK plots, compared to 0.9–3.0 g kg^{-1} in unfertilized plots. Balanced fertilization improved the SOC concentration. Similar trend was found in maize-wheat system. In the 60-cm soil profile the total SOC stocks in both the cropping systems were highest in FYM (31.3 and 23.3 Mg ha^{-1} in rice-wheat and maize-wheat system) followed by balanced fertilization (29.6 and 21.3 Mg ha^{-1}) and lowest in unfertilized control (21.4 and 18.7 Mg ha^{-1}). The SOC concentration in rice–wheat soils was 54 and 30 [percent] higher in FYM and NPK plots than in maize-wheat system. Improved SOC content enhances soil quality, reduces soil erosion and degradation, and increases soil. The soils under rice-wheat sequestered 55 [percent] higher SOC in FYM plots and 70 [percent] higher in NPK plots than in maize-wheat. These results document the capacity of optimally fertilized rice–wheat system to sequester higher C as compared to maize-wheat system." **S.S. Kukal, Rehana-Rasool, and D.K. Benbi**, *Soil and Tillage Research*, Available online September 6, 2008, doi:10.1016/j.still.2008.07.017, http://www.sciencedirect.com/science/article/B6TC6-4TCPN08-1/2/70af19034e27fea01361321482686148. (Subscription may be required.)

December 2008

"Carbon sequestration by forests and soils on mined land in the Midwestern and Appalachian coalfields of the U.S." The following is the abstract of this article: "Carbon accreditation of forest development projects is one approach for sequestering atmospheric CO_2, under the provisions of the Kyoto protocol. The [carbon] sequestration potential of reforested mined land is not well known. The purpose of this work was to estimate and compare the ecosystem [carbon] content in forests established on surface, coal-mined and non-mined land. [The authors] used existing tree, litter, and soil [carbon] data for [14] mined and eight adjacent, non-mined forests in the Midwestern and Appalachian coalfields to determine the [carbon] sequestration potential of mined land reclaimed prior to the passage of the Surface Mining Control and Reclamation Act (1977). [The authors] developed statistically significant and biologically reasonable models for ecosystem [carbon] across the spectrum of site quality and stand age. On average, the highest amount of ecosystem [carbon] on mined land was sequestered in pine stands (148 Mg ha^{-1}), followed by hardwood (130 Mg ha^{-1}) and mixed stands (118 Mg ha^{-1}). Non-mined hardwood stands sequestered 210 Mg [carbon] ha^{-1}, which was about 62 [percent] higher than the average of all mined stands. [The] mined land response surface models of [carbon] sequestration as a function of site quality and age explained 59, 39, and 36 [percent] of the variation of ecosystem [carbon] in mixed, pine, and hardwood stands, respectively. In pine and mixed stands, ecosystem [carbon] increased exponentially with the increase of site quality, but decreased with age. In mined hardwood stands, ecosystem [carbon] increased asymptotically with age, but it was not affected by site quality. At rotation age (60 yr), ecosystem [carbon] in mined hardwood stands was less on high quality sites, but similar for low quality sites compared to non-mined hardwood stands. The overall results indicated that the higher the original forest site quality, the less likely [carbon] sequestration potential was restored, and the greater the disparity between pre- and post-mining [carbon] sequestration stocks." **Beyhan Y. Amichev, James A. Burger, and Jason A. Rodrigue**, *Forest Ecology and Management*, Available online August 26, 2008, doi:10.1016/j.foreco.2008.07.020, http://www.sciencedirect.com/science/article/B6T6X-4T9BXHY-2/2/a55c3b6e1fecdf8258ebb8a7e7684159. (Subscription may be required.)

January 2009

"**A disconnect between O horizon and mineral soil carbon – Implications for soil C sequestration."** The following is the abstract of this article: "Changing inputs of carbon to soil is one

means of potentially increasing carbon sequestration in soils for the purpose of mitigating projected increases in atmospheric CO_2 concentrations. The effect of manipulations of aboveground carbon input on soil carbon storage was tested in a temperate, deciduous forest in east Tennessee, USA. A 4.5-year experiment included exclusion of aboveground litterfall and supplemental litter additions (three times ambient) in an upland and a valley that differed in soil nitrogen availability. The estimated decomposition rate of the carbon stock in the O horizon was greater in the valley than in the upland due to higher litter quality (i.e., lower C/N ratios). Short-term litter exclusion or addition had no effect on carbon stock in the mineral soil, measured to a depth of 30 cm, or the partitioning of carbon in the mineral soil between particulate- and mineral-associated organic matter. A two-compartment model was used to interpret results from the field experiments. Field data and a sensitivity analysis of the model were consistent with little carbon transfer between the O horizon and the mineral soil. Increasing aboveground carbon input does not appear to be an effective means of promoting carbon sequestration in forest soil at the location of the present study because a disconnect exists in carbon dynamics between O horizon and mineral soil. Factors that directly increase inputs to belowground soil carbon, via roots, or reduce decomposition rates of organic matter are more likely to benefit efforts to increase carbon sequestration in forests where carbon dynamics in the O horizon are uncoupled from the mineral soil." **Charles T. Garten Jr.**, *Acta Oecologica*, Available online November 22, 2008, doi:10.1016/j.actao.2008.10.004, http://www.sciencedirect.com/science/article/B6VR3-4V053MR-1/2/af2f1faf56d069ae6aa89ef4050aab78. (Subscription may be required.)

February 2009

"The effect of reduced tillage agriculture on carbon dynamics in silt loam soils." The following is the abstract of this article: "Reduced tillage (RT) agriculture is an effective measure to reduce soil loss from soils susceptible to erosion in the short-term and is claimed to increase the soil organic carbon (SOC) stock. The change in distribution and total SOC stock in the 0-60 cm layer, the stratification of microbial biomass carbon (MB-C) content in the 0-40 cm layer and the carbon mineralization in the upper 0-5 cm layer in silt loam soils in Western Europe with different periods of RT agriculture were evaluated. Ten fields at seven locations, representing the important RT types and maintained for a different number of years, and eight fields under conventional tillage (CT) agriculture with similar soil type and crop rotation were selected. RT agriculture resulted in a higher stratification of SOC in the soil profile than CT agriculture. However, the total SOC stock in the 0-60 cm layer was not changed, even after 20 years [of] RT agriculture. The MB-C was significantly higher in the 0-10 cm layer under RT agriculture, even after only [five] years, compared to CT agriculture. The higher SOC and MB-C content in the upper 0-5 cm layer of RT fields resulted in a higher carbon mineralization rate in undisturbed soil in the laboratory. Simulating ploughing by disturbing the soil resulted in inconsistent changes (both lower and higher) of carbon mineralization rates. A crop rotation with root crops, with heavy soil disturbance every two or three years at harvest, possibly limited the anticipated positive effect of RT agriculture in our research." **Karoline D'Haene, Steven Sleutel, Stefaan De Neve, Donald Gabriels, and Georges Hofman**, *Earth and Environmental Science*, Available online December 30, 2008, doi:10.1007/s10705-008-9240-9, http://www.springerlink.com/content/qjl77371v5868313/?p=7f041d14542a4b9eab90a3c2739555e9&pi=2. (Subscription required.)

March 2009

"Modelling how carbon affects soil structure." The following is the abstract of this article: "This paper presents a mechanistic model, named Struc-C, which describes how the soil organic carbon (SOC) influences the dynamics of soil structure, and consequently, soil physical behavior. The model is partly inspired from the Rothamsed Carbon model, RothC-26.3, divided into three sub-models; the first describes SOC dynamics, followed by how aggregates can be created from the combination of the SOC with the soil clay, and finally, how this process influences soil porosity. Soil aggregates are regarded as the elementary bricks building soil structure, which comprise of organo-mineral associations that are

subsequently bound together by more SOC to form the skeleton of larger aggregates. This is modeled by using two plant material pools from the RothC-26.3 model to create four new pools; three for increasing physical protection (or increasing aggregation), and one for the non-protected SOC (or non-aggregated). Struc-C has been tested over a simulated time of 200 years with input data from Rothamsted (England) and the Australian Capital Territory (Australia), and the output from the carbon model compared with RothC-26.3 outputs for both datasets. Although the model is still in its infancy, the simulations look promising when compared to RothC. Further improvements are also contemplated." **Karim Malamoud, Alex. B. McBratney, Budiman Minasny, and Damien J. Field**, *Geoderma*, Available online January 13, 2009, doi:10.1016/j.geoderma.2008.10.018, http://www.sciencedirect.com/science/article/B6V67-4VC743W-1/2/b5bb25b870f81829a6970f4353611119. (Subscription may be required.)

April 2009

"Carbon capture and sequestration by a treatment wetland." The following is the Introduction of this article: "The role of CO_2 in global warming is one of the most important environmental issues, and for this reason, it is necessary to develop technologies that minimize the discharge of CO_2 into the atmosphere. Atmospheric levels of CO_2 have been greatly affected by human activities, and these increases in CO_2 are accelerating global climate change. Scientists have recently developed several approaches to manage the levels of anthropogenic CO_2 emitted into the atmosphere, but one of the most understudied of these is CCS. A variety of CCS technologies exist for reducing anthropogenic CO_2 emission, including chemical absorption, membrane separation, chemical adsorption, and geologic formations including depleted oil and gas reservoirs, deep saline reservoirs, unminable coal seams and ocean disposal. Agroforestry and reforestry are two methods of phytotechnology currently being studied. However, there is much less research on the use of aquatic plants for removing anthropogenic CO_2. In particular, there is little information available about the use of wetlands as public remediation-sites for the purposes of CCS. Depending on environmental and treatment conditions, wetlands can be sources or sinks of CO_2. Many natural wetlands are known to be important sinks of CO_2, while wetlands created for wastewater purification are known to be sources of CO_2. The ability of treatment wetlands to sequester CO_2 depends on their design, dimensions, and the substrate used. In order to design such a CCS system, it would be useful to know detailed kinetic information that would help provide accurate descriptions of reaction mechanisms of both phytoremediation of CO_2 and plant-CO_2 interaction. Additionally, the question of which plant types are the most effective at sequestration is equally important, but has not yet been thoroughly studied. Utilizing different types of plants may result in different CO_2 removal rates. The aim of this study is to investigate the CO_2 removal performance by different types of plants in batch and continuous operations of treatment wetlands and to determine biokinetic coefficients of plants by applying saturation reaction and first-order reaction kinetic equations." **Jae Seong Rhee and Janjit Iamchaturapatr**, *Ecological Engineering*, Available online January 30, 2009, doi: 10.1016/j.ecoleng.2008.10.008, http://www.sciencedirect.com/science/article/B6VFB-4VGVX5K-1/2/74cd8da89dad5584947f8fe80e4f4c47. (Subscription may be required.)

May 2009

"Soil Carbon Sequestration in Tropical Agroforestry Systems: a Feasibility Appraisal." The following is the Abstract of this article: "Agroforestry is recognized as a strategy for soil carbon sequestration (SCS) under the afforestation/reforestation activities, but [society's] understanding of soil carbon dynamics under agroforestry systems (AFS) is not adequate. Although some SCS estimates are available, many of them lack scientific rigor. Several interrelated and site-specific factors ranging from agroecological conditions to system management practices influence the rate and extent of SCS under AFS, so that generalizations tend to become unrealistic. Furthermore, widely and easily adoptable methodologies are not available for estimating the SCS potential under different conditions. In spite of these, there is an increasing demand for developing "best-bet estimates" based on the current level of knowledge and experience. This document presents an attempt in that direction. The appraisal validates

the conjecture that AFS can contribute to SCS, and presents indicative ranges of SCS under different AFS in the major agroecological regions of the tropics. The suggested values range from 5 to 10 kg [carbon] ha^{-1} in about 25 years in extensive tree-intercropping systems of arid and semiarid lands to 100–250 kg [carbon] ha^{-1} in about 10 years in species-intensive multistrata shaded perennial systems and homegardens of humid tropics." **P.K. Ramachandran Nair, Vimala D. Nair, B. Mohan Kumar, and Solomon G. Haile**, *Environmental Science and Policy*, Available online March 9, 2009, doi: 10.1016/j.envsci.2009.01.010, http://www.sciencedirect.com/science/article/B6VP6-4VT17XH-2/2/37e663dfb58ddab6d5a7deb222b842fe. (Subscription may be required.)

June 2009

"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 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.)

July 2009

"Soil carbon dioxide flux, carbon sequestration and crop productivity in a tropical dryland agroecosystem: Influence of organic inputs of varying resource quality." The following is the Abstract of this article: "In view of the significance of agricultural soils in affecting global [carbon] balance, the impact of manipulation of the quality of exogenous inputs on soil CO_2–[carbon] flux was studied in rice-barley annual rotation tropical dryland agroecosystem. Chemical fertilizer, *Sesbania* shoot (high quality resources), wheat straw (low quality resource) and *Sesbania* + wheat straw (high + low quality), all carrying equivalent recommended dose of [nitrogen], were added to soil. A distinct seasonal variation in CO_2–[carbon] flux was recorded in all treatments, flux being higher during rice period, and much reduced during barley and summer fallow periods. During rice period the mean CO_2–[carbon] flux was greater in wheat straw (161 [percent] increase over control) and *Sesbania* + wheat straw (+129 [percent]) treatments; however, during barley and summer fallow periods differences among treatments were small. CO_2–[carbon] flux was more influenced by seasonal variations in water-filled pore space compared to soil temperature. In contrast, the role of microbial biomass and live crop roots in regulating soil CO_2–

[carbon] flux was highly limited. Wheat straw input showed smaller microbial biomass with a tendency of rapid turnover rate resulting in highest cumulative CO_2–[carbon] flux. The *Sesbania* input exhibited larger microbial biomass with slower turnover rate, leading to lower cumulative CO_2–[carbon] flux. Addition of *Sesbania* to wheat straw showed higher cumulative CO_2–[carbon] flux yet supported highest microbial biomass with lowest turnover rate indicating stabilization of microbial biomass. Although single application of wheat straw or *Sesbania* showed comparable net change in soil [carbon] (18 [percent] and 15 [percent] relative to control, respectively) and crop productivity (32 [percent] and 38 [percent]), yet they differed significantly in soil [carbon] balance (374 and −3 g [carbon] m^{-2} y^{-1} respectively), a response influenced by the recalcitrant and labile nature of the inputs. Combining the two inputs resulted in significant increment in net change in soil [carbon] (33 [percent] over control) and crop yield (49 [percent]) in addition to high [carbon] balance (152 g [carbon] m^{-2} y^{-1}). It is suggested that appropriate mixing of high and low quality inputs may contribute to improved crop productivity and soil fertility in terms of soil [carbon] sequestration." **K.P. Singh, Nandita Ghoshal, and Sonu Singh**, *Applied Soil Ecology*, Available online May 23, 2009, doi:10.1016/j.apsoil.2009.04.005, http://www.sciencedirect.com/science/article/B6T4B-4WBY51S-1/2/d19265c76cc03e77bf8898553d42a5a9. (Subscription may be required.)

August 2009

"Spatial and process-based modeling of soil inorganic carbon storage in an arid piedmont." The following is the Abstract of this document: "Inorganic carbon comprises approximately a third of the total carbon pool in soils worldwide, largely in the form of pedogenic calcite. Pedogenic calcite occurs in semi-arid and arid regions in the form of calcareous, calcic, and petrocalcic horizons. Understanding the processes governing the storage and flux of this inorganic carbon pool is crucial to the development of accurate regional and global carbon budgets. Objectives of this study were to: (1) develop a process-based pedogenic calcite model that accounts for landscape hydrology and geomorphic position, (2) calibrate model parameters with field data from a Mojave Desert landscape, and (3) apply the model to understanding soil inorganic carbon response to elevated atmospheric CO_2 concentrations. Two parameters are introduced in this study to account for surface water redistribution on the landscape: the precipitation threshold (Ω) and the topographic index threshold (Λ). These parameters account for runoff-generating rainfall events (Ω) and the potential to shed or collect water at a location (Λ). A one-dimensional compartmentalized thermodynamic model is used to simulate calcite precipitation and dissolution. Geomorphic delineation, sediment collected from dust traps, and detailed soil descriptions including percent sand and clay, and bulk density from 16 soil pits of the southern Fry Mountain piedmont served as inputs into the model. Precipitation and temperature inputs were simulated using stochastic models. Time steps for the sample sites used to calibrate the model were determined from optically-stimulated luminescence dates. Incorporation of precipitation and topographic index thresholds into the model allowed more information to be extracted from carbonate depth distributions than previous pedogenic calcite models. The model predicts a net loss of inorganic carbon from the upper 10 cm soil depth under elevated atmospheric CO_2 and a consequent gain in the 10-20 cm depth. The leaching of calcite from shallow depths to below 10 cm is evident in all landforms including those most susceptible to wind erosion. This leads to the conclusion that increased atmospheric CO_2 levels may result in a concentration of inorganic carbon at a depth that is protected from wind erosion creating a more geomorphically stable pool of carbon." **Daniel R. Hirmas, Christopher Amrhein, and Robert C. Graham**, *Geoderma*, Available online July 8, 2009, doi:10.1016/j.geoderma.2009.05.005, http://www.sciencedirect.com/science/article/B6V67-4WPS9N5-1/2/5165685689b2af372428e397b861fdff. (Subscription may be required.)

Trading

September 2008

***ClimateWire*, "WCI Releases Design Proposal; No Auction Percentage Specified,"** and ***Business Green*, "Western States Plan Cap-and-Trade By 2012."** The Western Climate Initiative (WCI) released a draft design for a carbon cap-and-trade scheme that outlines plans to cut regional emissions 15 percent below 2005 levels by 2020. The cap, which will go into effect in 2012, does not specify an emissions target; instead, the cap will start with the best estimate of actual emissions for the first year of the program and steadily decline through 2020. The estimate will be determined by WCI using reported data from emitters, while factoring in population and economic growth, as well as emission reductions that have occurred to date. Under the proposal, energy producers and industrial firms emitting more than 25,000 tonnes of CO_2 equivalent a year will be required to report their emissions from 2011 ahead of the 2012 starting date. WCI is made up of seven states and four provinces and is open to accepting new members, which will be considered prior to the start of each three-year compliance period. WCI includes roughly 20 percent of the United States' and 73 percent of Canada's economy, respectively. To view the WCI website, visit: http://www.westernclimateinitiative.org/index.cfm. July 24, 2008, http://www.eenews.net/climatewire/print/2008/07/24/3, and July 28, 2008, http://www.businessgreen.com/business-green/news/2222614/western-states-plan-cap-trade.

October 2008

***Blue Source News Release*, "Blue Source Forms Strategic Partnership with Affiliate Investment Funds of Och-Ziff Capital Management Group,"** and ***ClimateWire*, "Och-Ziff Putting $500M into CCS Projects."** Blue Source LLC and the hedge fund firm Och-Ziff Capital Management Group LLC announced an investment partnership on August 19 to fund the development of carbon infrastructure projects. Och-Ziff's investment funds will commit $500 million for new GHG reduction projects in partnership with Blue Source, a CCS and CH_4 project finance company. Blue Source will use the investment to support the ongoing development of pipeline infrastructure projects across North America that capture, transport, and sequester anthropogenic CO_2. The Och-Ziff investment will also support other ventures, such as climate change projects derived from power generation, fertilizer production, advanced energy conservation, natural gas production, and CH_4 management. According to Blue Source officials, the deal will fund their enterprises for three years, as Och-Ziff will also buy 10 percent of the emission credit generator. Blue Source has already sold credits representing 10 million metric tons of CO_2. August 19, 2008, http://www.ghgworks.com/5c-pr08-08-19.html, and August 20, 2008, http://www.eenews.net/climatewire/2008/08/20/8/.

November 2008

***ClimateWire*, "States Open First Carbon Auction,"** and ***Reuters*, "First U.S. Carbon Auction Brings States $39 Mln."** The Regional Greenhouse Gas Initiative (RGGI) began accepting bids on September 25, 2008, for permits that utilities must have for every ton of CO_2 they emit from their facilities. Designed to limit the amount of CO_2 that power plants can expel along the upper East Coast, the United States' first carbon auction program raised nearly $39 million in its first day of auctioning. All of the more than 12.5 million permits offered in the auction were purchased by the 59 participants from the energy, financial, and environment sectors. According to RGGI, the permits sold for $3.07 per ton, which was lower than the $4.00 to $4.50 per ton that the permits had brought in previous weeks on future markets. Carbon prices in the European Union (EU), where countries have national carbon limits under the Kyoto Protocol and have had a GHG allowance market since 2005, were approximately $34 per tonne on RGGI's first day of trading. The second RGGI auction for CO_2 allowances is expected to offer more than 31.5 million allowances and will be held on December 17, 2008. To view the RGGI press release, go to: http://www.rggi.org/docs/October_14_release_final.pdf. September 25, 2008, http://www.eenews.net/climatewire/2008/09/25/3/, and September 29, 2008, http://www.reuters.com/article/bondsNews/idUSN2937223920080929.

***Reuters*, "U.S.-Canada Group Unveils Carbon Trade Plan,"** and ***Environment News Service*, "Western States, Provinces Set Climate Emissions Trading Program."** The Western Climate Initiative (WCI) unveiled a regional market-based cap-and-trade program designed to reduce global warming pollution by 15 percent from 2005 levels by 2020. Each state and province is responsible for making laws and rules that fit the WCI plan with the goal of establishing, in 2012, the largest carbon market in the Western Hemisphere over a region that includes approximately 85 million people. The cap-and-trade program, one element of a regional effort by WCI to promote environmental sustainability and economic growth by reducing GHG emissions, will require emitters to cut their pollution by placing a limit on their emissions and allowing the market to identify the least costly ways to achieve the limit. The seven states and four provinces that make up WCI represent more than 70 percent of the Canadian economy and 20 percent of the US economy. The carbon reduction strategy will cover nearly 90 percent of the region's emissions, including those from electricity, industry, transportation, and residential and commercial fuel use. WCI's "Western Climate Initiative: Design Recommendations for the WCI Regional Cap-and-Trade Program" document is available at: http://www.westernclimateinitiative.org/ewebeditpro/items/O104F19866.PDF. September 23, 2008, http://uk.reuters.com/article/oilRpt/idUKN2338548620080923, and September 23, 2008, http://www.ens-newswire.com/ens/sep2008/2008-09-23-04.asp.

December 2008

***Greenwire*, "Relaunched Carbon Registry Preps for Cap and Trade."** The world's first GHG registry, formerly called the Greenhouse Gas Registry, relaunched on November 13, 2008, with a new name and accounting rules for companies and other entities that develop CO_2 offset projects and trade credits. The registry, which was co-founded by the Environmental Resources Trust (ERT) in 1997, is now referred to as the American Carbon Registry. With more than 20 million registered offsets, the American Carbon Registry is already a major player in the voluntary compliance market. An overarching standard was published, detailing GHG accounting principles and carbon offset and corporate emissions inventory eligibility requirements. ERT will also publish forestry and other sector-specific standards in the near future. In order to qualify their emissions reductions on the registry, offset developers will be required to verify their projects against these and other widely recognized standards, like the United Nations' (UN) Clean Development Mechanism (CDM). The World Bank suggests that the global carbon market will be worth more than $100 billion by the end of the year; in addition, the United States could help the global trading market turn nearly $3 trillion annually by 2020 by adopting a carbon cap-and-trade scheme, according to the London-based market analytics from New Energy Finance. To learn more about the American Carbon Registry, visit its website at: http://www.americancarbonregistry.org/. November 13, 2008, http://www.eenews.net/Greenwire/2008/11/13/11/.

January 2009

***Reuters*, "UK Sells 4 Mln EU CO_2 Emissions Permits in Auction,"** and ***Power Engineering*, "UK Holds Europe's First Phase II EU ETS Carbon Auction."** The British Government sold 4 million EU carbon emission permits in Europe's first such auction to allocate GHG allowances as part of Phase II (2008-2012) of the EU Emissions Trading Scheme (EU ETS). The auction was open to participants globally and was held by the United Kingdom's (UK) Department of Energy and Climate Change. The permits sold for ~$21.91 per tonne and raised ~$81.55 million for the British Treasury. To better prepare for Phase III, when allowances will no longer be issued for free to most participants, the European Commission allows governments to auction up to 10 percent of the allowances issued in Phase II. The EU ETS puts a cap on emissions from energy and heavy industrial sectors throughout the EU, which are collectively responsible for nearly half of the EU's CO_2 emissions. During 2009, Britain plans to auction 25 million more EU carbon allowances. To view the UK Department of Energy and Climate Change website, go to: http://www.decc.gov.uk/. November 19, 2008, http://in.reuters.com/article/oilRpt/idINLJ58992920081119, and November 19, 2008,

http://pepei.pennnet.com/display_article/345767/6/ARTCL/none/none/1/UK-holds-Europe's-first-Phase-II-EU-ETS-carbon-auction/.

February 2009

***RGGI News Release*, "RGGI States' CO_2 Auction Continues Strong Performance."** On December 17, 2008, the 10 northeastern and mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) held their second auction of CO_2 emissions allowances in the United States. All of the 31,505,898 allowances offered for sale were sold at $3.38 per allowance for a total of $106.5 million. The funds will be distributed to the 10 RGGI states and invested in energy efficiency and clean energy technologies. According to RGGI, 69 participants form the energy, financial, and environmental sectors took part in the bidding, which had a demand for the allowances at 3.5 times the available supply. Following the auction, RGGI released the "Post-Settlement Auction Report," which states that the auction was administered in a fair and transparent manner and in accordance with the noticed auction procedures. According to the report, compliance entities and their affiliates accounted for more than 80 percent of the quantity of bids submitted; a total of 46 entities won allowances and bid prices ranged from $1.86 (the minimum bid allowed) to $7.20. RGGI also issued a notice for Auction 3, which will be held on March 18, 2009. The notice can be found at: http://www.rggi.org/docs/Auction_Notice_Jan_12_2009.pdf. The complete Post-Settlement Auction Report for the RGGI CO_2 Allowance Auction 2 is available at: http://www.rggi.org/news/releases. December 19, 2008, http://www.rggi.org/docs/Auction_2_Release_Final_08_12_19b.pdf.

March 2009

***Forbes*, "Ore. Governor Pitches Plan to Cut Carbon Emissions."** Oregon Governor Ted Kulongoski proposed a cap-and-trade plan before a legislative panel on February 5, 2009 aimed at reducing CO_2 emissions from utilities and other sources. Under the governor's bill, the state Environmental Quality Commission will develop a plan and present it to Oregon's State Legislature in 2011. The governor also discussed implementing a new western regional plan to reduce GHGs. Oregon is already part of the Western Climate Initiative (WCI), which was created to establish a regional market to trade carbon emissions credits, allowing industries that emit GHGs to buy and sell credits. WCI's goal is to reduce the region's carbon emissions below the 2005 levels by approximately 15 percent by 2020. To learn more about WCI, visit their website at: http://www.westernclimateinitiative.org/. To view Oregon's Department of Environmental Quality website, click: http://www.deq.state.or.us/aq/climate/rulemaking.htm. February 6, 2009, http://www.forbes.com/feeds/ap/2009/02/06/ap6018979.html. (Subscription may be required.)

April 2009

***RGGI News Release*, "States Release Results of Third Auction for RGGI CO_2 Allowances."** The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) announced the results of the third auction for RGGI CO_2 allowances, which was held March 18, 2009. All of the 31,513,765 allowances for the 2009 vintage sold at a clearing price of $3.51 per allowance. The RGGI states, which raised $117,248,629.80 for energy efficiency, renewable energy, and other consumer benefit programs, also auctioned allowances for the second three-year control period, beginning in 2012. The 2,175,513 allowances for the 2012 vintage cleared at a price of $3.05 per allowance. According to Potomac Economics, RGGI's independent market monitor who observed the auction and confirmed procedures were consistent and fair, 50 separate entities submitted bids to purchase 2.5 times the available supply of 2009 allowances, and 20 entities submitted bids to purchase 2.3 times the available supply of 2012 allowances. Forty-two entities won allowances for the 2009 offering, and 12 entities won allowances for the 2012 offering. Bid prices ranged from $1.86 to $10.00 for the 2009 offering, and $1.86 to $4.40 for the 2012 offering. By the end of 2009, the RGGI states will have

offered five percent of the total supply of 2012 vintage allowances for sale. March 20, 2009, http://www.rggi.org/docs/Auction_3_News_Release_MM_Report.pdf.

***RGGI News Release*, "Report Shows Solid Foundation For Emerging Carbon Market."** On March 4, 2009, the 10 states participating in RGGI issued a report showing that the competitive process is working as intended in the secondary market for CO_2 allowances. Furthermore, the report, titled, "Report on the Secondary Market for RGGI CO_2 Allowances," concludes that there is no evidence of anticompetitive conduct amongst participants. The report covers August 2008 to January 2009 and conclusions were based on analysis of data reported to the Commodity Futures Trading Commission (CFTC) and the Chicago Climate Futures Exchange (CCFE). Potomac Economics, RGGI's independent market monitor that prepared the report, also concluded that the average volume of allowance futures trading per day grew from 155,000 in September 2008 to 330,000 in January 2009. To view RGGI's report, go to: http://www.rggi.org/docs/Secondary_Market_Report_March_2009_FINAL.pdf. March 4, 2009, http://www.rggi.org/docs/PE_Secondary_Market_Report_News_Release_FINAL.pdf.

May 2009

***RGGI News Release*, "States Initiate Bidding Process for Fourth RGGI CO_2 Allowance Auction."** The Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice, Qualification Application, and Intent to Bid for RGGI's fourth CO_2 allowance auction scheduled for June 17, 2009. The release starts the bidder qualification process and publicizes auction details, including the reserve price and number of allowances offered for sale; a reserve price of $1.86 for all allowances will continue to be used. The 10 participating states will offer 30,887,620 current control period allowances (2009 vintage) and 2,172,540 allowances for the future control period (2012 vintage). The June auction will be the second auction since compliance obligations under RGGI's CO_2 Budget Trading Programs became effective on January 1, 2009, and the second to offer allowances from current (2009-2011) and future (2012-2014) control periods. Auction documents are available for download at: http://www.rggi.org/co2-auctions/information. April 13, 2009, http://www.rggi.org/docs/Auction%204%20notice%20release_final.pdf.

***Reuters*, "Big China Hydro Plant Can Sell Carbon Credits-Xinhua."** The United Nations (UN) approved the Bingling hydropower plant in northwest China's Gansu province to begin selling carbon credits under the Clean Development Mechanism (CDM), making it the largest hydro project to receive this accreditation. The project, which is scheduled to go into full operation at the end of September 2009, will have a total generation capacity of 240,000 kilowatts and sell 760,000 tons worth of certified emission reductions (CERs) per year. Under the agreement, Gansu Electric Power Investment will sell the carbon credits to Italy's Enel. In order to receive CDM accreditation, a project needs to demonstrate that a quantifiable reduction in GHGs will result and the project would not have been economically viable without the capital generated by carbon trading. As part of the Kyoto Protocol, the CDM allows developed countries to achieve their emission reduction targets by investing in clean projects in developing nations. April 3, 2009, http://uk.reuters.com/article/oilRpt/idUKPEK3967320090403.

June 2009

***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.

July 2009

***KansasCity.com*, "Midwest Governors Group Sets Goals to Reduce Greenhouse Gases,"** and ***ClimateWire*, "Midwestern Governors Release Cap-and-Trade Recommendations."** The Midwestern Greenhouse Gas Reduction Accord Advisory Group released a plan that calls for a 20 percent reduction in GHG emissions from 2005 levels by 2020 and an 80 percent reduction by 2050 – the first such plan for a regional cap-and-trade program in the Midwest. The sectors covered in the recommendations include electricity generation and imports; residential, commercial, and industrial fuels; transportation fuels; and industrial processes. While the recommendations provide governors in the Midwest with a possible cap-and-trade framework, the group emphasized that the consortium would act only if a Federal cap-and-trade system does not reach fruition. The group recommends a different method than Congress for achieving GHG emission reduction goals in that most of the emissions allowances would initially be sold for a fee to help alleviate the cost to both industry and consumers. A portion of this income would be invested in new technology that could help meet the reduction goals. The consortium's members include Illinois, Iowa, Kansas, Michigan, Minnesota, Wisconsin, and the province of Manitoba; Indiana, Ohio, South Dakota, and Ontario participate as observers. For more information about the Midwestern Greenhouse Gas Reduction Accord, visit: http://www.midwesternaccord.org/, or click: http://www.midwesternaccord.org/Accord_Draft_Final.pdf to view the Advisory Group's recommendations. June 8, 2009, http://www.kansascity.com/news/politics/story/1240419.html, and June 9, 2009, http://www.eenews.net/climatewire/2009/06/09/6/.

***Environment Canada News Release*, "Offset System A Step Towards A Carbon Market In Canada."** The Canadian Government announced that it is working to finalize a domestic regulatory framework for a Canadian carbon market by moving forward with its Offset System for GHGs. Two draft guides were released on June 12, 2009, (available at: http://www.ec.gc.ca/creditscompensatoires-offsets/44B33F4A-34E2-49CE-9D3E-0775600A2AE6/Offsets_Projects%20June%2011_%20pdf.pdf and http://www.ec.gc.ca/creditscompensatoires-offsets/F86DD35D-2561-427D-9FA1-9A292A437FC2/Offsets_Verification%20June%209_e.pdf) that propose rules and guidance on the requirements and processes used to generate offset credits and establish methods that verify GHG reductions achieved from a registered project, respectively. The Offset System will establish tradable credits and encourage cost-effective, domestic GHG reductions in areas that will not be covered by planned Federal GHG regulations, like the forestry and agricultural sectors. Companies will be able to purchase offset credits on the carbon market and use them for compliance with their regulated targets. Interested parties will have 60 days to comment and the final versions of the Offset System guides are expected to be completed in Fall 2009. The release of these two draft guides follows the publication of the first draft guide in August 2008 (available at: http://www.ec.gc.ca/creditscompensatoires-offsets/default.asp?lang=En&n=7CAD67C6-1), which proposed the rules and guidance to quantify GHG reductions. To learn more about Canada's Offset System, visit: www.ec.gc.ca/creditscompensatoires-offsets. June 10, 2009, http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=23C6502E-4307-4647-A5C7-38B3B7EDDDF0.

August 2009

***RGGI News Release*, "Fourth RGGI Auction Yields $104.2 Million for Investment in the Green Economy."** On June 17, 2009, the 10 states participating in the Regional Greenhouse Gas Initiative

(RGGI) conducted their fourth regional carbon allowance auction, raising a total of $104.2 million from selling all of the 30,887,620 available allowances for the 2009 vintage at a price of $3.23. Potomac Economics, the RGGI independent market monitor, found that 54 separate entities submitted bids to purchase 2.6 times the available supply of 2009 allowances; compliance entities and their affiliates purchased 85 percent of the 2009 allowances offered. In a parallel offering, the RGGI states also auctioned all of the 2,172,540 allowances for the 2012 vintage at a price of $2.06 for the second three-year control period beginning January 1, 2012. Thirteen entities submitted bids to purchase 1.5 times the available supply of 2012 allowances; compliance entities and their affiliates purchased 81 percent of the 2012 allowances offered. Since the first auction in September 2008, RGGI members have auctioned more than 110 million allowances for a total of $366.5 million to invest in energy efficiency, renewable energy, and other programs. Potomac Economics' Marketing Monitoring Report for Auction 4 is available at the following link. June 19, 2009, http://www.rggi.org/docs/Auction_4_News_Release_MM_Report.pdf.

Recent Publications

September 2008

"Community Acceptance of Carbon Capture and Sequestration Infrastructure: Siting Challenges." Congress is considering policies to reduce U.S. emissions of carbon dioxide, a major contributor to global warming. These policies include promoting the capture and sequestration of carbon dioxide (CO_2) from manmade sources such as electric power plants and manufacturing facilities. Carbon capture and sequestration (CCS) is a three-part process involving a CO_2 source facility, an intermediate mode of CO_2 transportation (pipelines), and a permanent CO_2 sequestration site. CCS is of great interest because emerging technologies may be able to remove up to 95 [percent] of CO_2 emitted from an electric power plant or other industrial source. Power plants are the most likely initial candidates for CCS because they are predominantly large, single-point sources, and they contribute approximately one-third of U.S. CO_2 emissions from fossil fuels. As U.S. carbon policies evolve, congressional policy makers are becoming aware that a national CCS program could require an extensive new network of CO_2 related infrastructure. In the 110th Congress, there has been considerable debate and legislative activity related to the technical, economic, and regulatory aspects of such infrastructure. Another key consideration, however, is public acceptance, which may ultimately determine whether, where, and how anticipated CCS projects may be constructed. Although the general public is still largely unfamiliar with CCS, there are early indications that — similar to the siting of other kinds of energy and industrial infrastructure — community acceptance may prove a significant challenge to the siting of CCS infrastructure in the United States. This Congressional Research Service (CRS) report, prepared for Congressional members and subcommittees, can be found at: http://assets.opencrs.com/rpts/RL34601_20080729.pdf.

"Ensuring Offset Quality: Integrating High Quality Greenhouse Gas Offsets Into Cap-and-Trade Policy." As the United States embarks on the path toward addressing climate change, multiple strategies will be needed to achieve the significant cuts in GHG emissions ("emissions") necessary to stabilize the climate. Among the most important, complex and controversial of these strategies is the use of GHG offsets ("offsets"). An offset represents the reduction, removal or avoidance of GHG emissions from a specific project that is used to compensate for GHG emissions occurring elsewhere. While there is currently a growing voluntary market for offsets in the United States, offsets can also be effectively incorporated into mandatory policies such as cap-and-trade systems, which can be designed to allow firms to buy and trade credits generated by qualifying emission reduction projects ("projects") outside the boundaries of the emissions cap. These are referred to as offset credits ("offsets"), and each typically represents one metric ton of carbon dioxide equivalent. Offsets are used in lieu of an emissions reduction, removal or avoidance ("reduction") that would have otherwise been required to occur within the boundaries of the emissions cap. In other words, provided that the project meets the established eligibility criteria, the purchasing firm is allowed to use offset credits to meet its compliance obligation as

though the firm had made the reduction itself. The essential promise of an offset is the achievement of a real and verifiable reduction in global GHG emission levels beyond what would have otherwise occurred that is equally effective as on-site emission reductions by regulated entities. This document, intended to provide policymakers with recommendations regarding the integration of GHG offsets into emerging regulatory systems, is available at: http://www.offsetqualityinitiative.org/documents/WhitePaper.pdf.

"Carbon Pollution Reduction Scheme Green Paper." Addressing climate change is one of the key economic and environmental challenges facing Australia and the rest of the world. An effective global and domestic response to climate change is one of the highest priorities of the Australian Government. Indeed, the Government's first official act was to ratify the Kyoto Protocol, committing Australia to play its part in addressing climate change. Climate change involves profound challenges. It has the potential to fundamentally re-shape [Australia's] social, environmental and economic landscapes — particularly affecting water supply, agricultural industries, coastal zones and [Australia's] natural heritage. Climate change is a by-product of industrialization. Environmental damage is caused by greenhouse gas emissions which are predominantly carbon-based. The emissions constitute carbon pollution yet those who generate the pollution are not held accountable for the costs they impose. The resulting environmental degradation is not currently reflected in the costs of business or the price of goods and services. Because firms face no cost from increasing emissions, the level of emissions is too high. Unless businesses and individuals over time bear the responsibility for their consumption and production decisions, the level of carbon pollution will remain at unsustainable levels. Emissions trading schemes are designed to redress this market failure. Emissions trading schemes are simply a mechanism to achieve an objective. That objective is to reduce carbon pollution, and to do so efficiently, by putting a cap on emissions. The Government is therefore referring to the measure as the Carbon Pollution Reduction Scheme. To read the complete green paper, which outlines the Australian Government's approach to the design of a national emissions trading scheme, click: http://www.climatechange.gov.au/greenpaper/report/pubs/greenpaper.pdf.

October 2008

"Towards Carbon Capture and Storage." The following is from the executive summary of the document: "CCS is an integrated process that involves the capture of CO_2 from combustion plants (typically a fossil fuel power station); the compression of the CO_2 to a form where it is suitable for transport; the transport of the captured CO_2 to a storage site; and the permanent storage of the CO_2 in deep geological sites. The geology of the United Kingdom (UK) North Sea is thought to be particularly well suited to the storage of CO_2. CCS has the potential to reduce emissions from fossil fuel power stations by up to 90 [percent]. It is the only technology option currently available that could allow abundant and flexible fossil fuels to continue to be used for electricity generation without adding to the damaging effects of climate change. Whilst there is considerable confidence that CCS can be effectively deployed at commercial scale, there is, as yet, no practical experience of operating such a facility. The UK Government has launched a competition to build one of the worlds first commercial scale CCS projects. This is the first step towards demonstrating the full chain of CO_2 capture, transport and storage by 2014. In the meantime work is progressing on the regulatory and policy framework within which CCS should operate, both at the national level through the Energy Bill now in Parliament and at [the] EU level. This consultation deals with aspects of this framework." The complete consultation is available at: http://www.berr.gov.uk/files/file46810.pdf.

"Energy-Efficiency and Carbon Capture in New Fossil Power Plants in the EU." The following is from the executive summary of the document: "In this study [the authors] focus on energy-efficiency and capture-readiness of recently built (>1997) and planned fossil-fired power plants. The study has two main purposes: (1) to evaluate energy-efficiency of new fossil power plants and compare them with the energy-efficiency that would be expected when using best available techniques (BAT) [and] (2) to see what share of new power plants can be considered as capture-ready. For this purpose [the authors] first look at the energy-efficiency that would be expected to be achieved by applying BAT and [the authors]

define requirements for capture-readiness. In the second step [the authors] analyze the new power plants with respect to these two characteristics, i.e. energy efficiency and carbon capture readiness. Capture-ready means that a plant can be equipped with CO_2 capture technology while it is under construction or after it is built. If a plant is not capture-ready this means it is either more expensive to add CO_2 capture technology or impossible due to insufficient space at the site or no suitable reservoir to store the CO_2 in. This means that it is important for new fossil plants to be capture-ready in order to have the possibility to add CO_2 capture and storage at a later stage. In order for a power plant to be capture-ready the following requirements should be met: (1) a study on the possible options for CCS in terms of technology and feasibility should be done; (2) an assessment should be made of the elements of the plant that would need to be adapted when adding CO_2 capture equipment, their place in the plant layout and their physical size; (3) an assessment of the possible pre-investments that can be done in comparison to the costs of making changes when the power plant is built; (4) the availability of sufficient space for the required CCS technology during operation as well as during construction[, a]t the same time normal operation of the existing plant has to be assured both during construction and operation of CCS; and (5) and an assessment of a storage site and a credible route to the storage site is needed. Capture-ready plants are somewhat more expensive to build. The costs consist mainly of the purchase of additional land area." The complete document is available at: http://www.ecofys.com/com/publications/documents/RPTEnergy-efficiencyandcarboncaptureinnewpowerplantsENFinal.pdf. (Subscription required.)

"New Zealand Energy Greenhouse Gas Emissions 1990-2007." The following is from the overview of the report: "Like many countries, New Zealand is concerned about the potential adverse effects on climate change. Long-term risk to New Zealand's national interests include rising sea levels affecting the coastal environment and infrastructure, reduced agricultural production, and adverse effects on native ecosystems and natural resources. New Zealand has also recognized that climate change is a global challenge and that inaction would risk its international credibility. It was in this broad context that in 1993 New Zealand ratified the United Nations Framework Convention on Climate Change (UNFCCC). This step was followed by ratification of the Kyoto Protocol in 2002. As a party to the Kyoto Protocol, New Zealand has committed to reducing its emissions of GHGs over 2008-2012 (the first commitment period) to 1990 levels or take responsibility for any emissions above this level if it cannot meet this target. The information on energy sector emissions in this report will feed into the 2009 edition of the *New Zealand's Greenhouse Gas Inventory*, published by the Ministry for the Environment (MfE) as part of New Zealand's obligations under the UNFCCC and the Kyoto Protocol. The national inventory of GHG emissions includes emissions from agriculture, waste, land use change, and other factors. In 2006, it was estimated that New Zealand emitted around 78 millions tonnes of CO_2 equivalent GHGs into the atmosphere. However, through carbon sinks, such as forested land, and estimated 23 million tonnes was removed. This resulted in New Zealand's estimated 'net' emissions of CO_2 equivalent GHGs for 2006 totaling 55 million tonnes." The complete MfE document is available at: http://www.med.govt.nz/upload/63349/GHG%20Report.pdf.

November 2008

"Methodology for Development of Geologic Storage Estimates for Carbon Dioxide." The following is from the Foreword of this document: "This document is an update to the 2006 'Methodology for Development of Carbon Sequestration Capacity Estimates' published in the 2007 Carbon Sequestration Atlas of the United States and Canada (Atlas I). This document describes the methodologies used to produce the geologic resource estimates for CO_2 storage in the 2008 Carbon Sequestration Atlas of the United States and Canada (Atlas II). The rationales presented were used to simplify assumptions for estimating the amount of CO_2 that can be stored in subsurface geologic environments of the United States and parts of Canada. The primary focus of Atlas II is to add additional basins and formations to the CO_2 storage portfolio, update information on the DOE's Carbon Sequestration Program as well as the RCSPs, and provide definitions of CO_2 resource versus CO_2 capacity that reflect the uncertainty of geologic storage estimates for CO_2 across the RCSPs." To read the document, go to:

http://www.fossil.energy.gov/programs/sequestration/publications/Project_Reports/carbonstorage_method08.pdf.

"Development of a Policy Framework for CO_2 Carbon Capture and Storage in the States." The following is from the Executive Summary of this document. "This paper presents the background and policy issues surrounding development of a commercial market for captured CO_2, and seeks to foster among policymakers a deeper understanding of 1) both the generation and CCS technologies involved, as well as their costs; 2) the technical and regulatory barriers to deployment of those technologies, and 3) the opportunities CCS may offer for increased employment and income. [Enhanced oil recovery (EOR)] offers one potential pathway to large-scale, widespread use of captured CO_2, and Ohio seems particularly well-positioned to take advantage of these emerging opportunities. There are a number of state-specific actions that Ohio and other states might initiate to facilitate the deployment of next-generation coal technologies. States can compensate for, or even remove, many of the barriers facing first movers by recognizing CCS, and CO_2 stored through EOR, as clean energy options. States can provide various incentives for CO_2 capture, transportation, and storage, and, since public acceptance of storage of CO_2 in deep saline formations (DSFs) may be years away, adoption of CO_2-EOR as a recognized CCS activity could facilitate new projects today and set the stage for deeper, more permanent injection and storage in the future." To view the complete paper, prepared for the Pew Center on Global Climate Change, visit: http://www.pewclimate.org/docUploads/Pew_Melzer_08_08.pdf.

"Carbon Capture & Storage: Assessing the Economics." The following is from the Introduction of this document: "There is growing consensus among climate scientists, economists, and policymakers that the link between man-made emissions of GHGs and climate change is sufficiently likely to motivate global actions. Energy use and energy generation are at the heart of the problem, with the [International Energy Agency (IEA)] forecasting that global electricity generation will nearly double from 2005 to 2030. The Agency says that fossil fuels will remain a significant part of the energy mix up to 2030, comprising roughly 70 percent of global and 60 percent of European energy generation. One of the solutions being discussed to reduce GHG emissions from fossil fuel energy generation is CCS. CCS is a group of technologies for capturing the CO_2 emitted from power plants and industrial sites; compressing this CO_2; and transporting it to suitable permanent storage sites, such as deep underground. CCS is in a relatively early phase of development, with several key questions remaining, including about its costs, timing, and relative attractiveness versus other low carbon opportunities. Public understanding of CCS is low, and there is some confusion around its true economics, exacerbated by the wide range of cost numbers quoted and the limited information on how they are derived." To read the complete McKinsey & Company report, click: http://www.mckinsey.com/clientservice/ccsi/pdf/CCS_Assessing_the_Economics.pdf.

December 2008

"CO_2 Capture and Storage – A Key Carbon Abatement Option." The following is from the Executive Summary of this document: "Climate change is a major challenge. Secure, reliable and affordable energy supplies are needed for economic growth, but increases in the associated CO_2) emissions are the cause of major concern. About 69 [percent] of all CO_2 emissions, and 60 [percent] of all GHG emissions, are energy-related. Recent [International Energy Agency (IEA)] analysis in Energy Technology Perspectives 2008 (ETP) projects that the CO_2 emissions attributable to the energy sector will increase by 130 [percent] by 2050 in the absence of new policies or supply constraints, largely as a result of increased fossil fuel usage. The 2007 Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report indicates that such a rise in emissions could lead to a temperature increase in the range of 4 to 7 degrees Celsius, with major impacts on the environment and human activity. It is widely agreed that a halving of energy-related CO_2 emissions is needed by 2050 to limit the expected temperature increase to less than 3 degrees. To achieve this will take an energy technology revolution involving increased energy efficiency, increased renewable energies and nuclear power, and the de-carbonization of power generation from fossil fuels. The only technology available to mitigate GHG emissions from large-scale fossil fuel usage is CO_2 CCS. The ETP scenarios demonstrate that CCS will need to contribute nearly

one-fifth of the necessary emissions reductions to reduce global GHG emissions by 50 [percent] by 2050 at a reasonable cost. CCS is therefore essential to the achievement of deep emission cuts." This IEA publication is available for purchase at: http://www.iea.org/w/bookshop/add.aspx?id=335.

"Potential Offset Supply in a Cap-and-Trade Program." The following is from the Introduction of this document: "If Congress enacts a GHG emission reduction program, such as a cap-and-trade system, the treatment of offsets would be a critical design element. For example, EPA found that different offset scenarios – e.g., unlimited offsets versus no offsets – generated significant variances in cap-and-trade program costs. However, offsets have generated considerable controversy, primarily for the concern that illegitimate offsets could undermine the ultimate objective of a cap-and-trade program: emission reduction. An estimate of the quantity and type of offset projects that might be available would provide for a more informed debate over the design elements of a cap-and-trade program. An offset is a measurable reduction, avoidance, or sequestration of GHG emissions from a source not covered by an emission reduction program. From a climate change perspective, the location of the reduction, avoidance, or sequestration does not matter: a ton of CO_2 (or its equivalent in another GHG) reduced in the United States and a ton sequestered in another nation would have the same result on the atmospheric concentration of GHGs. If a cap-and-trade program includes offsets, covered sources would have the opportunity to purchase them to help meet compliance obligations. Offset projects vary by the quantity of emission credits they could generate and the implementation complexity they present. In general, agriculture and forestry activities offer the most potential, but these projects often pose multiple implementation challenges. This may create a tension for policymakers, who might want to include the offset projects that provide the most emission reduction opportunities, while minimizing the use of offset projects that pose more implementation complications, or have the potential to be invalid." The complete Congressional Research Service report can be accessed at: http://assets.opencrs.com/rpts/RL34705_20081014.pdf.

"Guidelines for Carbon Dioxide Capture, Transport, and Storage." The following is from the Executive Summary of this document: "The CCS Guidelines effort was initiated to develop a set of preliminary guidelines and recommendations for the deployment of CCS technologies in the United States, to ensure that CCS projects are conducted safely and effectively. As such, the CCS Guidelines are written for those who may be involved in decisions on a proposed project: the developers, regulators, financiers, insurers, project operators, and policymakers. These Guidelines are intended to guide full-scale demonstration of and build public confidence in CCS technologies by informing how projects should be conducted. Worldwide increases in energy demand coupled with a continued reliance on fossil fuel resources have contributed to a significant increase in atmospheric levels of CO_2. This increase shows no signs of slowing. According to IEA's World Energy Outlook 2007, the projected growth in energy demand will translate into a 57 percent rise in energy-related CO_2 emissions by 2030 (IEA 2007). Others argue – especially in the recent high energy price environment – that global energy demand will be much lower than the IEA forecast. Scenarios for stabilizing climate-forcing emissions suggest atmospheric CO_2 stabilization can only be accomplished through the development and deployment of a robust portfolio of solutions, including significant increases in energy efficiency and conservation in the industrial, building, and transport sectors; increased reliance on renewable energy and potentially additional nuclear energy sources; and deployment of CCS. Slowing and stopping emissions growth from the energy sector will require transformational changes in the way the world generates and uses energy." To view the complete document, go to: http://pdf.wri.org/ccs_guidelines.pdf.

January 2009

"Addressing Emissions From Coal Use in Power Generation." The following is the Introduction of this document: "Coal is a cheap and abundant resource, and CO_2 from coal use is responsible for about 40 percent of global GHG emissions from fossil fuel use. The United States and China are by far the largest emitters of CO_2 from coal consumption, accounting for nearly 60 percent of global CO_2 emissions from coal, with India a distant third. The United States currently relies on coal for roughly half of its

electricity generation resulting in roughly one third of total U.S. emissions. China generates 80 percent of its electricity from coal, and in recent years, emissions from coal use have grown five times faster in China than in the United States. With enough coal reserves to meet current consumption levels for centuries, the United States and the rest of the world face the challenge of reconciling the realities of coal use with the dangers posed by climate change. CCS is a means to meet this challenge. If widely deployed, CCS could allow the world both to continue to exploit its cheap and abundant supply of coal and to adequately address the threat of climate change. CCS works by separating CO_2 from other gases in the exhaust stream at power plants and industrial facilities, compressing the CO_2 to pressures suitable for pipeline transport, and injecting the CO_2 into deep geologic formations where it can be safely and indefinitely stored. Although components of the CCS suite of technologies have been used in a variety of situations, the entire suite has not been deployed at a commercial scale at any coal-fueled power plant to date. Deployment has not proceeded for a number of reasons, primarily the high costs of installing and operating CCS technologies and the absence of government policies that place a financial cost on GHG emissions. In addition, uncertainties remain concerning actual cost and performance of CCS technologies at commercial scale. Finally, CCS deployment requires an appropriate regulatory system for CO_2 storage, including long-term liability. This brief describes the potential role of government in facilitating widespread and more rapid deployment of CCS through a number of means including: providing financial incentives for initial CCS projects through the use of bonus allowances under a cap-and-trade program, or a fund generated by charges on electricity or fossil-fuel based sources of electricity; setting GHG emission performance standards for coal generators or electricity providers; and establishing the required regulatory and liability frameworks for CO_2 storage." To read the complete Congressional Policy Brief from the Pew Center for Global Climate Change, go to: http://www.pewclimate.org/docUploads/DDCF-Coal.pdf.

"CO_2 Emissions from Fossil Fuel Combustion (2008 Edition)." The following is the background of this document: "In recognition of fundamental changes in the way governments approach energy-related environmental issues, the [International Energy Agency (IEA)] has prepared this publication on CO_2 emissions from fuel combustion. This annual publication was first published in 1997 and has become an essential tool for analysts and policy makers in many international fora such as the Conference of the Parties. The fourteenth session of the Conference of the Parties to the Climate Change Convention (COP 14), in conjunction with the fourth meeting of the Parties to the Kyoto Protocol (CMP 4), will be meeting in Poland from [December 1-12, 2008]. The data in this book are designed to assist in understanding the evolution of the emissions of CO_2 from 1971 to 2006 for more than 140 countries and regions by sector and by fuel. Emissions were calculated using IEA energy databases and the default methods and emission factors from the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*." This IEA publication is available for purchase at: http://www.iea.org/w/bookshop/add.aspx?id=36. The Table of Contents can be viewed at: http://www.iea.org/Textbase/nptoc/CO2_TOC.pdf.

"Building a Low-Carbon Economy – The UK's Contribution to Tackling Climate Change." The following is the Executive Summary of this document: "Climate change resulting from CO_2 and other GHG emissions poses a huge threat to human welfare. To contain that threat, the world needs to cut emissions by about 50 [percent] by 2050, and to start cutting emissions now. A global agreement to take action is vital. But a global agreement will not be possible unless the countries of the rich, developed world provide leadership. A fair global deal will require the UK to cut emissions by at least 80 [percent] below 1990 levels by 2050. The good news is that reductions of that size are possible without sacrificing the benefits of economic growth and rising prosperity. Technologies are available or with appropriate support could be developed which deliver low-carbon energy; opportunities to increase the efficiency with which [energy is used] are huge; lifestyle changes which will not undermine welfare can produce significant cuts in energy consumption. And many of the actions required to tackle climate change [the UK] should want to do anyway because these have economic, wider environmental and security of supply benefits. But the potential will not be achieved without appropriate policies: financial incentives through carbon prices, taxes and subsidies; support for technology innovation; information and

encouragement; and regulation when needed. The challenge is not the technical feasibility of a low-carbon economy but making it happen. Ensuring action will require strong leadership from government and a concerted response from individuals and businesses. It will require policy commitment to cutting emissions steadily over time, sticking on the path to an 80 [percent] reduction, and reacting to any diversion with new policies to get back on track. The UK's Climate Change Act makes that commitment, establishing a system of five year 'carbon budgets'. The Committee on Climate Change is charged with recommending the level of those budgets." The document is available at: http://hmccc.s3.amazonaws.com/pdf/TSO-ClimateChange.pdf.

February 2009

"Greenhouse Gas Offsets in a Domestic Cap-and-Trade Program." The following is a summary of this document: "This brief presents the key issues and identifies options for the incorporation of GHG offsets into emerging U.S. climate change policy. A GHG offset represents a reduction, avoidance, destruction, or sequestration of GHG emissions from a source not covered by an emission reduction requirement. The elimination of GHG emissions can be converted into tradable offset credits, and cap-and-trade programs can be designed to permit firms to use these credits to meet their compliance obligations. A carefully crafted and implemented offset program can significantly reduce cap-and-trade compliance costs by providing lower cost emission reduction options. Yet, while economic modeling has shown that incorporation of offsets into a cap-and-trade program can significantly reduce costs and allowance prices, their inclusion is not without controversy or complication. Some are concerned that offset inclusion will reduce the price signal to the point that the innovation and technological change needed to address the climate problem will be diminished. Others focus on the difficulty associated with substantiating offsets as real emission reductions. Important considerations in designing offset programs include the way in which offsets are defined; the types, location and quantity of offsets allowed; and the methods for assessing and crediting projects. Generally speaking, offset projects come in three distinct types: (1) direct emission reductions, (2) indirect emission reductions, and (3) sequestration. Before a project can create an offset credit, the emission reductions should meet all of the following criteria: they must be real, measurable, additional, permanent, monitored, independently verified, measured from a credible baseline, not represent leakage, and be able to convey as a clear property right. Additionality is perhaps the most important yet complicated issue, as it requires an assessment of what would have happened in the absence of the project. Offset project assessments can be either project specific or standardized. A hybrid assessment approach, which uses some standardization methodologies but allows for a degree of flexibility in assessing projects, may be the most effective. Each of these important factors for creating high quality offsets are discussed in this brief." To read the entire policy brief, click: http://www.pewclimate.org/docUploads/DDCF-Offsets.pdf.

"From EOR to CCS: The Evolving Legal and Regulatory Framework for Carbon Capture and Storage." The following is the Synopsis of this document: "Carbon capture and storage has been proposed around the world as a potentially key technology for reducing CO_2 emissions. The United States oil and gas industry has a long experience in transporting, injecting, and effectively storing CO_2 in tertiary oil recovery operations usually known as [EOR]. As a result, there already exists a legal and regulatory framework that addresses many – but not all – of the issues that will need to be addressed if [CCS] is to be adopted by policymakers as part of a carbon regulation regime. A review of that existing framework allows identification of those aspects that appear adequate to govern the sale, transport, and injection of CO_2 for [CCS] purposes as well as those that do not. Building on this analysis, the authors conclude that the current legal framework will be largely adequate from a transactional and interim standpoint to allow parties to structure a relatively seamless transition from CO_2 storage that is an incidental result of oil production operations to those incremental injections of CO_2 intended solely for permanent underground storage. The authors also suggest some possible approaches for crafting new rules to fill potentially remaining legal or regulatory gaps." To view the entire document, click: http://www.marstonlaw.com/index_files/From%20EOR%20to%20CCS.pdf.

"Carbon Capture and Sequestration: Framing the Issues for Regulation." The following is from the Executive Summary of this document: "When fossil fuel (coal, oil and gas) is burned, much of the CO_2 that is produced stays in the atmosphere for over 100 years. In order to stabilize the atmospheric concentration of CO_2, [humans] must reduce emissions approximately 80 [percent] from current levels, otherwise the atmospheric concentration of CO_2 will continue to grow. While renewable and other low-carbon energy technology will help, for at least the next half century [humans] will also have to continue to use fossil fuel. Fortunately, there is technology that will allow [humans] to capture the CO_2 before it is released, and 'sequester' it permanently several thousand feet or more underground in appropriate geological formations. This process is called [carbon capture and sequestration]. CCSReg is an interdisciplinary project to develop recommendations for how best to regulate the process of capturing CO_2, transport it in pipelines, and sequester it safely and securely in appropriate deep geological formations. The project is anchored in the Department of Engineering and Public Policy at Carnegie Mellon, and involves co-investigators at the Institute for Energy and the Environment at the Vermont Law School, the Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota, and the Washington, DC law firm of Van Ness Feldman. A list of project investigators is provided on page ii of the report. This interim report is not designed to provide answers. Rather it frames the issues that the CCSReg project team believes must be considered if CCS is to be safely and effectively developed." The complete CCSReg report is available at: http://www.ccsreg.org/pdf/CCSReg_12_28.pdf.

March 2009

"Global Carbon Sequestration Markets & Strategies, 2009-2030." The following is a summary of this document: "Driven by industry and government urgency to preserve coal as part of the global power generation mix, carbon sequestration is poised for significant growth over the next two decades. The pace of carbon sequestration project development has escalated from a few sporadic demonstrations to a geographically dispersed pipeline growing in scale. Over 110 sequestration projects were in the development stages as of year-end 2008, but significant economic and commercial challenges remain. A new study from Emerging Energy Research, Global Carbon Sequestration Markets & Strategies, 2009-2030, analyzes the role of carbon policies in driving sequestration development, evaluates the strategies of oil and gas players, power companies and entrepreneurial upstarts, and measures the sequestration industry's long-term growth outlook." A full summary and the Table of Contents can be viewed at: http://www.emerging-energy.com/user/CarbonSequestrationMarketsandStrategies2009203050428395_pub/CarbonSequestrationStudyPromo.pdf. (Purchase required).

"A Blueprint for Legislative Action." The following is from the Introduction of this document: "The United States faces an urgent need to transform our Nation's economy, make the country more energy secure, and take meaningful action to slow, stop, and reverse GHG emissions to address climate change. The economic, energy, and global warming realities facing the Nation are characterized by a detrimental dependence on foreign oil, economic instability, and a growing recognition that the impacts of a warming planet are being felt today. To address these challenges successfully will require a fundamental shift in the way energy is produced, delivered, and consumed in the U.S. and around the globe. [Americans] need a new vision and policy direction to transition from the technologies and practices [Americans] relied upon in the 20th century to the technologies and practices America will need in the 21st century. [Americans] must: increase the overall energy efficiency of our economy; utilize responsibly our domestic supplies of coal, oil and natural gas; develop and export the transportation technologies and fuels of the future; and ensure the Nation has an adequate supply of electricity produced from low-carbon resources, including wind, solar, next generation nuclear technology, and coal with [CCS]. New and emerging technologies can put [Americans] on the right path, and the potential for other continued technology improvement is high. But to assure success, [Americans] need well-aligned national energy and climate policies that set out a new direction for the country. These policies must establish an orderly and predictable schedule of GHG reductions that will move the private sector to develop and deploy the new and advanced energy technologies of tomorrow. Thoughtful and

comprehensive national energy and climate policy will help secure [the] economic prosperity and provide American businesses and the Nation's workforce with the opportunity to innovate and succeed." To read the complete United States Climate Action Partnership (USCAP) document, click: http://www.us-cap.org/pdf/USCAP_Blueprint.pdf.

"A Roadmap for U.S.-China Cooperation on Energy and Climate Change." The following is an excerpt from the Introduction of this document: "A new comprehensive program for cooperation between the United States and China that focuses on reducing [GHG] emissions, and thus mitigating the potentially catastrophic effects of climate change, is both necessary and possible. Indeed, as this Report suggests, if human beings hope to avoid the worst consequences of global climate change, the United States and China – respectively the world's largest developed and developing nations, the two largest energy consumers, and the two largest producers of [GHGs] – have no alternative but to become far more active partners in developing low-carbon economies. To prevail in such a common effort, both countries will need not only bold leadership and a new set of national policies, but also a path-breaking cooperative agenda that can be sustained over the long run. The advent of a new U.S. presidential administration in Washington, D.C., coupled with a central leadership in Beijing that is increasingly aware of the destructive impact and long-term dangers of climate change, presents an unparalleled opportunity for this new strategic partnership. While the current global economic crisis could make joint action between the United States and China more difficult, it could also provide an unexpected impetus. If wisely allocated, funds invested by both governments in economic recovery can help address climate change while also advancing the "green technologies" and industries that will lead to a new wave of economic growth. Stronger bilateral collaboration on energy and climate change has at the same time the real prospect of helping to build a new, more stable, and constructive foundation under Sino-American relations, the most important bilateral relationship in the 21st century world." To read the entire Pew Center and Asia Society report, go to: http://www.pewclimate.org/docUploads/US-China-Roadmap-Feb09.pdf.

April 2009

"Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations." The following is from the Introduction of this document: "The storage of industrially generated CO_2 in deep geologic formations is being seriously considered as a method for reducing CO_2 emissions into the atmosphere. This growing interest has lead to significant investment by governments and the private sector to develop the necessary technology and to evaluate whether this approach to CO_2 control could be implemented safely and effectively. Depleted oil and gas reservoirs, unmineable coalbeds, and deep brine-filled (saline) formations are all being considered as potential storage options. Depleted oil and gas reservoirs are particularly suitable for this purpose, as they have shown by the test of time that they can effectively store buoyant fluids like oil, gas, and CO_2. In principle, storage in deep brine-filled formations is the same as storage in oil or gas reservoirs, but the geologic seals that would keep the CO_2 from rapidly rising to the ground surface need to be characterized and demonstrated to be suitable for long-term storage. Over hundreds to thousands of years, some fraction of the CO_2 is expected to dissolve in the native formation fluids. Some of the dissolved CO_2 will react with formation minerals and dissolved constituents and may precipitate as carbonate minerals, although this might take a long time. Once dissolved or precipitated as minerals, CO_2 is no longer buoyant and storage security may be increased. Coalbeds offer the potential for a different type of storage in which CO_2 becomes chemisorbed on the solid coal matrix." To view the complete MVA document, visit: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/MVA_Document.pdf.

"Developing a Pipeline Infrastructure for CO_2 Capture and Storage: Issues and Challenges." The following is from the Executive Summary of this document: "This study focuses on the pipeline infrastructure requirements for CCS in connection with compliance with mandatory [GHG] emissions reductions. The major conclusion of the study is that while CCS technologies are relatively well defined, there remain technological challenges in the [CCS] phases, and less so in transportation. Carbon capture

is the most significant cost in the CCS process. The study forecasts that the amount of pipeline that will be needed to transport CO_2 will be between 15,000 miles and 66,000 miles by 2030, depending on how much CO_2 must be sequestered and the degree to which EOR is involved. The upper end of the forecast range is of the same order of magnitude as the miles of existing U.S. crude oil pipelines and products pipelines. While there are no significant barriers to building the forecasted pipeline mileage, the major challenges to implementing CCS are in public policy and regulation. Because a CCS industry can evolve in several ways, public policy decisions must address key questions about industry structure, government support of early development, regulatory models, and operating rules. Such issues must be resolved before necessary investments in a CCS pipeline system can be made." To read the complete study, which was commissioned by the Interstate Natural Gas Association of America (INGAA) Foundation, click: http://ingaa.org/File.aspx?id=8228.

"Designing a U.S. Market for CO_2." The following is the Abstract of this document: "In this paper [the authors] focus on one component of the cap-and-trade system: the markets that arise for trading allowances after they have been allocated or auctioned. The efficient functioning of the market is key to the success of cap-and-trade as a system. [The authors] review the performance of the EU CO_2 market and the U.S. [sulfur dioxide (SO_2)] market and examine how the flexibility afforded by banking and borrowing, and the limitations on banking and borrowing, have impacted the evolution of price in both markets. While both markets have generally functioned well, certain episodes illustrate the importance of designing the rules to encourage liquidity in the market." To read the complete report from the Massachusetts Institute of Technology (MIT) Joint Program on the Science and Policy of Global Change, go to: http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt171.pdf.

"A Roadmap for a Secure, Low-Carbon Energy Economy." The following is from the Executive Summary of this document: "This 'roadmap' presents the results of a year-long effort by the Center for Strategic and International Studies (CSIS, an international policy and security-oriented think tank) and the World Resources Institute (WRI, an environmental policy think tank) to identify a set of policies to address energy security and climate change simultaneously. This document presents the results of a difficult process to reconcile the priorities of two sometimes conflicting constituencies. The resulting recommendations are designed to be implemented as a package. Policymakers must not simply pick the recommendations they favor or that are most politically palatable. The balanced approach recommended in this brief would greatly increase the United States' chances of meeting both its energy security and climate goals. It won't be easy. Shifting the United States to a secure, low-carbon economy will take decades. The costs will be high, but they will be even higher if immediate action is not taken. The United States has ample natural, human, and technological resources, and if policymakers get started promptly and make smart decisions, the benefits of this transformation can be great: economic opportunity, a healthier planet, and a more secure future for the United States." To read the complete roadmap, go to: http://pdf.wri.org/secure_low_carbon_energy_economy_roadmap.pdf.

May 2009

"Development of a Probabilistic Assessment Methodology for Evaluation of Carbon Dioxide Storage." The following is from the Introduction of this document: "USGS has a long history of assessing national and global ground- and surface-water resources and geologically based energy and mineral resources. In 2007, the Energy Independence and Security Act (Public Law 110–140) authorized the USGS to conduct a national assessment of geologic storage resources for CO_2 in cooperation with EPA and DOE. A first step in planning for a national assessment is the development of a methodology to estimate storage resource potential that can be applied uniformly to geologic formations across the United States. This report defines and describes an assessment methodology for evaluation of the resource potential for storage of CO_2 in the subsurface. Descriptions of assessment methods are available in the literature that address storage resources and capacities at a variety of scales, using a variety of storage mechanisms. The methodology presented in this report is intended for evaluations from the regional to sub-regional scale in which storage assessment units (SAUs) can be defined on the

basis of common geologic and hydrologic characteristics. The resource that is assessed is the volume of pore space into which CO_2 can be injected and retained for tens of thousands of years. The calculation of subsurface pore volume for potential CO_2 storage has been described in a number of publications. The methodology in this report uses probabilistic methods to incorporate uncertainty and natural variability in volumetric parameters. The methodology incorporates statistical evaluation of the sizes and numbers of potential storage sites to identify the range of possible storage resources within a storage assessment unit and the probability that some fraction of all the storage sites could retain a minimum storage mass of CO_2. The estimated mass of storage resource is further evaluated with parameters that describe the probability of successful containment of CO_2." The document is available at: http://pubs.usgs.gov/of/2009/1035/ofr2009-1035.pdf.

"Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act." The following is from the Summary of this document: "Today the Administrator is proposing to find that [GHGs] in the atmosphere endanger the public health and welfare of current and future generations. Concentrations of [GHGs] are at unprecedented levels compared to the recent and distant past. These high atmospheric levels are the unambiguous result of human emissions, and are very likely the cause of the observed increase in average temperatures and other climatic changes. The effects of climate change observed to date and projected to occur in the future – including but not limited to the increased likelihood of more frequent and intense heat waves, more wildfires, degraded air quality, more heavy downpours and flooding, increased drought, greater sea level rise, more intense storms, harm to water resources, harm to agriculture, and harm to wildlife and ecosystems – are effects on public health and welfare within the meaning of the Clean Air Act. In light of the likelihood that [GHGs] cause these effects, and the magnitude of the effects that are occurring and are very likely to occur in the future, the Administrator proposes to find that atmospheric concentrations of [GHGs] endanger public health and welfare within the meaning of Section 202(a) of the Clean Air Act. [Administrator Lisa P. Jackson] proposes to make this finding specifically with respect to six [GHGs] that together constitute the root of the climate change problem: [CO_2], [CH_4], [NO_X], [HFCs], [PFCs], and [SF_6]." A pre-publication copy of this document is available at: http://www.epa.gov/climatechange/endangerment/downloads/GHGEndangermentProposal.pdf.

"Measurement, Reporting, and Verification in a Post-2012 Climate Agreement." The following is from the Introduction of this document: "The Bali Action Plan initiated a new round of negotiations under the UN Framework Convention on Climate Change (UNFCCC) with the aim of achieving an 'agreed outcome' addressing the full range of climate-related issues, including mitigation, adaptation, technology, and finance. In framing these negotiations, the Bali plan introduces a new construct with its requirement that certain actions be 'measurable, reportable and verifiable.' Specifically, in paragraphs 1(b)(i) and (ii), addressing mitigation, the plan calls for consideration of: 'Measurable, reportable and verifiable nationally appropriate mitigation commitments or actions, including quantified emission limitation and reduction objectives, by all developed country Parties....[and] Nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner.' The Bali plan appears, then, to anticipate that a new climate agreement will provide for the measurement, reporting, and verification of three categories of action: developed country mitigation commitments or actions, developing country mitigation actions, and the provision of support for developing country mitigation actions." The complete document, which is part of the Pew Center's series on "Advancing the International Effort Against Climate Change," is available at: http://www.pewclimate.org/docUploads/mrv-report.pdf.

June 2009

"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.

"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.

July 2009

"Framework for Geological Carbon Sequestration on Public Land." The following is from the Executive Summary of this document: "Geological carbon sequestration has been discussed as one potential approach to reducing [GHGs] in [the] atmosphere. Sequestration of carbon in geological formations on public lands presents many challenges, and it is essential that those challenges be recognized in developing a regulatory framework. First, a proposed regulatory framework must recognize CO_2 as a commodity, resource, contaminant, waste, or pollutant. Unlike most other resources that are managed, CO_2 is a material that is either being stored for disposal or is extracted for use. CO_2 is currently leased under the Mineral Leasing Act (MLA) for uses such as refrigeration (in its solid form as dry ice), fire extinguishers, and carbonation of water and soft drinks. CO_2 also is used to enhance oil recovery which to some extent results in its sequestration. It is also important to recognize that any discussion addressing the geologic sequestration of CO_2 must distinguish between pure CO_2 and CO_2 mixed with other gases such as hydrogen sulfide, carbon monoxide, methane, and oxides of nitrogen and sulfur. These impurities have the potential to impact the economics, technical feasibility, location preferences, land use planning requirements, environmental impact mitigation, multiple-resource conflict potential, and regulatory oversight of geologic CO_2 sequestration. Impurities in CO_2 impact its value as a commodity, as well as its behavior in storage." To read the complete U.S. Department of Interior (DOI) document, go to:
http://www.doi.gov/news/09_News_Releases/EISA_Sec._714_Report_to_Congress_V12_Final.pdf.

"Geological Carbon Sequestration Opportunities in Pennsylvania." The following is from the Executive Summary of this document: "The Pennsylvania Department of Conservation and Natural Resources (DCNR) Bureau of Topographic and Geologic Survey has concluded an initial study of suitable geologic formations for the location of a state CO_2 sequestration network in accordance with Section 2815 of Act 129 of 2008. By enacting this legislation, Pennsylvania acknowledges what is generally regarded by many in the carbon sequestration research community – that the use of subsurface geologic reservoirs offers the most promising means of permanently sequestering large volumes of CO_2. Based on this preliminary assessment and the geographic coverage afforded by these potential reservoirs, the geology of Pennsylvania (subject to the adequacy of storage rights and detailed characterization work to be performed at each prospective sequestration site) can support the development of a state geologic sequestration network. Further, the Commonwealth has potential for value-added enhanced oil recovery (EOR) with permanent geologic sequestration of CO_2." To view the DCNR News Release, go to: http://www.dcnr.state.pa.us/news/newsreleases/2009/0509-carbonreport.htm. The document is available at: http://www.dcnr.state.pa.us/info/carbon/mastercstareport.pdf.

"Fortifying the Foundation: State of the Voluntary Carbon Markets 2009." The following is from the Executive Summary of this document: "This report was created to answer fundamental questions about the voluntary carbon markets such as transaction volumes, credit prices, project types, locations, and the motivations of buyers in this market. Over the past several years, these markets have not only become an opportunity for citizen consumer action, but also an alternative source of carbon finance and an incubator for carbon market innovation. As the voluntary carbon markets have rapidly gained traction, the answers, to these questions have become increasingly important to investors, policymakers, and environmentalists alike. For example, since the last edition of this report, various U.S. climate bills [have made] reference to voluntary carbon offset standards, the Japanese government [launched] a voluntary carbon-offsetting scheme, and the U.K. government [issued] an official definition of 'carbon neutral.' Last year saw further establishment and greater functionality of voluntary offset standards; the emergence of new registries; the forging of new partnerships between infrastructure providers; the formation of coalitions to encourage self-regulation; and increased market transparency." To view the Ecosystem Marketplace and New Carbon Finance report, visit: http://ecosystemmarketplace.com/documents/cms_documents/StateOfTheVoluntaryCarbonMarkets_2009.pdf.

August 2009

"A Performance Standards Approach to Reducing CO_2 Emissions from Electric Power Plants." The following is the Abstract of this document: "The premise of this paper is that significant reductions in the CO_2 emissions from fossil fuel power plants are urgently needed as part of a national effort to address global climate change. This paper describes one of several policy approaches for reducing CO_2 emissions from U.S. electric power plants, namely, the application of performance standards limiting CO_2 emissions from electric power generators. In contrast to a cap-and-trade policy that limits the total annual mass emissions of CO_2 from a collection of sources, a performance standard may apply to individual generating units or to a collection of plants. It typically specifies a maximum allowable rate of emissions per unit of product (e.g., pounds of CO_2 per megawatt-hour of electricity generated or sold), or a required percentage reduction in potential emissions. For new fossil fuel power plants that begin construction after a specified date, a New Source Performance Standard (NSPS) could restrict CO_2 emissions to levels achievable only with CCS. For existing power plants, emissions could be restricted in any of several ways, including: age-based performance standards for individual units; fleet-wide performance standards that vary over time (with flexibility for emissions trading); or performance standards applied to electricity sales from either coal plants or all plant types (also varying over time). Several types of CO_2 performance standards are evaluated and compared to a cap-and-trade policy based on nine criteria established under the Pew Center Coal Initiative. Maintaining a significant role for coal in the U.S. generating mix emerges as an especially important criterion in evaluating alternative policy options." To

read the complete document, click: http://www.pewclimate.org/docUploads/Coal-Initiative-Series-Rubin.pdf.

"Realistic Costs of Carbon Capture." The following is the Abstract of this document: "There is a growing interest in CCS as a means of reducing CO_2 emissions. However, there are substantial uncertainties about the costs of CCS. Costs for pre-combustion capture with compression (i.e. excluding costs of transport and storage and any revenue from EOR associated with storage) are examined here for First-of-a-Kind (FOAK) plant and for more mature technologies (Nth-of-a-Kind plant [NOAK]). For FOAK plant using solid fuels the levelized cost of electricity on a 2008 basis is approximately 10¢/kWh higher with capture than for conventional plants (with a range of 8-12 ¢/kWh). Costs of abatement are found typically to be approximately \$150/tCO_2 avoided (with a range of \$120-180/tCO_2 avoided). For NOAK plants, the additional cost of electricity with capture is approximately 2-5¢/kWh, with costs of the range of \$35-70/tCO_2 avoided. Costs of abatement with carbon capture for other fuels and technologies are also estimated for NOAK plants. The costs of abatement are calculated with reference to conventional supercritical pulverized coal (SCPC) plant for both emissions and costs of electricity. Estimates for both FOAK and NOAK are mainly based on cost data from 2008, which was at the end of a period of sustained escalation in the costs of power generation plant and other large capital projects. There are now indications of costs falling from these levels. This may reduce the costs of abatement so costs presented here may be 'peak of the market' estimates." This document is available at: http://e360.yale.edu/images/digest/2009-ccs-report-harvard.pdf.

"CCSReg Project Policy Brief Summaries." The following is a summary of the policy brief series: "The Carbon Capture and Sequestration Regulatory Project (CCSReg) is developing recommendations for regulation of deep geological sequestration of [CO_2] in the United States. The project is funded by a grant from the Doris Duke Charitable Foundation and anchored at Carnegie Mellon University with collaborators at the University of Minnesota, Vermont Law School, and the law firm of Van Ness Feldman. In January of 2009, the project released an interim report titled 'Carbon Capture and Sequestration: Framing the Issues for Regulation.' The interim report identifies a number of regulatory and legal barriers to the large-scale deployment of CCS technology and various options to remove them. The next stage of [the authors'] work is to prepare policy briefs that recommend specific options to address these issues." The summary policy brief is available at: http://www.ccsreg.org/pdf/Brief%20Summaries_07212009.pdf. The collection of policy briefs, including "Comprehensive Regulation of Geologic Sequestration," "Regulating Carbon Dioxide Pipelines for the Purpose of Transporting Carbon Dioxide to Geologic Sequestration Sites," "Governing Access to and Use of Pore Space for Deep Geologic Sequestration," and "Compensation, Liability and Long-Term Stewardship for CCS," is available at: http://www.ccsreg.org/policy_briefs.html.

Legislative

September 2008

***US Senator Jay Rockefeller Press Release*, "Rockefeller Authors Bill to Promote West Virginia Coal as Solution to Energy Crisis."** US Senator Jay Rockefeller introduced a bill that would fund CCS research, expand incentives for the development of clean coal technologies, and create a coal-to-liquid program. The bill, called the "Future Fuels Act of 2008," would provide the following incentives: Federal loan options for coal-to-liquid projects; tax credits for pipelines to transport coal-derived fuels; CBM capture; Integrated Gasification Combined Cycle (IGCC) projects capturing and storing 65 percent of CO_2 emissions; and CCS projects annually capturing a minimum of 500,000 metric tons of CO_2. The Future Fuels Act would also create the Future Fuel Corporation (FFC), a new research facility that brings together scientific experts with the focus of accelerating the production and deployment of CCS. The privately-run, government-funded FFC would be authorized to spend up to \$520 billion on CCS demonstration projects from 2010 to 2014. To view the entire bill, go to:

http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:s3345is.txt.pdf. To read Senator Rockefeller's official press release, visit: http://rockefeller.senate.gov/press/record.cfm?id=301368.

October 2008

***Congresswoman Tammy Baldwin Press Release*, "Baldwin Crafts Greenhouse Gas Registry,"** and ***Carbon Control News*, "House Bill Would Set New Requirements For EPA GHG Registry."** On September 11, Congresswoman Tammy Baldwin introduced legislation to ensure the U.S. Environmental Protection Agency's (EPA) national GHG registry will contain complete, reliable, and accurate information to reduce GHG emissions and address possible global climate change. The new bill, entitled the "Greenhouse Gas Registry Act," will provide additional guidance to previous legislation that requires EPA to establish a method for mandatory reporting of GHG emissions. The new legislation hopes to ensure comprehensive GHG emissions reporting while providing publicly available data that will support national, regional, state, and local climate change policies; define what entities are covered by the registry; set verification protocols without specifying "third party" verification (current EPA regulations allow for self-reporting); and mandate that EPA consider existing state and multi-state efforts, including the Climate Registry. Under current law, EPA is required to create a final registry rule by July 1, 2009. To view Congresswoman Baldwin's bill, go to: http://climate.alston.com/files/docs/EPAGHGRegistryBill.pdf. September 11, 2008, http://tammybaldwin.house.gov/PRArticle.aspx?NewsID=1494, and September 11, 2008, http://carboncontrolnews.com/index.php/ccn/show/6900. (Subscription required.)

November 2008

***Greenwire*, "Dingell, Boucher Release Draft Cap-and-Trade Bill."** Energy and Commerce Chairman John Dingell and Energy and Air Quality Subcommittee Chairman Rick Boucher released a 461-page draft climate change bill proposing the creation of a cap-and-trade system that would cover about 88 percent of US GHG emissions. The Dingell-Boucher plan would place restrictions on electric utilities, petroleum producers and importers, large industrial plants, bulk gas producers and importers, natural gas and local distribution companies, and geologic sequestration sites. In addition, the US Environmental Protection Agency (EPA) would retain the authority to handle smaller industries that release less than 25,000 tons of GHGs per year. The proposal calls for US GHG emissions to decline six percent below 2005 levels by 2020, 44 percent below 2005 levels by 2030, and 80 percent below 2005 levels by 2050. The money earned from the auctioning of permits would be used to finance energy efficiency initiatives and clean technologies; eventually all profits would be redirected back to taxpayers, barring Congressional amendment(s). The bill will not be subject to legislative hearings or a markup until 2009. The Dingell-Boucher draft bill is available at: http://www.eenews.net/features/documents/2008/10/07/document_gw_04.pdf. October 7, 2008, http://www.eenews.net/Greenwire/2008/10/07bn/.

***The New York Times*, "Chicago Unveils Multifaceted Plan to Curb Emissions of Heat-Trapping Gases,"** and ***Greenwire*, "Chicago Unveils Plan to Slash Greenhouse Gases."** Chicago Mayor Richard M. Daley unveiled the "Chicago Climate Action Plan" to promote energy efficiency with hopes of cutting GHG emissions 25 percent from 1990 levels by 2020 and 80 percent of 1990 levels by 2050. Chicago emits 34.6 million metric tons of GHGs each year and according to researchers who were commissioned by the city to study climate change, summer heat indexes could climb as high as 105 degrees by the end of the century. Some parts of the initiative have already been put into effect and, according to modelers of the plan, this will be the first time a major American city has produced models to show local effects of potential climate change. The initiative involved 18 months of research and discussion with business and labor leaders, scientists, and environmentalists. To view the Chicago Climate Action Plan, go to: http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINAL.pdf. September 18,

2008, http://www.nytimes.com/2008/09/19/us/19chicago.html?_r=3&ref=environment&oref=slogin&oref=slogin&oref=slogin (Subscription required), and September 19, 2008, http://www.eenews.net/Greenwire/2008/09/19/22/.

December 2008

***Oregon Department of Environmental Quality News Release*, "Greenhouse Gas Reporting."** On October 23, 2008, Oregon's Environmental Quality Commission approved new GHG reporting rules to monitor the state's GHG emissions sources and track progress toward meeting the state's GHG emission reduction goals. Oregon's GHG reporting rules will occur in two phases: Phase 1 will require businesses that have a state air discharge permit or a Title V permit to report GHG emissions in 2010 for emissions in 2009 and Phase 2 will require businesses that are not required to have an air quality permit to report GHG emissions in 2011 for emissions in 2010. All facilities will be required to report their GHG emissions unless their total emissions are less than 2,500 metric tons of CO_2 equivalent per year, meaning the new rules will impact roughly 600 businesses and 77 local government entities. Oregon's Department of Environmental Quality (DEQ) is currently developing reporting procedures for sources to report their GHG emissions in a format compatible with The Climate Registry, which will host the national GHG database. In the near future, the DEQ website will contain information about reporting procedures, a breakdown of DEQ-approved reporting protocols and GHG emissions quantification methods, GHG emissions calculation tools, and GHG reporting forms. The Western Climate Initiative (WCI), a collaboration of seven states (including Oregon) and four Canadian provinces, may adopt "Essential Requirements of Greenhouse Gas Emissions Reporting Rules" in 2009; a draft of the essential requirements is expected by the end of January 2009 and Oregon's GHG reporting guidelines may be adjusted to align with these requirements. The GHG reporting rules are available at: http://www.deq.state.or.us/aq/climate/docs/FinalGHGRule.pdf. October 23, 2008, http://www.deq.state.or.us/aq/climate/rulemaking.htm.

January 2009

***AZoCleantech*, "Illinois Law Means Clean Coal Power Plant Will Have to be Clean as Natural Gas."** On November 20, the Illinois Senate passed SB 1987, the Clean Coal Portfolio Standard, which would enable the development of coal gasification with CCS projects in Illinois. SB 1987 provides a framework for the development of clean coal projects and would require project developers to capture and store more than 50 percent of CO_2 emissions. The legislation calls for electric utilities that serviced at least 100,000 customers in the state as of December 31, 2005, to enter into contracts to obtain at least five percent of their supply from facilities employing CCS. The Clean Coal Portfolio Standard Law defines clean coal facilities as those scheduled to begin operations before 2016 that capture and sequester at least 50 percent of total CO_2 emissions; for facilities scheduled to begin operations after 2017, at least 90 percent of total CO_2 emissions must be captured and sequestered. Electric facilities in operation that fail to meet these targets would have to purchase offsets accordingly. Furthermore, the legislation creates the Illinois Power Agency, which would develop, finance, construct, or operate electric generation and co-generation facilities and be located near a site suitable for geologic storage. The Clean Coal Portfolio Standard is available at: http://www.ilga.gov/legislation/95/SB/09500SB1987lv.htm. November 20, 2008, http://www.azocleantech.com/Details.asp?newsID=3974.

February 2009

***Forbes*, "Wyoming to Continue Work on Carbon Storage Bills," a**nd ***Casper Star-Tribune*, "Carbon Storage Bills Could Protect Wyo Coal."** The Joint Judiciary Interim Committee of the Wyoming Legislature sponsored three new carbon storage-related bills that gained approval on January 15, 2009. They build upon legislation passed in 2008 for regulating the underground storage of CO_2 emissions

from coal plants and other sources. One bill ensures responsibility remains with those who inject CO_2 emissions. The second bill will prohibit the injecting of CO_2 in areas with recoverable hydrocarbon deposits without permission of the owner of the deposits. The third bill will specify the mineral portion of the real estate takes legal precedence over the carbon storage portion. The previous bills passed by Wyoming's Legislature, which were some of the Nation's first bills to regulate various aspects of CCS, established that Wyoming's Department of Environmental Quality will oversee carbon storage projects and that the owners of the surface property also own the underground storage rights. December 30, 2008, http://www.forbes.com/feeds/ap/2008/12/30/ap5867888.html, and January 15, 2009, http://www.trib.com/articles/2009/01/15/news/wyoming/433026826eec35ad872575400006c627.txt.

***Chicago Tribune*, "Iowa Council Releases Plan to Cut Greenhouse Gases,"** and ***Des Moines Register*, "Climate Change Report Proposes $4.8 Billion in Programs."** The 23-member Iowa Climate Change Advisory Council (ICCAC) presented a report on January 2, 2009, that suggests methods for reducing GHG emissions by as much as 90 percent by 2050. In the first of two scenarios the report proposes, the state would plan a 50 percent reduction of emissions by 2050, with interim goals of one percent by 2012 and 11 percent by 2020. In the second scenario, the state would plan a 90 percent reduction of emissions by 2050, with interim goals of three percent by 2012 and 22 percent by 2020. The report also includes 56 policy options that would help meet the second scenario goals. Both scenarios are based on 2005 numbers and projections supplied by the non-profit Center for Climate Strategies. The proposals would require the energy industry, which accounts for 31 percent of the state's GHG emissions, to reduce CO_2 emissions and increase renewable energy sources. To view the ICCAC report, click: http://www.iaclimatechange.us/capag.cfm. January 2, 2009, http://www.chicagotribune.com/news/chi-ap-ia-stateclimaterepor,0,1689286.story, and January 2, 2009, http://www.desmoinesregister.com/article/20090102/NEWS/90102013/1001.

March 2009

***Odessa American Online*, "Clean Coal Bill."** Texas officials filed a bill on January 15, 2009, to make clean coal projects economically viable through different incentives. Under the bill, which requires sequestering at least 60 percent of the CO_2 produced, the first three projects to qualify will receive up to $100 million in franchise tax credits. The bill will also give a 30-year tax rate reduction to oil producers using CO_2 generated by clean coal plants for EOR. The Bureau of Economic Geology (BEG) at the University of Texas at Austin will perform monitoring, mitigating, and accounting (MVA) duties for the CO_2 sequestration at the first three clean coal sites selected. Colorado-based Summit Power is considering building a plant at a Penwell, Texas, site, but will need to secure the 600 acres where the project would be built. To view the bill, go to: http://www.legis.state.tx.us/tlodocs/81R/billtext/pdf/HB00469I.pdf. January 15, 2009, http://www.oaoa.com/news/bill_24958___article.html/coal_texas.html.

***Bismarck Tribune*, "Carbon Capture Bills Presented."** On January 16, 2009, North Dakota's Senate Natural Resources Committee heard testimony on SB 2095, which would establish a framework for carbon sequestration. The legislation stems from a two-year project that joined state and energy industry officials from North Dakota's Department of Health to the North Dakota Petroleum Council. The bill would establish the criteria that an applicant must meet before the Industrial Commission can issue a permit to allow CO_2 storage, create a CO_2 storage facility administrative fund and a CO_2 trust fund, and set a fee that storage operators would pay for each ton of CO_2 stored. North Dakota's Director of Mineral Resources said SB 2095 would provide oversight of CO_2 sequestration projects to the Industrial Commission, which would issue a certificate after at least 10 years have passed since CO_2 injected ended. The certificate would be issued after the project successfully passed several tests and transfer title of the CO_2 and liability from the storage operators to the state. SB 2095 can be viewed at: http://www.legis.nd.gov/assembly/61-2009/bill-text/JQTA0100.pdf. January 17, 2009, http://www.bismarcktribune.com/articles/2009/01/17/news/topnews/174211.txt.

April 2009

***The Register-Herald*, "Manchin's Carbon Sequestration Bill Arrives in Senate,"** and ***The State Journal*, "Carbon Sequestration Bill Introduced in Legislature."** West Virginia Governor Joe Manchin introduced a bill to the West Virginia House and the Senate on February 26, 2009, moving to expand the use of coal and lower the CO_2 emissions from coal-fired power plants. The bill is intended to set regulations, monitor sequestration, and allow permits for renewable and alternative sources projects. It emphasizes the importance of CCS technologies and would create construction standards for future sequestration operations. A study group would also be created under the bill to develop a strategy to regulate the process and clarify the ownership of pore space, which is an underground area used for storing substances such as CO_2. To view the bill, H.B. 2682, go to: http://www.legis.state.wv.us/Bill_Status/bills_text.cfm?billdoc=hb2682%20intr.htm&i=2682&yr=2009&sestype=rs&btype=bill&docfrom=billtrack&list=Div%20of%20Energy. February 26, 2009, http://www.register-herald.com/local/local_story_057215805.html, and February 27, 2009, http://www.statejournal.com/story.cfm?func=viewstory&storyid=53253.

***Associated Press*, "Wyoming Senate Moves on Carbon Capture Bills,"** and ***Casper Star-Tribune*, "Gov Signs CO_2 Storage Bills."** Wyoming Governor Dave Freudenthal signed three bills this session aimed at jump starting an underground CO_2 storage industry in Wyoming. H.B. 80 would require companies to apply to the Wyoming Oil and Gas Conservation Commission for orders allowing them to proceed with underground storage and addresses pore space. The other two bills were H.B. 58, which would assign liability for underground storage of CO_2 to the injector, and H.B. 57, which would establish that the right to mine or drill for resources would supersede the right to store CO_2 underground. Wyoming lawmakers hope that creating a legal framework for the underground storage of CO_2 will encourage a carbon storage industry and offset the CO_2 produced by coal-fired power plants. To view H.B. 57, H.B. 58, or H.B. 80, click: http://legisweb.state.wy.us/2009/billindex/BillCrossRef.aspx?type=HB. February 18, 2009, http://finance.yahoo.com/news/Wyoming-Senate-moves-on-apf-14399731.html, and February 28, 2009, http://www.casperstartribune.net/articles/2009/02/28/news/wyoming/222972968061b3e68725756b0007d71f.txt.

May 2009

***Energy and Commerce Committee News Release*, "Chairmen Waxman, Markey Release Discussion Draft of New Clean Energy Legislation."** On March 21, 2009, Chairman Henry A. Waxman of the Energy and Commerce Committee and Chairman Edward J. Markey of the Energy and Environment Subcommittee released a draft of clean energy legislation, called the "American Clean Energy and Security Act of 2009." The draft legislation is composed of four primary sections: (1) a clean energy portion that promotes renewable sources of energy, CCS technologies, the Smart Grid, and electricity transmission; (2) an energy efficiency portion that increases energy efficiency; (3) a climate change portion that places limits on GHG emissions; (4) and a transitioning portion that promotes green jobs. In regards to CCS, the draft includes plans for a CCS demonstration program, incentives for the commercial deployment of CCS, and performance standards for new coal-fired power plants. A discussion draft summary of the American Clean Energy and Security Act of 2009 is available at: http://energycommerce.house.gov/Press_111/20090331/acesa_summary.pdf and the complete text is available at: http://energycommerce.house.gov/Press_111/20090331/acesa_discussiondraft.pdf. March 31, 2009, http://energycommerce.house.gov/index.php?option=com_content&task=view&id=1560&Itemid=1.

***Congressman Jim McDermott News Release*, "Rep. McDermott Introduces Breakthrough Legislation on Climate Change."** On March 24, 2009, U.S. Representative Jim McDermott of Washington introduced H.R. 1683, known as "The Clean Environment and Stable Energy Market Act of

2009," which would reduce GHG emissions by 80 percent by the middle of the century. Under H.R. 1683, the producers of products and/or resources that emit GHGs would be required to purchase Federal Emission Permits. The Secretary of the Treasury would establish the price for permits, which would be made available in a limited supply and occasionally adjusted to ensure that permit demand does not exceed an annual national allocation. The legislation sets a five-year price schedule for permits and prohibits the trading of permits. In addition, the legislation would also create a "Climate Protection and Economic Security Trust Fund" that would hold the revenue generated from permit sales. To view The Clean Environment and Stable Energy Market Act of 2009, go to: http://www.house.gov/mcdermott/The%20Clean%20Environment%20and%20Stable%20Energy%20Market%20Act.pdf. March 24, 2009, http://www.house.gov/mcdermott/pr090324.shtml.

***Congressman Rick Boucher News Release*, "Boucher Introduces Legislation to Accelerate the Availability of Carbon Capture and Storage Technology."** U.S. Representative Rick Boucher of Virginia introduced legislation on March 24, 2009, to advance the development and deployment of CCS technologies. The legislation would establish an annual $1 billion fund to award grants to large-scale CCS projects and finance research projects investigating several CO_2 capture methods, ranging from combustion processes and the reliability of conversion or storage in multiple storage sites. The legislation would authorize the Nation's fossil fuel-based electricity distribution utilities to hold a referendum on the establishment of a Carbon Storage Research Corporation; if approved by representatives from two-thirds of these utilities, the corporation would be created and authorized to collect a tax on most consumer electric bills derived from fossil fuel-based electricity generation. The corporation would operate as a division of the Electric Power Research Institute (EPRI). To view the legislation, click: http://www.boucher.house.gov/images//ccs%20111th.pdf. March 24, 2009, http://www.boucher.house.gov/index.php?option=com_content&task=view&id=1634&Itemid=75.

June 2009

***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.

July 2009

***Power Engineering International*, "Texas Lawmakers Pass Clean Coal Bills."** During a recent legislative session, Texas legislators passed several bills aimed at promoting clean coal technology projects. H.B. 469 establishes a sales tax exemption on certain equipment for projects that capture at least half of their CO_2 emissions, with local taxing authorities retaining the right to grant further tax breaks during a project's initial development phase. In addition, the bill authorizes $100 million franchise tax credits to the first three in-state projects that achieve a carbon capture rate of 70 percent. A provision in another piece of legislation, H.B. 469, grants a tax exemption for EOR using CO_2 captured from an anthropogenic emission source. Moreover, H.B. 1387 addresses the regulatory oversight of captured CO_2, and H.B. 1796 creates an offshore carbon storage program and a grant program for GHG emissions reducing technologies, such as CCS. Finally, H.B. 3676 and H.B. 3896 deal with attracting

energy and other economic development projects to the region. To view any of these bills, visit the Texas Legislature website at: http://www.legis.state.tx.us/. June 4, 2009, http://pepei.pennnet.com/display_article/364023/6/ARTCL/none/none/1/Texas-lawmakers-pass-clean-coal-bills/.

***U.S. Senate Committee on Energy and Natural Resources Press Release*, "Capturing Carbon."** On May 14, the U.S. Senate Committee on Energy and Natural Resources held a hearing on S. 1013, the "Department of Energy Carbon Capture and Sequestration Program Amendments Act of 2009," which would establish a national indemnity program through DOE for up to 10 commercial-scale CCS projects. The legislation authorizes DOE to conduct these commercial-scale geological storage demonstrations to reduce GHG emissions from industrial facilities, such as coal- and natural gas-fired utilities, cement plants, refineries, and other industrial processes. The legislation also requires sufficient geologic information to prove safe and permanent storage, provides liability protection and Federal indemnity for these demonstration projects, addresses legal rights property rights, requires compliance with existing relevant laws for environmental protection, outlines criteria for site closure certification, includes provisions for siting the demonstrations on public land, and establishes a training program for state regulators. The bill is available at: http://energy.senate.gov/public/_files/END09611_xml2.pdf. May 14, 2009, http://energy.senate.gov/public/index.cfm?FuseAction=PressReleases.Detail&PressRelease_id=62320b82-66cc-4e77-991f-5e418cd5e6a9&Month=5&Year=2009.

August 2009

***Senator Robert P. Casey, Jr. News Release*, "Casey, Enzi Introduce Bill to Encourage Private Investment in Carbon Capture and Storage."** On July 22, 2009, U.S. Senators Bob Casey (Pennsylvania) and Mike Enzi (Wyoming) introduced the Carbon Storage Stewardship Trust Fund Act of 2009 (S. 1502) to create a program for managing the liability of the long-term CO_2 storage. The program would provide the private sector with a framework for the legal and financial responsibilities of commercial carbon storage operations, create a carbon storage liability trust fund, and share liability between the private sector and the Federal government. Specifically, S. 1502 would: (1) require private liability insurance for geological storage facility construction and for CO_2 transport, injection, well plugging, post-closure monitoring; (2) establish a Federal trust fund from fees paid for by commercial CO_2 storage facility operators; (3) establish a Federal program to certify closure of commercial facilities and transfer of liability to the Federal government; (4) transfer post-closure liability to the Federal government or state upon closure; and (5) provide for prompt compensation for damages from the transport, injection, or storage of CO_2 in geological storage units. The Carbon Storage Stewardship Trust Fund Act of 2009 is available at: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:s1502is.txt.pdf. July 22, 2009, http://casey.senate.gov/newsroom/press/release/?id=1dcc1f91-d977-4818-b6f4-9a5226a52b62.

***U.S. Senator Dianne Feinstein Press Release*, "Senators Feinstein and Snowe Introduce Measure to Establish Federal Oversight for New Carbon Markets."** U.S. Senators Dianne Feinstein (California) and Olympia Snowe (Maine) introduced the Carbon Market Oversight Act of 2009 (S.1399), which would establish a framework to regulate the trading of carbon allowances and standardized carbon derivatives. The legislation would also grant full oversight authority for all carbon market trading to the Commodity Futures Trading Commission (CFTC). The legislation is derived from the three following principles: carbon market trading should be transparent and electronically monitored; manipulation, fraud, and speculation should be prohibited and violations should be punished; and professional standards for all registered carbon market traders, dealers, and brokers should be established. In terms of transparency, the legislation would require all carbon allowance trading and standardized allowance derivatives to occur through "registered carbon trading facilities" and be cleared by CFTC. With respect to manipulation, fraud, and speculation, "registered carbon trading facilities" would be required to monitor for manipulation using electronic tools; establish and enforce fair trading rules; and enforce aggregate

position limits. Finally, traders cannot be felons; may not have been stripped of a financial license; submit to a background check; complete at least 20 hours of pre-registration education on trading ethics, rules, and laws; and must pass a test approved by CFTC. The Carbon Market Oversight Act of 2009 is available at: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:s1399is.txt.pdf. July 7, 2009, http://feinstein.senate.gov/public/index.cfm?FuseAction=NewsRoom.PressReleases&ContentRecord_id=56882a2e-5056-8059-7641-d899a09efeac.

Announcements

September 2008

Carbon Sequestration Atlas of the United States and Canada. NETL received an APEX Grand Award from Communications Concepts, Inc. for its Carbon Sequestration Atlas of the United States and Canada. This publication, compiled by DOE/NETL, the Regional Carbon Sequestration Partnerships, and the National Carbon Sequestration Relational Database and Geographical Information System (NATCARB), presents the first coordinated assessment of carbon capture and storage (CCS) potential across the majority of the United States and portions of Western Canada. The Atlas provides an overview of the entire CO_2 capture and sequestration process and summarizes DOE's sequestration activities. The Atlas is being updated and is expected to be re-released in November 2008. To view the Atlas, click: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlas/ATLAS.pdf.

The Carbon Sequestration Newsletter Annual Index. The Carbon Sequestration Newsletter Annual Index, covering the September 2007 to August 2008 issues of NETL's Carbon Sequestration Newsletter, is now available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/subscribe.html.

Carbon Dioxide Group Launched. Scientists at Durham University launched the Carbon Storage Research Group to find efficient and reliable ways of gathering and storing CO_2 from fossil fuel-fired power plants. The new professorship is a three-way partnership between Durham University's Centre for Research into Earth Energy Systems (CeREES), DONG Energy, and Ikon Science. To learn more, go to: http://www.dur.ac.uk/news/newsitem/?itemno=6776.

October 2008

New Workgroup Focuses on Carbon Capture Regulations. Created by the Utah Department of Environmental Quality, the newly formed Carbon Capture and Geologic Sequestration Workgroup will develop state regulations for capturing CO_2 from coal-fired power plants. The workgroup is composed of three subcommittees that will study the environmental and health impacts of CO_2 capture from an emission source, the transportation of pressurized CO_2 to the sequestration site, and the injection of CO_2 into the Earth's crust. The official news release is available at: http://www.deq.utah.gov/News/2008/docs/New_Workgroup_Focuses_on_Carbon_Capture_Regs_090308.pdf.

Oklahoma to Give Carbon Credits. The Carbon Council of Oklahoma (CCO_2) assisted the Oklahoma Conservation Commission (OCC) in establishing a procedure allowing Oklahoma to become the first state to formally authorize the issuing of carbon credits for the underground injection of CO_2. The action permits OCC to issue carbon credits for specific forestry and agricultural activities. To view the CCO_2 website, go to: http://www.cco2.org/.

Interactive CCS Map Launched. The Scottish Centre for Carbon Storage (SCCS) recently launched an interactive CCS Google world map for the emerging CCS industry and interested individuals (www.geos.ed.ac.uk/ccsmap). The CCS map serves as an accurate resource where users can "zoom in"

to locate further information on their relevant site, such as the company name, a project description, the separation technology in use, and the amount of CO_2 injected. This map is a free resource and individuals are invited to send project updates. For further information or to provide updates, please contact Yasmin Bushby (yasmin.bushby@ed.ac.uk) or visit: http://www.geos.ed.ac.uk/sccs.

November 2008

Panel Addresses Key Regulatory, Liability Issues Associated With CCS. E&E TV presented a video of a roundtable discussion held at the 2008 Gasification Technologies Conference that addressed non-technical issues associated with CCS, such as economic, legal, regulatory, and liability issues. The video can be found at: http://www.eenews.net/tv/video_guide/870?page=1&sort_type=date. To view a transcript of the discussion, visit: http://www.eenews.net/tv/transcript/870.

South Africa to Publish Carbon-Storage Atlas in 2010. South Africa will begin an 18-month investigation into locating and characterizing potential carbon geological-storage sites for the compilation of a CO_2 Geological Storage Atlas. The Atlas will report methodologies and storage-potential evaluations for all of the onshore and offshore basins of South Africa to provide ranking of the basins according to risk and tectonic settings. For more information, visit: http://www.geoscience.org.za/index.php?option=com_content&task=view&id=697&Itemid=337.

December 2008

WRI Outlines Policy and Investment Guidelines for Carbon Transport and Storage. E&E TV presented a video of an executive from the World Resources Institute (WRI) discussing the next Congress' role in developing CCS. The video also outlines guidelines for CCS policymakers, regulators, and project developers. The video can be found at: http://www.eenews.net/tv/video_guide/886. To view a transcript of the discussion, go to: http://www.eenews.net/tv/transcript/886.

January 2009

Global Carbon Capture and Storage Institute to be Launched. The Australian Government plans to launch the Global Carbon Capture and Storage Institute (GCCSI) in January 2009. GCCSI will aid in Australia's goal of delivering at least 20 commercial-scale CCS plants around the world by 2020 by providing international policy and management oversight. GCCSI will work with government and industry on a global basis to accelerate the development of commercial-scale CCS technology. For more information, go to: http://www.carboncapturejournal.com/displaynews.php?NewsID=310&PHPSESSID=af607492f06143fc39fdd6753e6a6b50.

ICLEI and The Climate Registry Partner to Track GHG Emissions. The International Council for Local Environmental Initiatives (ICLEI) and The Climate Registry have partnered to promote responsible greenhouse gas (GHG) emissions accounting by encouraging governments to use the highest standards of the Local Government Operations Protocol. By becoming members of both ICLEI and The Climate Registry, governments will be given access to the organizations' comprehensive support for building emissions inventories. To view The Climate Registry's press release, click: http://www.theclimateregistry.org/downloads/press/iclei-the-climate-registry-120208.pdf.

February 2009

PCOR Receives IOGCC Award. The University of North Dakota's Energy & Environmental Research Center (EERC) received the prestigious Chairman's Stewardship Award from the Interstate Oil and Gas Compact Commission (IOGCC) for its work in the Plains CO_2 Reduction (PCOR) Regional Carbon

Sequestration Partnership (RCSP). EERC was selected in the environmental partnership category. PCOR is composed of more than 90 members that provide data, guidance, financial resources, and practical experience with CCS and terrestrial sequestration. For more information about PCOR, visit: http://www.undeerc.org/pcor/default.asp.

List of CCS Projects Released. On December 22, 2008, the American Coalition for Clean Coal Electricity (ACCCE) released a list of 80 projects in the United States that are related to various aspects of CCS. The majority are research and development (R&D) projects for the commercial deployment of CCS technology. To view the list, click: http://www.americaspower.org/Media/Files/List-of-80-Projects. An interactive U.S. map can be found at: http://www.americaspower.org/The-Facts/Clean-Coal-Technology%20.

March 2009

NETL Released Video on CCS/RCSP Program. NETL has released a video documenting the safe implementation of CCS by their seven RCSPs. The RCSPs, which were formed by DOE in 2003, focus on assessing geologic formations suitable for storage and determining the best approaches to implement carbon sequestration in each of their respective regions. To watch the video, click: http://prod-mmedia.netl.doe.gov/Video/CCS2008.wmv.

April 2009

The Bellona Foundation Launches CCS Website. The Bellona Foundation, an international, non-government organization based in Oslo, Norway, has launched an interactive website designed to educate the public on CCS. The website also includes an interactive map that explores all of the current CCS projects worldwide, as well as CO_2 sources that have the potential to apply CCS. To view the Bellona website, click: http://www.bellona.org/ccs.

May 2009

Global Carbon Capture and Storage Institute Launched. The Australian Government launched the Global Carbon Capture and Storage Institute (GCCSI) on April 16, 2009, to accelerate the global deployment of CCS technology and the sharing of information. GCCSI is part of the Australian Government's climate change strategy, which is designed to reduce carbon pollution, adapt to the impact of potential climate change, and help to develop a global solution. To view the Prime Minister of Australia's news release, go to: http://www.pm.gov.au/media/Release/2009/media_release_0913.cfm.

June 2009

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/.

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/.

July 2009

NETL Releases Annual Accomplishments Report. NETL released its annual accomplishment report, which highlights breakthroughs in research and technology development during the past fiscal year. The report showcases the successes of NETL and its research partners in advancing environmentally sound technologies to meet the Nation's energy challenges. To read the report, click: http://www.netl.doe.gov/publications/others/accomp_rpt/accomp08.pdf.

CCS Policy Brief Released. Indiana University researchers released a policy brief that states CCS can help the United States meet future energy needs and control GHG emissions. The authors recommend: (1) CCS should be deployed only if it is a cost-effective solution; (2) Congress must be cautious when designing incentives for CCS; (3) states need to be involved in developing CCS regulations, particularly with regard to property rights, safety, and liability; and (4) policymakers must consider the interests of geographic regions and business sectors. To view the policy brief, go to: http://www.iu.edu/~speaweb/faculty/pdfs/SPEA_insights_May09.pdf.

August 2009

New Zealand Joins International Carbon Storage Group. New Zealand became the 23rd member of the Carbon Sequestration Leadership Forum (CSLF) during a meeting in San Francisco, California, on June 29, 2009. To visit the CSLF website, go to: http://www.cslforum.org/. For more information, click: http://www.fossil.energy.gov/news/techlines/2009/09042-New_Zealand_Joins_CSLF.html.

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For more information on the Carbon Sequestration Program please visit our web site:
NETL Carbon Sequestration Page at:
http://www.netl.doe.gov/technologies/carbon_seq/index.html.