THE NETL CARBON SEQUESTRATION NEWSLETTER: ANNUAL INDEX

SEPTEMBER 2011 – AUGUST 2012

This is a compilation of the National Energy Technology Laboratory's monthly Carbon Sequestration Newsletter published over the last year. The newsletter is produced by the NETL to provide information on activities and publications related to carbon storage. It covers domestic, international, public sector, and private sector news. This compilation covers newsletters issued from September 2011 to August 2012. Outdated Information (e.g., conference dates, paper submittals, etc.) has been removed.

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HIGHLIGHTS

September 2011

***Fossil Energy Techline*, "Large-Scale Industrial Carbon Capture, Storage Plant Begins Construction."** Construction activities have begun at an ethanol plant in Decatur, Illinois, that will demonstrate carbon capture and storage (CCS), making it the first large-scale integrated carbon capture and storage (ICCS) demonstration project funded by the American Recovery and Reinvestment Act (ARRA) to move into the construction phase. The Illinois-ICCS project is designed to store approximately 2,500 metric tons of carbon dioxide (CO_2) per day in the saline Mount Simon Sandstone formation at depths around 7,000 feet. Researchers estimate that the formation has the potential to store all of the more than 250 million tons of CO_2 generated by industry each year in the Illinois Basin region. The injected CO_2 is a byproduct from processing corn into fuel-grade ethanol at Archer Daniels Midland Company's (ADM) biofuels plant near the storage site in Decatur, Illinois. The Illinois-ICCS project is managed by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL) and received $141.4 million in ARRA funding and $66.5 million in private sector cost-sharing. The operations phase of the project is expected to begin in late summer 2013 and create approximately 260. The U.S. Department of Energy (DOE) sponsored project is led by ADM, a member of DOE's Midwest Geological Sequestration Consortium (MGSC). To learn more about DOE's Carbon Sequestration Program, go to: http://www.fossil.energy.gov/programs/sequestration/index.html. August 24, 2011, http://www.fossil.energy.gov/news/techlines/2011/11047-Industrial_CCS_Plant_Begins_Constr.html.

***Fossil Energy Techline*, "CO_2 Injection in Kansas Oilfield Could Greatly Increase Production, Permanently Store Carbon Dioxide, DOE Study Says."** The University of Kansas Center for Research studied the feasibility of using CO_2 injection for recovering 250 million to 500 million additional barrels of oil from Kansas oilfields. The DOE-funded study examined the possibility of CO_2 flooding in the Arbuckle Formation while simultaneously providing permanent geologic storage of CO_2. Researchers used core samples from the Arbuckle Formation to simulate CO_2 flooding; according to the results, more than 50 percent of the residual oil remaining after water-flooding could be recovered from Berea Sandstone, Baker dolomite, and Arbuckle dolomite cores at pressures below the minimum miscibility pressure (MMP). Simulation studies were also conducted indicating that oil recovery is dependent on the degree of reservoir heterogeneity, and maximum efficiency can be achieved through proper design and optimization of CO_2 injection pressure, CO_2 injection rates, and the well pattern. The project is now moving into the second phase of research, in which a variety of tests will be conducted by researchers to improve characterization of Arbuckle reservoirs. The results of the tests will be used to determine the nature of the flow paths and average properties in the reservoir, assess the effect of geology on process performance, calibrate a reservoir simulation model, and identify operational issues and concerns for future applications of near-miscible CO_2 flooding. August 31, 2011, http://www.fossil.energy.gov/news/techlines/2011/11050-_Study_Confirms_CO2_Injection_Feas.html.

October 2011

***CSLF News Release*, "World-Class Carbon Capture and Storage Projects Honored by International Body."** The Carbon Sequestration Leadership Forum (CSLF) selected three projects pioneering carbon capture and storage (CCS) technologies at a large commercial scale to receive its Global Achievement Award. Each of the three projects reached milestones with sustained operation demonstrating capture, injection, and storage of several million tonnes of carbon dioxide (CO_2). The three recipients of the award are: the In Salah CO_2 Storage Project in Algeria; the Sleipner CO_2 Project in the North Sea; and the Weyburn-Midale CO_2 Project in Canada. In addition to providing scientific research opportunities, the projects are also being recognized as exemplary global models for their willingness to share their experiences in implementing CCS technologies. The CSLF is a ministerial-level international climate change initiative marshalling worldwide resources to develop improved, cost-

effective technologies for the separation, capture, transport, and long-term storage of CO_2 from power plants and industrial facilities. It is comprised of 25 nations that account for approximately 60 percent of the world's population, 76 percent of the world's anthropogenic CO_2 emissions, 75 percent of the world's energy consumption, and 70 percent of the world's energy production. To learn more about CSLF, visit: www.cslforum.org. September 21, 2011, http://www.cslforum.org/pressroom/publications/beijing_cslf_awards.pdf.

***CSLF News Release*, "Energy Ministers Endorse CCUS as Key to Combating Climate Change."** In an official announcement made by member country ministers and heads of delegation, the CSLF endorsed carbon capture, utilization, and storage technologies (CCUS) as a significant component of international plans to combat climate change. The CSLF member nations affirmed CCUS as an important element of any effective response to climate change and suggested an increase in the number of worldwide demonstrations in order to enable commercial deployment of CCUS by the end of the decade. CCUS, a group of technologies for capturing CO_2 emissions from power plants or industrial facilities for enhanced oil and gas recovery (EOR/EGR) and safe and permanent underground storage, is believed to be, an essential part of effective management and reduction of CO_2 emissions. September 22, 2011, http://www.cslforum.org/pressroom/publications/beijing_communique_92211.pdf.

November 2011

***Fossil Energy Techline*, "CO_2 Injection Begins in Illinois."** The Midwest Geological Sequestration Consortium (MGSC) has begun injecting carbon dioxide (CO_2) for their large-scale CO_2 injection test in Decatur, Illinois. The CO_2 is being captured from the Archer Daniels Midland (ADM) Ethanol Production Facility in Decatur, Illinois. A processing plant built for this project removes water from the CO_2 stream and then compresses the dry CO_2 to a supercritical phase. The compressed CO_2 then travels through a 1 mile-long pipeline to the wellhead where it is injected into the Mt. Simon Sandstone at a depth of about 7,000 feet. November 21, 2011, http://www.netl.doe.gov/publications/press/2011/111121_co2_injection.html.

***Fossil Energy Techline*, "Midwest Has Potential to Store Hundreds of Years of CO_2 Emissions."** Injection field tests conducted by the Midwest Regional Carbon Sequestration Partnership (MRCSP) indicate that their region has the geologic potential to store hundreds of years of regional carbon dioxide (CO_2) emissions primarily in deep saline formations. The MRCSP Phase II field tests included seven small-scale field validation tests: three geologic injection tests, one in each of the major geologic provinces of the region (the Michigan Basin, the Appalachian Basin, and the Cincinnati Arch) and four terrestrial field tests representative of the region's diversity (croplands, reclaimed minelands, reclaimed marshlands, and forested wetlands). The small-scale geologic field tests injected CO_2 into saline formations to validate data gathered in Phase I research. The field tests also found that oil and gas reservoirs have a high potential for enhanced oil and gas recovery (EOR/EGR). MRCSP is one of seven Regional Carbon Sequestration Partnerships (RCSPs) established by the U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) to determine the safest approaches and technology applications for the permanent storage of CO_2 emissions, which are believed to be key elements in moving toward the commercial deployment of geologic storage technologies. November 16, 2011, http://www.fossil.energy.gov/news/techlines/2011/11057-Midwest_CO2_Storage_Validated.html.

***Thunderbird Energy News Release*, "Thunderbird Energy Operations Update."** Drilling and workover operations are officially underway at Thunderbird Energy's Gordon Creek natural gas field, commencing a total of 50 new wells and five workovers of existing wells to be carried out in 2011 and 2012. The Southwest Regional Partnership on Carbon Sequestration (SWP) Deployment Phase activities are sited at Gordon Creek and the partnership is proceeding with a variety of design and permitting activities. An extensive 3-D seismic shoot will be included in the field activities in order to further understand the structure that is believed to host the previously discovered CO_2 at Gordon Creek, as well as to optimize the initial CO_2 source well that will be drilled in 2012. In addition, the existing

injection well at Gordon Creek will be re-worked to conduct a CO_2-water injectivity test. To learn more about SWP, visit: http://southwestcarbonpartnership.org/. For more information on DOE's RCSP Program, go to: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html. October 28, 2011, http://www.thunderbirdenergy.com/s/NewsReleases.asp?ReportID=487678&_Type=News-Releases&_Title=Thunderbird-Energy-Operations-Update.

December 2011

***Fossil Energy Techline*, "CO_2 Injection Begins in Illinois."** The Midwest Geological Sequestration Consortium (MGSC), one of seven of the U.S. Department of Energy's (DOE) Regional Carbon Sequestration Partnerships (RCSPs), has begun injecting carbon dioxide (CO_2) for their large-scale CO_2 injection test in Decatur, Illinois. The CO_2 is being captured from the Archer Daniels Midland (ADM) Ethanol Production Facility in Decatur, Illinois. A processing plant built for this project removes water from the CO_2 stream and then compresses the dry CO_2 to a supercritical phase. The compressed CO_2 then travels through a 1 mile-long pipeline to the wellhead where it is injected into the Mt. Simon Sandstone at a depth of about 7,000 feet. November 21, 2011, http://www.netl.doe.gov/publications/press/2011/111121_co2_injection.html.

***Kansas Geological Survey News Release*, "Kansas Geological Survey Receives $11.5 Million to Test Storage of CO_2 Underground."** DOE's National Energy Technology Laboratory (NETL) has awarded the Kansas Geological Survey (KGS) at the University of Kansas $11.5 million to test the safety and efficacy of storing CO_2 deep underground in south-central Kansas. This four-year project is a collaborative effort between government and industry and represents the first time CO_2 emitted during industrial activities will be captured and stored long-term underground in the state. The CO_2 will be transported from a global biotech company – the Abengoa Bioenergy Corporation, located near Colwich, Kansas – to an injection well at the Wellington oil field, south of Wichita in Sumner County. A minimum of 40,000 metric tons of CO_2 emitted from the plant will be compressed and injected more than 5,000 feet underground into the lower portion of the Arbuckle formation, which is located approximately 1,350 feet beneath the Wellington field's Mississippian producing zone. Also, approximately 30,000 metric tons of CO_2 will be injected into the shallower oil-producing Mississippian formation as part of an enhanced oil recovery (EOR) pilot program. December 2, 2011, http://www.kgs.ku.edu/General/News/2011/arbuckle.html.

January 2012

***FutureGen Alliance News Release*, "FutureGen 2.0 Geologic Characterization Well Successfully and Safely Completed."** Drilling of the characterization well at the FutureGen 2.0 carbon dioxide (CO_2) storage site in Morgan County, Illinois, was successfully completed, according to the FutureGen Alliance. Reaching a final depth of 4,812 feet, geologists examined the 460-foot thick Eau Claire formation that will form the caprock overlaying a 500-foot thick portion of the Mt. Simon sandstone that forms the potential CO_2 storage reservoir. Further geologic testing will be conducted on data collected from the well to confirm that the geology is suitable for CO_2 storage. Once the drill rig is removed from the well site and a smaller service rig is installed over the well head, hydrologic testing will be conducted in which saline water will be removed from the Mt. Simon sandstone and then reinjected to monitor the formation's response. When the hydrologic testing is complete, the well will be used as a monitoring well for use in future phases of the project. The FutureGen Alliance is a non-profit membership organization created to further the development and demonstration of near-zero emissions coal technology. For more information on FutureGen 2.0, visit: http://www.futuregenalliance.org/. December 20, 2011, http://www.futuregenalliance.org/wp-content/uploads/2011/12/FutureGen_2_0_Geologic_Characterization_Well_Successfully_and_Safely.pdf .

***Fossil Energy Techline*, "CO_2 Injection Begins in Illinois."** The Midwest Geological Sequestration Consortium (MGSC), one of seven U.S. Department of Energy (DOE) Regional Carbon Sequestration Partnerships (RCSPs), has begun injecting CO_2 for their large-scale CO_2 injection test in Decatur, Illinois. The CO_2 is being captured from the Archer Daniels Midland (ADM) Ethanol Production Facility in Decatur, Illinois. A processing plant built for this project removes water from the CO_2 stream and then compresses the dry CO_2 to a supercritical phase. The compressed CO_2 then travels through a one mile-long pipeline to the wellhead where it is injected into the Mt. Simon Sandstone at a depth of approximately 7,000 feet. November 21, 2011, http://www.netl.doe.gov/publications/press/2011/111121_co2_injection.html.

February 2012

***Fossil Energy Techline*, "Utility to Purchase Electricity from Innovative DOE-Supported Clean Coal Project."** The Texas Clean Energy Project (TCEP) will supply electricity to CPS Energy of San Antonio, the largest municipally owned utility in the United States, under a recently signed Power Purchase Agreement announced by the U.S. Department of Energy (DOE). CPS Energy will purchase approximately 200 megawatts (MWs) of power from TCEP, making it the first U.S. purchase by a utility of low-carbon power from a commercial-scale, coal-based power plant with carbon capture. The 400-MW TCEP plant is a first-of-its-kind integrated gasification combined cycle (IGCC) poly-generation facility capable of capturing 90 percent of the carbon dioxide (CO_2) it produces. The $2.4-billion plant was a third round selection under DOE's Clean Coal Power Initiative (CCPI), a cost-shared collaboration between the Federal government and private industry aimed at stimulating investment in low-emission, coal-based power generation technologies through successful commercial demonstrations. CCPI will provide $450 million in funding for the plant, with $211 million coming from the American Recovery and Reinvestment Act of 2009 (ARRA). The facility is expected to be fully operational in 2015. For more information on DOE's Clean Coal Technology Program and CCPI, visit: http://www.fossil.energy.gov/programs/powersystems/cleancoal/index.html. January 17, 2012, http://www.fossil.energy.gov/news/techlines/2012/12002-Utility_To_Purchase_Electricity_fr.html.

March 2012

***DOE/NETL's Carbon Storage Program*, "Funding Opportunity Announcement DE-FOA-0000652."** In support of the Carbon Storage Program, the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has issued a Funding Opportunity Announcement (FOA) to request applications that develop technologies and simulation tools to ensure geologic storage of carbon dioxide (CO_2). DE-FOA-0000652, titled, "Technologies to Ensure Permanent Geologic Carbon Storage," addresses key geologic storage challenges and uncertainties that include improving and validating containment, improving injection operations, increasing reservoir storage efficiency, and mitigating potential releases of CO_2 from the engineered containment system. The following four technical areas of interest are addressed: *Area of Interest 1* – Studies of Existing Wellbores Exposed to CO_2; *Area of Interest 2* – Advanced Wellbore Integrity Technologies; *Area of Interest 3* – Field Methods to Optimize Capacity and Ensure Storage Containment; and *Area of Interest 4* – Enhanced Simulation Tools to Improve Predictions and Enhance Performance of Geologic Storage. The FOA was posted on March 6, 2012, and applications must be received by April 17, 2012. The FOA can be accessed at: http://www.grants.gov/search/search.do;jsessionid=NFJqPXtBQGC57zbP0701H6cygPFBRhn405l0jmgGNGtBl5RqpTNM!-2135146600?oppId=150113&mode=VIEW.

***EPA News Release*, "EPA Proposes First Carbon Pollution Standard for Future Power Plants."** On March 27, the U.S. Environmental Protection Agency (EPA) proposed the first Clean Air Act (CAA) standard for carbon emissions from new power plants. EPA's rule creates a path forward for new technologies to be deployed at future facilities that will allow companies to burn coal, while emitting less carbon. The rulemaking proposed concerns new generating units that will be built in the future, and does

not apply to existing units already operating or units that will start construction over the next 12 months. For more information, visit: http://epa.gov/carbonpollutionstandard/. The proposed rule can be viewed at: http://epa.gov/carbonpollutionstandard/pdfs/20120327proposal.pdf. March 27, 2012, http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/9b4e8033d7e641d9852579ce005ae957!OpenDocument.

April 2012

***Fossil Energy Techline*, "NETL Shares Computing Speed, Efficiency to Tackle Technology Barriers."** One of the world's fastest supercomputers will be installed at the Office of Fossil Energy's (FE) National Energy Technology Laboratory's (NETL) Simulation-Based Engineering User Center this summer to help develop solutions to carbon capture, utilization, and storage technology barriers. The energy-efficient, high-performance supercomputer will be used to develop and deploy advanced simulation tools that are needed to quickly and reliably overcome energy technology challenges. Researchers from partnering organizations, such as the members of the NETL-Regional University Alliance (NETL-RUA), will be able to access the supercomputer via NETL's user centers in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, which will also provide advanced visualization hardware and software. For more information on the five universities that are part of the NETL-RUA, go to: http://www.netl.doe.gov/rua/index.html. March 29, 2012, http://www.fossil.energy.gov/news/techlines/2012/12009-NETL_Shares_Computing_Speed.html.

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May 2012

***NETL News Release*, "Energy Department Announces New Mapping Initiative to Advance North American Carbon Storage Efforts."** The U.S. Department of Energy (DOE), with partners from Canada and Mexico, released the North American Carbon Storage Atlas (NACSA), the first-ever atlas mapping the potential carbon dioxide (CO_2) storage resource in North America. According to NACSA, North America contains at least 500 years of geologic storage resource for CO_2 emissions that result from either industrial sources or power plants. In addition to estimating storage resource for North American oil and gas fields, unmineable coal, and saline formations, NACSA also documents the location of approximately 2,250 large stationary CO_2 sources, which, along with documenting the locations of storage potential of various geological sites, helps quantify the benefits and opportunities for potential carbon capture, utilization, and storage (CCUS) projects. Created through the North American Carbon Atlas Partnership (NACAP) and developed by DOE, Natural Resources Canada, and the Mexican Ministry of Energy, NACSA also includes work from DOE's Regional Carbon Sequestration Partnerships (RCSPs), whose 400 organizations provide input to DOE's National Energy Technology Laboratory's (NETL) National Carbon Sequestration Database and Geographic Information System. To view the atlas, go to: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/NACSA2012.pdf. For more information on NACAP, visit: http://www.nacsap.org/. The NACSA Interactive Viewer is available at: http://gis.netl.doe.gov/NACAP/. May 2, 2012, http://www.netl.doe.gov/publications/press/2012/120502_energy_department_announces.html.

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June 2012

***Fossil Energy Techline*, "New DOE 'Best Practices' Manual Features Top Strategies for Carbon Storage Wells."** The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) released its latest best practices manual (BPM), titled, "Carbon Storage Systems and Well Management Activities." The BPM covers the planning, permitting, design, drilling, implementation, and decommissioning of carbon dioxide (CO_2) storage wells. The manual builds on lessons learned through NETL research; the experiences of the Regional Carbon Sequestration Partnerships' (RCSPs) carbon capture, utilization, and storage (CCUS) field tests; and the acquired knowledge of industries that have been actively drilling wells for more than 100 years. In addition, the BPM provides an overview of the well-management activities associated with CCUS projects, beginning with pre-injection planning and continuing through post-injection operations; it provides a roadmap and resource for lessons learned about well-management issues and what project planners and operators can expect as a project progresses. The manual discusses the types of experts needed for a successful CCUS project team and informs the general public about the approach that project developers undertake to ensure human and environmental safety as they design, drill, maintain, and close these wells. **(See Recent Publications section for the Executive Summary and a link to the "Carbon Storage Systems and Well Management Activities" BPM.)** The BPM is available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf. June 7, 2012, http://www.fossil.energy.gov/news/techlines/2012/12025-NETL_Issues_Best_Practices_Manual.html.

***Fossil Energy Techline*, "NETL Publications Earn National Communications Awards."** NETL, the research laboratory for DOE's Office of Fossil Energy (FE), received two National Association of Government Communicators (NAGC) 2012 first-place awards for superior government communications for the Carbon Sequestration Atlas of the United States and Canada (Atlas III) and netlognews. The annual Blue Pencil & Gold Screen Awards recognize communications pieces produced by government agencies that are particularly high quality and effective. Atlas III received top honors in the Technical or Statistical Report category. The atlas updates U.S. and Canadian geologic CO_2 storage potential and provides information on the activities of DOE's RCSPs. NETL developed the atlas in collaboration with the RCSPs and the National Carbon Sequestration Database and Geographical Information System (NATCARB) team. Two versions of Atlas III – an interactive viewer and a print version – are available for viewing and downloading from NETL's website. The NAGC Blue Pencil & Gold Screen Awards program is an international competition that recognizes superior government communications products and those who produce them. Atlas III can be viewed at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIII/2010atlasIII.pdf. More information on NATCARB is available at: http://www.netl.doe.gov/technologies/carbon_seq/natcarb/index.html. June 8, 2012, http://www.fossil.energy.gov/news/techlines/2012/12026-NETL_Publications_Earn_National_Aw.html.

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July 2012

***U.S. Department of Energy News Release*, "United States, Canada Announce Next Phase of U.S.-Canada Clean Energy Dialogue."** On June 21, 2012, the U.S. Department of Energy (DOE) and Environment Canada released the U.S.-Canada Clean Energy Dialogue (CED) Action Plan II, renewing their commitment to collaborate on carbon capture and storage (CCS) technologies; build more efficient, clean, "smart" electrical grids; and advance clean energy research and development (R&D). The new action plan also places a greater emphasis on energy efficiency to take advantage of both countries' approaches and tools to help facilitate the uptake of energy efficiency technologies and practices. Accomplishments to date under the CED include: (1) completing the final phase of the Weyburn-Midale Carbon Dioxide Monitoring and Storage Project, which focuses on best practices for the safe and permanent storage of carbon dioxide (CO_2) used in enhanced oil recovery (EOR); and (2) the North American Carbon Storage Atlas (NACSA), which is the first atlas to map the potential CO_2 storage resource in North America. Action Plan II will include new and ongoing initiatives, such as projects to enhance collaboration, ensuring the integrity of permanent CO_2 storage in geological formations; an initiative to clarify U.S. and Canadian regulatory authorities for deployment of offshore renewable energy and technologies; and further investigation of the potential of power storage technologies. The CED was established in 2009 to encourage the development of clean energy technologies to reduce greenhouse gases (GHGs) and combat potential climate change in both countries. **(See Recent Publications section for a link to the "U.S.-Canada Clean Energy Dialogue Action Plan II.")** June 21, 2012, http://energy.gov/articles/united-states-canada-announce-next-phase-us-canada-clean-energy-dialogue.

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August 2012

***U.S. Department of Energy News Release*, "United States, Canada Announce Next Phase of U.S.-Canada Clean Energy Dialogue."** On June 21, 2012, the U.S. Department of Energy (DOE) and Environment Canada released the U.S.-Canada Clean Energy Dialogue (CED) Action Plan II, renewing their commitment to collaborate on carbon capture and storage (CCS) technologies, build more efficient electrical grids, and advance clean energy research and development (R&D). The new action plan also places a greater emphasis on energy efficiency. Accomplishments to date under the CED include: (1) completing the final phase of the Weyburn-Midale Carbon Dioxide Monitoring and Storage Project, which focuses on best practices for the safe and permanent storage of carbon dioxide (CO_2) used in enhanced oil recovery (EOR); and (2) the North American Carbon Storage Atlas (NACSA), which is the first atlas to map the potential CO_2 storage resource in North America. Action Plan II will include new and ongoing initiatives, such as projects to permanently store CO_2 in geological formations; clarify U.S. and Canadian regulatory authorities for deployment of offshore renewable energy and technologies; and investigate the potential of power storage technologies. The CED was established in 2009 to encourage the development of clean energy technologies to reduce greenhouse gases (GHGs) and address potential climate change. **(See Recent Publications section for a write-up and a link to the "U.S.-Canada Clean Energy Dialogue Action Plan II.")** June 21, 2012, http://energy.gov/articles/united-states-canada-announce-next-phase-us-canada-clean-energy-dialogue.

***Fossil Energy Techline*, "DOE-Sponsored Project Begins Demonstrating CCUS Technology in Alabama."** A Southeast Regional Carbon Sequestration Partnership (SECARB) project sponsored by DOE has initiated CO_2 injection using CO_2 from Alabama Power's 2,657-MW Barry Electric Generating Plant. The "Anthropogenic Test" demonstrates carbon capture, utilization, and storage (CCUS) by diverting and capturing flue gas, and transporting CO_2 approximately 12 miles to the Citronelle Dome. The injection spans two years at a rate of up to 550 metric tons of CO_2 per day, and monitoring technologies will track the CO_2 plume, measure the pressure front, evaluate trapping mechanisms, and ensure that CO_2 remains in the formation. The formation is more than 9,000 feet underground and

overlain by multiple geologic confining units. After three years of post-injection monitoring, the site will be closed and the wells either plugged or abandoned per state regulations or re-permitted for CO_2-EOR and CO_2 storage operations. August 22, 2012, http://www.fossil.energy.gov/news/techlines/2012/12037-CO2_Injection_Begins_in_Alabama.html.

Sequestration in the News

September 2011

***Carbon Capture and Storage Association Press Release*, "CCSA Launches New UK CCS Strategy."** On September 7, 2011, the Carbon Capture and Storage Association (CCSA) launched a plan to reduce 100 megatonnes (Mt) of CO_2 per year and store 500 Mt per year by 2030 in the United Kingdom (UK). The strategy outlines the potential of CCS and describes the policy and regulatory framework required by industry for the integration of CCS technologies, which could create more than 50,000 jobs by 2030. The report includes the following highlights and recommendations: (1) a framework for a maintaining the UK's CCS Demonstration Program and enabling a "Progressive Roll-Out," increasing from 1 Gigawatt (GW) in 2018 to 3 GW per year in 2030 and beyond; (2) 20 to 30 GW of power station capacity equipped with CCS by 2030 could save 100 Mt of CO_2 per year with a total of 500 Mt of CO_2 stored by 2030; (3) emphasis on the need to launch CCS demonstration projects in the industrial sector; (4) proposal development and deployment of CCS infrastructure could create cost and operational efficiencies; and (5) analysis of regulatory barriers, R&D, and political and public perception. (**See Recent Publications section in this newsletter to view a portion of the Executive Summary and a link to CCSA's "A Strategy for CCS in the UK and Beyond."**) September 7, 2011, http://www.ccsassociation.org.uk/index.php/download_file/view/252/97/.

***Wyoming Business Report*, "Casper CO_2 Pipeline Underway."** According to Denbury Resources, construction has initiated on the 232-mile Greencore Pipeline, which will transport CO_2 from the Lost Cabin gas plant located in Fremont County, Wyoming, northeast to the Bell Creek Field in Powder River County, Montana. Initial plans call for another future CO_2 pipeline to connect with the Greencore Pipeline. Officials said that crews began moving equipment onsite and plans call for the construction of 115 miles of the pipeline this year, ending in mid-November. Some of the crew will stake the right of way, while others will dig the trench for the 20-inch pipe. At the end of the project, fencing will built along the right of way. A number of inspectors will work on the project to check welds, compliance with Federal permit stipulations, and reclamation of the construction site. Once complete, the pipeline will have a capacity of 725 million cubic feet of CO_2 per day, which can be used to pump 10 to 17 percent more oil from aging oil fields. More information on the Greencore Pipeline is available at: http://www.greencorepipeline.com/. September 2, 2011, http://www.wyomingbusinessreport.com/article.asp?id=59546.

***Carbon Management Canada*, "Research Team Developing Tools for Secure Carbon Storage."** University of Saskatchewan researchers will test and develop new computer simulations for studying safe, permanent CO_2 storage underground. The project, supported by Carbon Management Canada (CMC), is aimed at determining the viability of CCS to help offset CO_2 emissions from coal-fired power plants. The University of Saskatchewan geomechanics group, in collaboration with researchers at the University of Waterloo and the University of Calgary will squeeze rock cores to simulate conditions deep underground, and inject them with pressurized water or CO_2 to monitor how they react under stress and how fluids flow. In addition, the cores can also be heated to test how they react to temperature change. The data acquired will form the basis for computer simulations that predict how the injected CO_2 might behave underground. The tools will allow for the assessment of potential CCS sites and demonstrate the most effective injection methods. August 22, 2011, http://www.carbonmanagement.ca/news/2011/08/22/research-team-developing-tools-for-secure-carbon-storage/.

October 2011

***Fossil Energy Techline*, "Innovative Texas Clean Coal Project Takes Major Step Forward as DOE Issues Record of Decision."** A DOE-issued Record of Decision (ROD), along with a cooperative agreement between DOE's Office of Fossil Energy (FE) and Summit Texas Clean Energy, LLC (STCE), states that Federal funding will be used to help build the Texas Clean Energy Project west of Midland-Odessa, Texas. The 400-megawatt (MW), environmentally clean, coal-based power plant will combine integrated gasification combined cycle (IGCC) power generation, urea production, and CCUS technology. The National Energy Technology Laboratory (NETL)-managed project will be partially funded with $450 million from DOE's Clean Coal Power Initiative (CCPI), with $211 million coming from the American Recovery and Reinvestment Act (ARRA) funds for CCPI. Approximately 90 percent of the CO_2 will be captured from the plant's syngas (about 3 million tons per year); while a portion of the captured CO_2 will be used to produce urea for fertilizer, the majority will be transported to the oilfields of the west Texas Permian Basin via existing regional pipelines and used for enhanced oil recovery (EOR). The project is expected to create approximately 1,000 jobs during construction and 300 during operations. To read DOE's ROD, click: http://www.netl.doe.gov/publications/others/nepa/ROD-EIS-0444.pdf. To learn more about DOE's Clean Coal Technology Program, visit: http://www.fossil.energy.gov/programs/powersystems/cleancoal/index.html. September 27, 2011, http://www.fossil.energy.gov/news/techlines/2011/11053-Texas_Clean_Coal_Project_Moves_For.html.

***Wyoming Business Report*, "Drilling Complete at CO_2 Storage Study Site."** The University of Wyoming Carbon Management Institute (CMI) and its industry partner Baker Hughes have completed drilling and collecting data at a 12,810-foot-deep stratigraphic test well in southwestern Wyoming. The data collected from the $16.9-million Wyoming Carbon Underground Storage Project (WY-CUSP) will be used to aid researchers in evaluating the Rock Springs Uplift as a potential geologic CO_2 storage site. WY-CUSP researchers will perform additional analyses on the 912 feet of core recovered from the well, focusing on any fractures in the rock formations. In addition, researchers will also study a comprehensive wire line log suite from the test well, which will provide information about the characteristics of the storage and sealing formations at the site; analyze fluid samples collected from the potential CO_2 storage reservoirs for trace elements, alkalinity, hardness, and other parameters; and study the results of testing of the storage reservoirs and primary sealing formation, which will allow CMI to evaluate the strength of the rock layers comprising the various formations. The project, which began in December 2009 and is scheduled for completion in December 2012, is expected to produce a detailed characterization of two saline formations in the Rock Springs Uplift for potential pilot- and commercial-scale CO_2 storage. Preliminary data indicates that the Rock Springs Uplift could store approximately 26 billion tons of CO_2 over 50 years. September 20, 2011, http://www.wyomingbusinessreport.com/article.asp?id=59938.

***Bellona*, "Alstom and Datang to Develop Two Carbon Dioxide Capture Projects in China."** China Datang Corporation and Alstom have signed a Memorandum of Understanding (MOU) for a partnership to jointly develop two CCS demonstration projects in two oilfields. Under the terms of the MOU, a 350-megawatt (MW) coal-fired power plant located in Daqing, Heilongjiang province, will be equipped with Alstom's oxy-firing technology, and a 1,000-MWe coal-fired power plant located in Dongying, Shandong province, will also be equipped with one of Alstom's CO_2 capture technologies. Both projects are expected to be completed and operating by 2015 with each capable of capturing more than 1 million tonnes of CO_2 per year. Due to their close proximity to oilfields, the projects are expected to provide cost-effective CO_2 transport, utilization, and storage, as well as serve as an effective tool for enhanced oil recovery (EOR). September 26, 2011, http://www.bellona.org/news/news_2011/Alstom_and_Datang_projects.

November 2011

***Mining Weekly*, "Centre for Carbon Capture and Storage Aiming to Start Test Injection in 2016."** According to officials, the South African Centre for Carbon Capture and Storage (SACCCS) will initiate a CCS test injection in 2016. The regulatory requirements for a test injection are being investigated under the current regulatory regime, and a scoping study is being conducted in areas indentified in a 2010 atlas as suitable for CO_2 capture; this study is expected to be completed by the end of the year, followed by a business plan. In addition, geologic modeling of storage sties, CCS financial opportunities in South Africa, and public outreach are being investigated, and a definition of capture readiness is being determined. A joint industry study investigating industry development and collateral benefits, such as job creation and preservation, is also underway. November 4, 2011, http://www.miningweekly.com/article/sa-building-up-to-ccs-test-injection-2016-2011-11-04.

***SSE Press Release*, "Joint Development Agreement on Carbon Capture and Storage."** Shell and power company SSE have entered into a joint development agreement that will enable the proposed CCS project at SSE's gas-fired power station in Peterhead, Aberdeenshire, to accelerate a number of pre-Front-End Engineering Design (FEED) studies. The intent of the agreement is to place the project in a position to undertake a full FEED study in the second half of 2012. The project's goal is to design and develop a full-chain, post-combustion CCS facility capable of capturing CO_2 from a 385-megawatt (MW) combined cycle gas turbine unit at SSE's Peterhead Power Station and transporting CO_2 with the use of existing infrastructure to the Shell-operated Goldeneye gas field in the North Sea. The Peterhead project is one of seven United Kingdom (UK) CCS applications to the European Investment Bank for consideration in the European Union's (EU) New Entrant Reserve (NER) scheme to support CCS and renewable energy projects across the EU. November 9, 2011, http://www.sse.com/PressReleases2011/JointDevelopmentAgreementCarbonCapture/.

***Magellan Petroleum Press Release*, "MPC Provides Update on Popular Infill Drilling."** Magellan Petroleum Corporation (MPC) has begun a new series of infill wells at Poplar Field in Roosevelt County, Montana, with the goal of boosting their production levels while providing useful data for implementation of a CO_2-EOR pilot. The first infill well, EPU 119, was completed in mid-October and, according to testing, produces approximately 45 barrels of oil per day. After several more weeks of pump-testing, a second interval will be tested; as more developments become definitive, Magellan will communicate results. October 25, 2011, http://www.magellanpetroleum.com/news/newsView.asp?NewsId=40968112.

December 2011

***Linc Energy Media Release*, "Linc Energy Starts Enhanced Oil Recovery (EOR) with Injection of CO_2 in Wyoming."** Linc Energy has commenced the injection of CO_2 into its first well in its Glenrock, Wyoming oil fields. Well preparation work has also begun, including the installation a new liner to ensure injection integrity. By introducing EOR in the Glenrock oil fields, Linc Energy expects to recover more than 80 million barrels of oil. As part of the operation, CO_2 will be delivered, heated to approximately 16°C, and then pumped at high pressure at an approximate rate of one to three barrels per minute. Once injection is completed, the well will "soak" for 19 to 21 days and the CO_2 will disperse in the reservoir. The well will then be flowed back to tanks where the oil, water, and CO_2 are separated. An independent analysis of the South Glenrock field determined that CO_2 flooding has the potential to produce more than 10,000 barrels per day. Planning, engineering, and permitting are underway for introduction of CO_2 for EOR at the South Glenrock B Oil Field, and will begin in the Dakota formation before the end of 2011. The formation will be the first of nine potential stratigraphic zones identifies for EOR using CO_2 injection. November 23, 2011, http://www.lincenergy.com/data/media_news_articles/LNC-Media_Release-711.pdf.

***SSE Press Release*, "UK's First Carbon Capture Plant Opens at Ferrybridge Power Station,"** and ***Reuters*, "UK's Biggest Carbon Capture Pilot Project Opens."** The largest carbon capture pilot plant

in the United Kingdom (UK) has begun capturing emissions from Scottish and Southern Energy's (SSE) 490-MW coal-fired power station at Ferrybridge, West Yorkshire. A joint development by SSE, Doosan Power Systems, and Vattenfall, the project is the first of its size to be integrated into a live power plant in the UK. According to SSE, the plant bridges the gap between small pilot trials currently underway and \ commercial-scale demonstration projects by capturing 100 tonnes of CO_2 per day from the equivalent 5-MW coal-fired generating capacity. The project represents a learning tool for industry regulators, enabling the UK to move closer to widespread deployment of CCS. For more information on the pilot project at Ferrybridge, go to: http://www.sse.com/ferrybridge/. November 30, 2011, http://www.sse.com/PressReleases2011/FerrybridgeCarbonCapturePlant/ and November 30, 2011, http://uk.reuters.com/article/2011/11/30/uk-carbon-capture-pilot-idUKTRE7AT1CI20111130.

***BBC News*, "Route of Proposed Carbon Dioxide Capture Pipe Announced."** The proposed route of a 40-mile long pipeline in the North Sea has been announced by National Grid. The underground pipeline would carry liquid CO_2 from a power station near Doncaster to formations off of the Holderness coast to be stored. If approved, construction work on the route, which was drawn up after consulting with local residents, would begin in 2014. According to National Grid, the pipe would be three feet wide and the corridor would be approximately 1 kilometer wide to allow for environmental and engineering considerations on the final route of the pipeline. Local facilities producing CO_2 emissions may also be able to connect to the pipeline in the future. November 17, 2011, http://www.bbc.co.uk/news/uk-england-humber-15781524.

***Carbon Capture Journal*, "Alstom to do Feasibility Study for CCS at Daqing Oil Fields."** China Datang Corporation and Alstom, building on a Memorandum of Understanding (MOU) signed in September 2011, have signed a feasibility study agreement for a 350-megawatt (MW) oxy-combustion CCS demonstration project located in Daqing, Heilongjiang province. Using its oxy-firing technology, Alstom will conduct the study for the project, which is scheduled to be in operation in 2015. The Daqing CCS demonstration project will be capable of capturing more than 1 million metric tonnes of CO_2 per year. In addition, the project will aim to establish the most cost-effective demonstration plant and set a benchmark for the CCS industry. November 15, 2011 http://www.carboncapturejournal.com/displaynews.php?NewsID=868.

January 2012

***B&W News Release*, "B&W Awarded $2.8 Million in DOE Funding for Carbon Capture Research."** DOE has awarded the Babcock & Wilcox Power Generation Group, Inc. (B&W PGG) $2.8 million in funding to study chemical formulations to improve the performance of its Regenerable Solvent Absorption Technology™ (RSAT) process solvent used to capture CO_2 from coal-fired power plants. B&W will contribute $700,000 toward research and development (R&D) for the project, which will be managed by the National Energy Technology Laboratory (NETL). Work will be conducted at the B&W Research Center in Barberton, Ohio, where multiple technologies have been developed and tested to capture CO_2 emissions from coal-fired power plants. December 19, 2011, http://phx.corporate-ir.net/phoenix.zhtml?c=236851&p=irol-newsArticle_print&ID=1640860&highlight=.

***The Standard*, "Report Backs Nirranda South Carbon Storage Project,"** and ***Carbon Capture Journal*, "Otway Project Findings Support Geological CO_2 Storage."** The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) Otway Project at Nirranda South in southwest Victoria, Australia, has verified the potential for geologic CO_2 storage, according to a paper published in the journal "Proceedings of the National Academy of Sciences of the USA." The project, which began in April 2008 and is now in its second stage (running until 2015), studies CO_2 storage in a nearby depleted natural gas reservoir two kilometers underground. According to the journal paper, titled, "Safe storage and effective monitoring of CO_2 in depleted gas fields," the project confirmed that depleted gas fields could store significant amounts of CO_2, and that large-scale geologic storage could be monitored. The Australian Federal Government, the Victorian State Government, and CO2CRC members support this

project. To read the journal paper, click: http://www.pnas.org/content/early/2011/12/16/1107255108.full.pdf+html. December 14, 2011, http://www.standard.net.au/news/local/news/general/report-backs-nirranda-south-carbon-storage-project/2391952.aspx and December 18, 2011, http://www.carboncapturejournal.com/displaynews.php?NewsID=883.

***Engineering News*, "Norway to Commission $1 [Billion] Carbon Capture and Storage Project in 2012."** According to the Norwegian State-owned oil and gas company Gassnova, the Technology Centre Mongstad (TCM) project in Norway will be commissioned in the second quarter of 2012. Currently under construction and approximately 85 percent complete, the $1 billion TCM project will further develop carbon capture and storage (CCS) technologies by testing, verifying, and demonstrating technology suitable for CO_2 capture facilities. For more information on TCM, the world's largest facility for testing CO_2 capture technologies, visit: http://www.tcmda.com/en/. December 1, 2011, http://www.engineeringnews.co.za/article/norway-to-commission-1bn-carbon-capture-and-storage-project-in-2012-2011-12-01.

February 2012

***Global CCS Institute Media Release*, "Global CCS Institute Supports Key Australian Carbon Capture and Storage Initiatives."** The Global CCS Institute (GCCSI) announced it will fund a package of Australian CCS demonstration projects and research initiatives that highlight the technology's role in reducing greenhouse gas (GHG) emissions. Specifically, the Institute will provide: $1.84 million in support to Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) to research the impact of CO_2 capture technology on air quality; $240,000 in support to CarbonNet for a study ensuring emissions are safely stored and accounted for; and $226,000 to study post-combustion capture deployment impacts on an existing subcritical pulverized fuel power plant (the Loy Yang A power station in Victoria, Australia). GCCSI works with organizations and governments to accelerate the broad deployment of commercial CCS. GCCSI captures knowledge from different stages of the project life cycle, across different technologies and regions, and shares it via workshops, group discussions and meetings, their digital knowledge platform, private and public discussions, case studies, reports, and other communications. January 13, 2012, http://cdn.globalccsinstitute.com/sites/default/files/media-releases/29356/global-ccs-institute-supports-key-australian-carbon-capture-and-storage-initiatives.pdf.

***Carbon Capture Journal*, "Foster Wheeler to Lead Don Valley CCS Project."** Foster Wheeler Energy Limited (Foster Wheeler) has been appointed to lead 2Co Power's CCS power plant development at the planned 650-MW Don Valley Power Project in Yorkshire, England. The Don Valley Power Project will provide low-carbon electricity to approximately 1 million homes, capturing at least 90 percent of its CO_2 output (up to 5 million tonnes a year). When built, the Don Valley Power Project will combine a coal gasification plant with CO_2 capture to a conventional-style, gas-fired power station fired by a hydrogen-rich fuel. Planning permission for the power plant has been granted and main construction activities are planned to start in 2013. To view the 2Co Energy press release, go to: http://www.2coenergy.com/download.aspx?file=resources/pdf/2Co_Power_Foster_Wheeler.pdf. To view the Foster Wheeler news release, click: http://phx.corporate-ir.net/phoenix.zhtml?c=80422&p=irol-newsArticle&ID=1654478&highlight=. February 3, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=892&PHPSESSID=ci886gldtb02u208p7omuaces1.

March 2012

***Carbon Capture Journal*, "Duke Energy & China Huaneng Sign CCS Research Agreement."** Duke Energy and China Huaneng Group will expand their research cooperation in the areas of advanced coal and carbon capture and storage (CCS) technologies as part of a recently signed three-year agreement.

A Memorandum of Understanding (MOU) on several renewable and clean-energy fronts was originally signed in 2009, when Huaneng Group developed a facility that captured 120,000 tons of CO_2 per year from the 1,320-megawatt (MW), coal-fired Shidongkou power station in China. The expanded agreement includes an engineering study to determine the potential feasibility of applying Huaneng Group's carbon capture process on Duke Energy's Gibson Station Unit 3. A Joint Working Group will be created to coordinate the project, which will be funded by the U.S.-China Clean Energy Research Center (CERC). February 18, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=898.

***Mywesttexas.com*, "Kinder Morgan CO_2 Readies Doe Canyon Expansion, adds St. Johns Field."** Kinder Morgan CO_2 announced plans to increase enhanced oil recovery (EOR) operations at two fields. The Colorado Doe Canyon field, which currently supplies 105 mmcf/day of CO_2 into the Cortez pipeline, is expected increase to 170 mmcf/day. The company's current total throughput in the Cortez pipeline is 1.25 bcf/day and the new production will increase this total to 1.3 to 1.31 bcf/day. Kinder Morgan's Katz field, which produced 200 to 250 barrels per day before CO_2 injection, is now pumping 1,300 barrels per day. In addition, a possible expansion of Kinder Morgan's McElmo Dome production is in the engineering feasibility study phase. Kinder Morgan CO_2 also recently purchased the St. Johns CO_2 field in eastern Arizona (Apache County) and western New Mexico (Catron County); early studies estimate the field's CO_2 reserves at 12 trillion cubic feet. Kinder Morgan plans to drill 4 to 6 test wells in addition to the 8 to 12 wells already in place. February 24, 2012, http://www.mywesttexas.com/business/oil/top_stories/article_3143d85f-8ad8-5997-9702-4373aea5a3d9.html.

***Reuters*, "UK Government Files Plans to Build Carbon Capture Plans,"** and ***Reuters*, "Government Publishes Details of Carbon Capture Tender."** The UK government called for proposals to build at least one CCS power plant in a notice of contract published in the European Union's (EU) official journal. The notice document also called for proposals for a wide range of engineering projects for CCS, including construction of a power plant, gas storage, and pipelines. Participants are invited to make proposals by April 13, 2012; the notification is one step short of launching the official tender, which the Department of Energy and Climate Change (DECC) anticipates to be released shortly. The EU will raise money to fund CCS or renewable energy projects through its New Entrant Reserve 300 (NEW300) Program by selling 300 million EU Allowances (EUAs). According to the notice document, DECC expects Britain's first CCS project to begin operation in the 2016 to 2020 timeframe. February 24, 2012, http://www.reuters.com/article/2012/02/24/us-britain-ccs-notice-idUSTRE81N1BY20120224, and February 24, 2012, http://uk.reuters.com/article/2012/02/24/uk-britain-ccs-notice-idUKTRE81N1CD20120224.

***Government of Saskatchewan News Release*, "Saskatchewan Partners with Research Groups in The Netherlands."** The government of Saskatchewan's Advanced Education, Employment, and Immigration Minister signed an MOU with the Petroleum Technology Research Centre (PTRC) of Regina, the University of Regina, and CATO-2 of The Netherlands to encourage the sharing of information on CCS through student exchange, research collaboration, and technology transfer. PTRC, a non-profit R&D organization that manages the Weyburn-Midale CO_2 Project, and the government of Saskatchewan also signed an MOU with INCAS^3, a Netherlands-based sensor technology institution, giving Saskatchewan access to critical sensor technologies needed to deploy new EOR technologies. March 6, 2012, http://www.gov.sk.ca/news?newsId=9a5e05de-4e3a-470c-baaa-78eb47f5b1e7.

***ABC News*, "Carbon Capture Trial Drilling Begins."** The Government of Western Australia Department of Mines and Petroleum has begun drilling in Harvey, Western Australia, to determine the feasibility of storing carbon underground. The $8.5-million South West Hub project will collect data from as deep as 1.9 miles underground at the Harvey One Well. The first non-commercial one of its kind in Western Australia and the second in Australia, the project is expected to take up to three years to complete. February 22, 2012, http://www.abc.net.au/news/2012-02-22/carbon-capture-trial-drilling-begins/3844882?section=wa.

***GreenCareer*, "Research Project to Test Geosequestration of CO_2."** Researchers from Curtin University have been awarded a $1.4 million grant from the Australian National Low Emissions Coal (ANLEC) Research & Development (R&D) Program to assess the injection capacity of CO_2 at selected sites. The two-year study will test eight cores from a range of potential CO_2 storage sites to determine their suitability for injectivity. February 14, 2012, http://www.greencareer.net.au/news-articles/research-project-to-test-geosequestration-of-co2.

April 2012

***Reuters*, "Petrofac, UK National Grid Plan Carbon Capture Plant,"** and ***Summit Power News Release*, "Summit Power, National Grid and Petrofac Team Up on DECC Carbon-Capture Program in UK."** National Grid and Petrofac announced plans to partner with Summit Power to build a 400-megawatt (MW) coal-fired power plant with carbon capture and storage (CCS) in Britain. The companies will submit the Caledonia Clean Energy Project to the United Kingdom's (UK) Department of Energy and Climate Change (DECC) for funding through the UK's CCS Delivery Competition, which is expected to re-launch a $1.6-billion tender for CCS projects. The proposed plant would be based at the Scottish port of Grangemouth, west of Edinburgh, and capture carbon emissions from more than 90 percent of its production capacity. The captured carbon dioxide (CO_2) would then be transported via pipeline by National Grid and transferred offshore for geologic storage beneath the North Sea by CO_2DeepStore, a subsidiary of Petrofac. The location of the project site provides the benefit of being close to the North Sea for CO_2 storage, as well as for potential future enhanced oil recovery (EOR) opportunities. March 20, 2012, http://www.reuters.com/article/2012/03/20/britain-ccs-caledonia-idUSL6E8EK80E20120320, and March 20, 2012, http://www.summitpower.com/in-the-news/summit-power-national-grid-and-petrofac-team-up-on-decc-carbon-capture-programme-in-uk/.

***Government of Canada News Release*, "Government of Canada Invests in Carbon Capture and Storage Technology."** Natural Resources Canada announced an investment of $14 million for a CCS demonstration project near Estevan, Saskatchewan. The Government of Canada will contribute $9 million from its ecoENERGY Technology Initiative and $5 million through Sustainable Development Technology Canada (STDC). In addition, the Saskatchewan Ministry of Environment, through its Go Green Fund, is also investing $5 million in this research and demonstration (R&D) project, which is being managed by the Petroleum Technology Research Center (PTRC). March 20, 2012, http://www.nrcan.gc.ca/media-room/news-release/2012/32/6082.

***Carbon Capture Journal*, "SaskPower & Hitachi to Build CCS Test Facility."** SaskPower and Hitachi Ltd. are partnering to build a test facility in southeastern Saskatchewan to capture CO_2 emissions from coal-fired thermal power plants. SaskPower and Hitachi will each contribute approximately $30 million toward the test facility, which will be located at SaskPower's Shand Power Station. SaskPower will act as the owner/operator of the test facility and Hitachi will supply their process development team and process equipment from their Saskatoon manufacturing facility. The test facility will accommodate a wide range of test configurations; Hitachi's amine technology will be the first technology tested at the facility and SaskPower plans to evaluate a number of current and emerging carbon capture technologies over the life of the facility. Construction of the test facility will begin in late 2012 or early 2013, and is expected to be completed in the summer of 2014. March 25, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=918&PHPSESSID=qdrk6l1btpc5ilvhchlfg0fgd0.

***The Star*, "Petronas, Total to Study Potential of CO_2 Field."** Petronas and Total will jointly study the development and production potential of a high CO_2 gas field offshore Sarawak called K5. Under the Heads of Agreement (HOA), Petronas' newly established research unit – the Exploration and Production Technology Center – and Total will explore the possibility of developing the field in ways that are technically, commercially, and environmentally viable. The scope of the study, which is expected to begin

immediately and take up to 15 months to complete, will also include the development of CO_2 management technologies in the areas of carbon capture, transportation, and storage. Discovered in 1970, K5 is a sour gas field with up to 70 percent CO_2 content located approximately 140 miles from Bintulu. If the study finds the field to be viable, it will be the first gas field with more than 50 percent CO_2 content to be developed in Malaysia. March 29, 2012, http://biz.thestar.com.my/news/story.asp?file=/2012/3/29/business/11005641&sec=business.

May 2012

***Fossil Energy Techline*, "DOE-Sponsored IGCC Project Could Lead to Lower-Cost Carbon Capture Technologies."** New research from a DOE-sponsored project at their National Carbon Capture Center (NCCC) has shown that changes in operating conditions, coupled with changes in commercially manufactured catalysts, can produce both power generation increases and significant cost savings at integrated gasification combined cycle (IGCC) power plants. The project's results have the potential to eventually lead to lower-cost carbon capture technologies and help to provide affordable, reliable, and clean energy from the Nation's domestic coal resources. The test results are being provided to manufacturers to assist them in specifying future water-gas shift (WGS) systems for IGCC plants that incorporate carbon capture, and the findings are also being implemented at a commercial IGCC plant now under construction in Kemper County, Mississippi. Further tests are being planned with other commercially available, newly formulated WGS catalysts. May 9, 2012, http://www.fossil.energy.gov/news/techlines/2012/12019-Catalyst_Tests_Successful.html.

***Reuters*, "Norway Opens Major Facility to Test Carbon Capture,"** Norway has launched a $1-billion, government-funded center to develop CCS technology. The facility, the Technology Center Mongstad (TCM), will test two post-combustion carbon capture technologies that have the potential to be upscaled to industrial-scale use. The center will be capable of testing exhaust gases from two nearby sources – a 280-megawatt (MW) combined heat and power plant, and the 10 million ton-per-year Mongstad refinery; the two sources produce flue gases with different CO_2 contents (approximately 3.5 percent and 13 percent, respectively). According to TCM's technology manager, the center has two carbon capture plants with a combined capacity to process 100,000 tons of CO_2 per year. May 7, 2012, http://www.reuters.com/article/2012/05/07/us-norway-carboncapture-idUSBRE8460SE20120507.

***Carbon Capture Journal*, "Imperial College London Opens [~$3.16 Million] Carbon Capture Pilot Plant."** Imperial College London has opened a carbon capture plant that demonstrates how CO_2 emissions can be captured by a power plant, providing hands-on education in a controlled environment to undergraduate engineers. In addition to teaching students the principles that can be applied in a range of industrial settings, the plant will also perform several other roles, such as hosting a summer school for engineering students from around the world and acting as a laboratory for Imperial academics who are improving technology to capture CO_2 emissions. It is expected that approximately 8,000 undergraduates will be trained during the plant's predicted 25-year lifespan. April 21, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=928&PHPSESSID=181cig4coo7bptbebtcc8j84e2.

***EPA News Release*, "EPA Proposes First Carbon Pollution Standard for Future Power Plants."** On March 27, the U.S. Environmental Protection Agency (EPA) proposed the first Clean Air Act (CAA) standard for carbon emissions from new power plants. EPA's rule creates a path forward for new technologies to be deployed at future facilities that will allow companies to burn coal, while emitting less carbon. The rulemaking proposed concerns new generating units that will be built in the future, and does not apply to existing units already operating or units that will start construction over the next 12 months. For more information, visit: http://epa.gov/carbonpollutionstandard/. The proposed rule can be viewed at: http://epa.gov/carbonpollutionstandard/pdfs/20120327proposal.pdf. March 27, 2012,

http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/9b4e8033d7e641d9852579ce005ae957!OpenDocument.

June 2012

***Natural Resources Canada News Release*, "Government of Canada Invests in Carbon Capture and Storage Technology,"** and ***Carbon Capture Journal*, "Canada's Husky Energy Launches CCS and EOR Project."** The government of Canada announced an investment in Husky Energy's enhanced oil recovery (EOR) and carbon capture and storage (CCS) project in Lloydminster, Saskatchewan. The investment will help support the project's goal to develop new knowledge and methods for EOR while reducing greenhouse gas (GHG) emissions. Husky Energy's facility began operating in mid-March and converts approximately 250 tonnes of CO_2 produced daily by its ethanol plant into a high-pressure liquid, which is transported to oil fields for EOR. Husky Energy is one of eight companies to receive funding from the ecoENERGY Technology Initiative, which has provided a total of approximately $150 million for industry-led initiatives to advance CCS technologies. May 17, 2012, http://www.nrcan.gc.ca/media-room/news-release/2012/61/6227, and May 20, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=949&PHPSESSID=hlevpjmfhqg35gfjc2h9n14st0.

***NewsOK.com*, "Carbon Dioxide Spurs Devon's Oil Production in Wyoming."** Devon Energy Corporation is using CO_2 to produce approximately 5,700 barrels of oil per day through EOR at its Beaver Creek operation in central Wyoming. The CO_2 used for EOR is piped from an Exxon Mobil Corporation field approximately 100 miles away. Officials believe the oil field, which has been producing oil since 1954 and includes around 18 production wells and injection wells, could produce as much as 12 million barrels of oil; to date, it has yielded approximately 3.5 million barrels. Devon Energy is currently studying the geology and reservoir properties of other fields where EOR could be applied. Wyoming lawmakers have allocated funding to help address right-of-way issues with the U.S. Interior Department's Bureau of Land Management (BLM) as part of an effort to support pipeline development to boost EOR operations. May 11, 2012, http://newsok.com/carbon-dioxide-spurs-devons-oil-production-in-wyoming/article/3674340?custom_click=pod_headline_energy-news.

***Reuters*, "Scotland Opens Research [Center] for CO_2 Oil Recovery."** Scotland's University of Edinburgh opened a research center to study the use of EOR, which experts believe has the potential to release 3 billion barrels of oil in the North Sea. Funded by the Scottish government, Scottish Enterprise, and the CCS developer 2CO, the center will conduct research under the umbrella of Scottish Carbon Capture and Storage, which is a collaboration between the University of Edinburgh, Heriot-Watt University, and the British Geological Survey. May 23, 2012, http://www.reuters.com/article/2012/05/23/us-britain-eor-centre-idUSBRE84M0RP20120523.

***Bloomberg*, "Abu Dhabi May Inject CO_2 in Offshore Fields to Boost Output."** Abu Dhabi National Oil Company (ADNOC) may start injecting CO_2 into its offshore fields for EOR, according to an official from the company's Abu Dhabi Marine Operating Co. unit. ADNOC is exploring methods to reduce the oil industry's use of the 5 billion cubic feet of gas produced daily in the United Arab Emirates. ADNOC is also working with Abu Dhabi's renewable energy company Masdar to capture carbon. ADNOC is planning to boost output to 3.5 million barrels a day by 2017, up from approximately 2.8 million barrels currently. ADNOC's onshore unit, Abu Dhabi Co. for Onshore Oil Operations, has completed a pilot project to inject 1.2 million cubic feet of CO_2 a day into the Rumaitha field and is now planning four to five pilot projects for 2013 and 2014, according to an official. June 6, 2012, http://www.rggi.org/docs/PR060412_Compliance.pdf.

July 2012

***Skyonic News Release*, "Skyonic Raises $9 Million and Signs Northwater Capital, ConocoPhillips, BP and PVS as New Investors."** Skyonic Corporation finalized funding for the construction of a carbon capture and utilization facility. The $9 million is part of a $35-million investment that aims to demonstrate the viability of capturing and reusing CO_2 as a commercial-scale venture. The new funding, which comes from Northwater Capital Management, ConocoPhillips, BP, and PVS Chemicals, will be used to support construction costs for the plant's groundbreaking, advancement of its green carbon chemistry solutions, and other R&D and operations purposes. The facility, expected to become operational in 2014 at Capitol Aggregates, Inc., in San Antonio, Texas, will capture 83,000 short tons of CO_2 and offset an additional 220,000 short tons of CO_2 annually. June 26, 2012, http://skyonic.com/wp-content/uploads/2012/06/Skyonic-Funding-Announcement-Release-June-26-2012.pdf.

***Carbon Capture Journal*, "DNV - Improving CO_2 Pipeline Design."** The DNV-led CO2PIPETRANS joint industry project (JIP) released experimental CO_2 pipeline design data to provide industry with an improved design basis. The datasets were collected during a research project undertaken in 2006 by BP as part of their Peterhead/Miller CO_2 capture and EOR project. During this project, a number of experiments were undertaken to investigate the behavior of releasing dense phase CO_2 up to 150 bar and 150°C through pipelines up to 25 mm diameter. According to DNV, the CO2PIPETRANS JIP is a cooperation of operators, suppliers, and regulators aiming to close technical knowledge gaps to commercialize CCS-related technology. The project will conclude in mid-2013 and the recommended practice "DNV-RP-J202 Design and Operation of CO2 Pipelines" will be updated. The CO2PIPETRANS data is available at: http://www.dnv.com/industry/energy/segments/carbon_capture_storage/recommended_practice_guidelines/co2pipetrans/Index.asp. June 27, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=967&PHPSESSID=935t8kmbm9gv69d29kkp7qmo87.

***2Co Energy News Release*, "BOC Takes Stake in 2Co Energy's Don Valley CCS Power Project."** BOC has entered into an agreement with 2Co Energy Limited to take a 15 percent stake in the development of the United Kingdom's (UK) Don Valley CCS Power Project in South Yorkshire. According to the agreement, BOC and its parent company Linde will supply the carbon capture technology and air separation units (ASUs) for the CCS plant, which will be built in Stainforth in the Humber Gateway. BOC will work with 2Co Energy's other contractors to complete the project's revised Front-End Engineering and Design (FEED) study. The twin ASUs will be constructed by Linde Engineering and produce the oxygen needed for the coal gasification process. In addition, Linde's Rectisol technology will be used for the carbon capture process. June 13, 2012, http://www.2coenergy.com/download.aspx?file=resources/downloads/2Co_Don_Valley CCS_power project_FINAL.pdf.

***The Guardian*, "World's First CCS [Release] Experiment Completed in Sea Off Scotland."** The world's first experiment to investigate the impact of a potential CO_2 release has been completed off the coast of Scotland. Led by Plymouth Marine Laboratory, the Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage (QICS) research project injected more than 4.5 tonnes of CO_2 into the seabed to simulate a gas release as part of a larger study on the safety of CCS technology. For 30 days, a "pop-up" lab supplied CO_2 through a borehole under the sediment to the release site, located 350 meters from the shore and 12 meters below the seabed of Ardmucknish Bay, near Oban, Scotland. Initial results of the experiment confirmed researchers' expectations. The injection has been turned off, but monitoring of the site will continue through at least September, as researchers believe ongoing monitoring and analysis will aid in furthering the understanding of how released CO_2 moves through sediment. June 29, 2012, http://www.guardian.co.uk/environment/2012/jun/29/ccs-leak-experiment?newsfeed=true.

***Bloomberg News*, "Shell Gets Conditional Alberta Approval for Carbon-Capture Plan."** Royal Dutch Shell Plc (RDSA) received conditional approval from Alberta's energy regulator for a CCS project planned north of Edmonton, Alberta, Canada. The Quest project is designed to capture and store more than 1 million tons of CO_2 per year from the Scotford upgrader near Fort Saskatchewan, Alberta, according to Shell. The approval has 23 conditions related to data collection and analysis and reporting; according to the energy board, Shell must obtain approval for any additions to the project. July 11, 2012, http://www.businessweek.com/news/2012-07-11/shell-gets-conditional-alberta-approval-for-carbon-capture-plan.

***PennEnergy*, "Alstom Advances CO_2 Capture Program at Mongstad in Norway."** After successful completion of a Phase I feasibility study, Alstom has proceeded to Phase II of the CO_2 capture technology qualification program for the full-scale CO_2 capture plant at Technology Centre Mongstad (TCM). The technology qualification program for TCM is divided into three Phases: (I) a feasibility study; (II) demonstrating the capability of the technology to achieve the performance; and (III) a concept study for the full-scale plant. Under Phase II, Alstom will test their chilled ammonia technology at TCM on flue gas from a gas-fired power station, as well as on industrial off-gas from the nearby refinery to prove that the technology performs well under conditions valid for a full-scale plant. July 2, 2012, http://www.pennenergy.com/index/power/display/4333821873/articles/pennenergy/power/gas/2012/july/alstom-advances_co2.html.

August 2012

***United Press International*, "Canada Gives Nod to CCS Project,"** and ***The Chronicle Herald*, "Alberta Board Approves First Plan to Store Gas Emissions Underground."** Canadian regulators have conditionally approved the first proposal to inject emissions from Alberta's oil sands. Shell Canada received approval for its $1.35 billion Quest underground carbon project, which calls for the permanent storage of up to 1.2 million metric tons of CO_2 a year from its Scotford upgrader. The project's plan is to pipe liquefied CO_2 to injection wells north of the upgrader and permanently and safely store it more than two kilometers underground, beneath multiple layers of rock and mineral formations, beginning in 2015. The province said its goal is to reduce CO_2 emissions by 5 million metric tons per year by 2015. The provincial regulator, the Energy Resources Conservation Board, attached 23 provisions to its consent, the majority of which relate to data collection, analysis, and reporting. July 12, 2012, http://www.upi.com/Business_News/Energy-Resources/2012/07/12/Canada-gives-nod-to-CCS-project/UPI-80471342102377/?spt=hs&or=er, and July 12, 2012, http://thechronicleherald.ca/business/116297-alberta-board-approves-first-plan-to-store-gas-emissions-underground.

***Billings Gazette*, "Wyoming Oil Field Latest Reborn with CO_2 Flooding."** Elk Petroleum and Denbury Resources were granted environmental clearance from the Bureau of Land Management to begin pumping CO_2 into an oil field near Casper, Wyoming. The two companies plan to use the CO_2 flooding to extract up to 24 million additional barrels of oil from the Grieve Oil Field, which they co-own, through the practice of EOR. Crews will construct a three-mile supply pipeline that connects the Grieve site, located approximately 50 miles west of Casper, to an already-existing Anadarko CO_2 pipeline. Construction is expected to be completed by October and in operation by November. July 31, 2012, http://billingsgazette.com/news/state-and-regional/wyoming/wyoming-oil-field-latest-reborn-with-co-flooding/article_c5c71b4b-8803-5a62-a800-aac1857d1e8e.html.

***Wyoming Business Report*, "CO_2 Pipeline Back Underway."** Construction is underway on the 232-mile Greencore pipeline north of Casper, Wyoming. The construction started in August 2011 and was suspended in November; construction is only permitted by the Federal government between August and November due to wildlife protection. The 20-inch pipeline will carry CO_2 from ConocoPhillips' gas plant at Lost Cabin in eastern Fremont County and head toward Campbell County and north to Montana's Bell

Creek field. The CO_2 will also be used in the Cedar Creek Anticline field. The Greencore pipeline has a capacity of more than 700 million cubic feet of CO_2 a day and will cost an estimated $275 million to $325 million to complete. Pipeline construction will result in more than 200 jobs in the Casper area. Greencore is a subsidiary of Denbury Resources, headquartered in Plano, Texas. August 7, 2012, http://www.wyomingbusinessreport.com/article.asp?id=63703.

Science

September 2011

***Canada.com*, "Global Warming Brings Crab Threat to Antarctica."** According to research conducted by the University of Hawaii at Manoa, potential climate change may cause the sea floor around the West Antarctic peninsula to attract a species of king crab that had previously only inhabited the Ross Sea on the opposite side of West Antarctica. Biologists conducted a remotely operated vehicle survey in Palmer Deep, a mud-floored basin in the Weldin Sea located approximately 75 miles from the edge of the continental shelf, and discovered a large, reproductive population of lithodid crabs, which were believed to be excluded from cold Antarctic continental shelf waters for more than 14 million years. The survey identified 42 crabs, all at depths lower than 2,760 feet where the water was 1.4°C; none were found at shallower depths, where the seas are colder. The waters of the West Antarctic peninsula's continental shelf warm at a rate of 0.1°C per decade, which researchers believe could allow for future advancement. This species of king crab feeds on tiny animals in the sea floor, which could have repercussions on the marine food chain. Researchers believe the total crab population in Palmer Deep could be more than 1.5 million. To view the study, which was published in the British scientific journal *Proceedings of the Royal Society B*, click: http://rspb.royalsocietypublishing.org/content/early/2011/09/05/rspb.2011.1496.short?rss=1. September 6, 2011, http://www.canada.com/technology/Global+warming+brings+crab+threat+Antarctica/5360901/story.html?id=5360901.

***Science Daily*, "Arctic Sea Ice Reached Minimum 2011 Extent, Making It Second Lowest in Satellite Record."** The University of Colorado Boulder's National Snow and Ice Data Center (NSIDC) reported that the Arctic sea ice extent fell to 1.67 million square miles (4.33 million square kilometers) on September 9, 2011. The 1.67 million square miles is more than 1 million square miles below the 1979 to 2000 monthly average extent for September and the second lowest recorded since satellites began measuring it in 1979. During the all-time low in 2007, NSIDC attributed the low sea ice extent to winds pushing more warm air over the Arctic than usual, which melted the sea ice. NSIDC scientists believe that the primary driver of low sea ice conditions is rising temperatures in the Arctic, which could lead to ice-free summers by approximately 2030 to 2040. NSIDC will issue an analysis of the 2011 results and a comparison to previous years in the coming months. NSIDC's sea ice data is provided from the Special Sensor Microwave Imager/Sounder sensor on the Defense Meteorological Satellite Program F17 satellite using methods developed at NASA's Goddard Space Flight Center. September 15, 2011, http://www.sciencedaily.com/releases/2011/09/110915163527.htm.

October 2011

***USA Today*, "Study: Climate Change to Impact Where Wine Grapes Can Grow."** According to climate scientists at Stanford University, premium wine growing areas in the United States could shrink within 30 years as a result of potential climate change. The research, published in the journal *Environmental Research Letters*, was based on a 2009 Federal report that found that average U.S. temperatures could increase by two to four degrees by 2020 compared to 1970's averages. Following their 2006 climate study, which projected that as much as 81 percent of premium U.S. wine grape acreage could become unsuitable for some varieties by the end of the century, the researchers found

that the amount of land suitable for premium wine cultivation could shrink by 50 percent in high-value areas of Northern California by 2040. In addition, the study found that potential climate change could also lead to cooler areas, such as parts of Oregon and Washington state, seeing an increase in premium grape-growing acreage. To read the Stanford University news release, visit: http://news.stanford.edu/news/2011/june/wines-global-warming-063011.html. October 6, 2011, http://www.usatoday.com/weather/climate/story/2011-10-06/climate-change-could-impact-wine-growing-regions/50682188/1.

***Science Daily*, "Unexpected Effect of Climate Change on Body Size for Many Different Species."** According to a study conducted by researchers at the National University of Singapore, potential climate change is causing a reduction in size for many different species across the world, which could affect many food webs and biodiversity. The study, which was published in the online journal *Nature Climate Change*, found that increasing temperatures have had broad effects on various species, from plants to predators, and that many organisms are already shrinking in size, with more organisms likely to follow. Researchers claim that the reductions in size have varying effects on different species, which could potentially upset ecosystems and food webs, as not all organisms are adapting to their new sizes in the same manner. October 17, 2011, http://www.sciencedaily.com/releases/2011/10/111017092029.htm.

November 2011

***San Jose Mercury News*, "Bay Area Songbirds are Getting Bigger,"** and ***Examiner*, "Scientific Study Suggests Birds are Getting Bigger to Survive Global Warming."** According to a study released by PRBO Conservative Science, potential climate change may be causing birds in central California to grow longer wings and larger bodies in order to adapt to weather conditions. The research is based partly on data that suggests over the past 40 years birds such as sparrows, chickadees, and robins are growing to respond to environmental changes. The study estimates a growth rate in central Californian birds of approximately 0.05 percent each year spanning the past four decades. According to researchers, the change in size may be due to the birds storing more fat either to prepare for the weather conditions or as a effect of an increase in food supply as changing weather patterns are resulting in more vegetation in their region. Published in the journal *Global Change Biology*, the study resulted from data collected at two long-term research stations (Palomarin at the southern end of Point Reyes National Seashore and the Coyote Creek Field Station at the southern end of San Francisco Bay) where a wide variety of birds were captured, banded with an identification tag, and weighed and measured before being released. Researchers collected data at both stations from 1971 to 2010 to draw their conclusions. November 1, 2011, http://www.mercurynews.com/science/ci_19240005, and November 13, 2011, http://www.examiner.com/green-activism-in-national/scientific-study-suggests-birds-are-getting-bigger-to-survive-global-warming.

December 2011

***ScienceDaily*, "Walnut Trees May Not Be Able to Withstand Climate Change."** Research conducted at Purdue University has found that warmer, drier summers, coupled with weather events brought on by potential climate change, could be fatal for walnut trees. Researchers studied the physiology of walnut trees, which are economically significant for their lumber, veneer, and nuts, for five years and discovered that the tree is sensitive to particular climates and would have difficulty tolerating droughts that could potentially be brought on by climate change. In addition, the study found that walnut trees are also sensitive to cold weather and do not begin sprouting leaves until nearly a month after other trees in the spring. This "defense mechanism" could be compromised by weather events associated with potential climate change; specifically, late spring frosts could kill the trees after walnuts have developed leaves. Purdue's Hardwood Tree Improvement and Regeneration Center has a walnut breeding program that is currently attempting to identify trees that can be used in different climates, with a goal of finding walnuts

that can survive in heat or cold stresses. November 29, 2011, http://www.sciencedaily.com/releases/2011/11/111129103312.htm.

***The Vancouver Sun*, "Thawing Permafrost Could Speed Global Warming, Researchers Warn,"** and ***Bloomberg*, "Permafrost Thaw May Emit More than Deforestation, Study Says."** According to an international team of scientists, thawing permafrost may contribute more to climate change than originally expected. Research conducted by biologists from the University of Florida and the University of Alaska estimated that Arctic warming of 7.5°C this century may thaw soils and release the equivalent of 380 billion tons of CO_2. The study was based on a survey of 41 international permafrost scientists who performed calculations such as the percentage of surface permafrost likely to thaw and how much CO_2 would be released as a result. The United Nations calculated that Arctic warming is nearly twice the average rate for the rest of the planet. According to the International Energy Agency (IEA), the global average temperature may rise by more than 3.5°C, implying a potential 7°C rise in the Arctic region. The report, which was published in the journal *Nature*, also concludes that this effect on the climate could be 2.5 times worse than deforestation, and under a "high warming scenario," up to 15 percent of the top three meters of permafrost could degrade by 2040, jumping to 61 percent by 2100. November 30, 2011, http://www.vancouversun.com/technology/Thawing+permafrost+could+speed+global+warming+researchers+warn/5791260/story.html and December 1, 2011, http://www.businessweek.com/news/2011-12-01/permafrost-thaw-may-emit-more-than-deforestation-study-says.html.

January 2012

***Discovery News*, "Rattlesnakes Can't Keep Up With Climate Change."** According to researchers, potential climate change could force rattlesnakes to adapt as much as 1,000 times more quickly than in the past in order to find new, tolerable habitats. The study, published in the journal "PLoS One," created maps of the ranges of 11 rattlesnake species at 4,000-year intervals, going back 320,000 years. Researchers then analyzed each era's climate conditions, studying how temperature and precipitation affected the snakes' suitable ranges. In the past, rattlesnakes moved to new habitats when facing unsuitable changes in climate to which they could not physically adapt. However, using accepted climate projections from the Intergovernmental Panel on Climate Change (IPCC) to see how potential climate change would affect them through the year 2100, researchers found that rattlesnakes would have to move from 100 to 1,000 times more quickly than they have over the last 300 millennia to survive and reach acceptable habitats. December 14, 2011, http://news.discovery.com/animals/rattlesnake-climate-change-111214.html.

***Tehran Times*, "Pair of NASA Studies Reaffirm Impact of Global Warming."** NASA officials have released a pair of studies showing that potential climate change over the next century may lead to a transformation for Earth's plants and animals. In the first report, titled, "Paleoclimate Record Points Toward Potential Rapid Climate Changes," researchers from NASA's Goddard Institute for Space Studies analyzed the Earth's paleoclimate history and suggested the possibility of changes, such as sea level rise and the change of ecological habitats, if potential climate change is not avoided. In the second study, titled "NASA – Climate Change May Bring Big Ecosystem Changes," researchers from NASA's Jet Propulsion Laboratory and the California Institute of Technology examined the effect potential climate change could have on Earth's plant life over the next three centuries, such as reducing biodiversity and affecting Earth's element cycles. The NASA report, "NASA – Climate Change May Bring Big Ecosystem Changes," is available at: http://www.nasa.gov/topics/earth/features/climate20111214.html. The NASA report, "Paleoclimate Record Points Toward Potential Rapid Climate Changes," is available at: http://www.nasa.gov/topics/earth/features/rapid-change-feature.html. December 20, 2011, http://www.tehrantimes.com/science/93704-pair-of-nasa-studies-reaffirm-impact-of-global-warming.

February 2012

***Discovery News*, "Birds Flying Faster Due to Climate Change."** According to new research, birds are flying at faster speeds over the Southern Ocean due to an increase in wind speed believed to be caused by potential climate change. The study, published in the journal "Science," focused on the wandering albatross, a bird that inhabits the Crozet islands in the Southern Ocean, and found that higher wind speeds are currently having a beneficial impact by shortening the length of foraging trips, improving breeding success, and leading to weight gain. Researchers analyzed years of data from tracking the Crozet albatross population's feeding and breeding; their travels were tracked with satellite transmitters since 1989. They found that winds in the Southern Ocean have increased by an average of 15 percent over the past few decades, with both the male and female albatross flight speeds increasing as well; females alone traveled approximately 124 more miles per day in 2010 than in 1990. However, the research also shows that if wind strength continues to increase, so too will a shift of all animals in the region; by 2080, this could lead to the wind flow currently centered around Crozet to move further south, affecting the birds' ability to reach foraging areas. January 12, 2012, http://news.discovery.com/animals/birds-flying-faster-wind-speeds-120112.html.

***ABC Science*, "Carbon Dioxide Affecting Fish Brains: Study."** According to the Australian Research Council's Centre of Excellence for Coral Reef Studies, rising CO_2 emissions may be affecting the brains and central nervous systems of sea fish. In a paper published in the journal "Nature Climate Change," the researchers claim that CO_2 concentrations predicted to occur in the ocean by the end of this century could interfere with the ability of sea fish to hear, smell, and evade predators. The Australian researchers gathered data by testing the performance of baby clown and damsel fishes alongside their predators in sea water containing higher levels of dissolved CO_2. They found that while the predators were affected, the baby fish experienced more effects, including with their sense of hearing, which they use to locate and hone in on reefs at night and avoid them during the day to evade predators. In addition, the research showed that the fish tended to lose their natural instinct to turn left or right, which is important in schooling behavior. January 16, 2012, http://www.abc.net.au/science/articles/2012/01/16/3409053.htm.

***Wired.com*, "Global Warming May Make Reptiles Smarter."** Researchers have found that potential warmer temperatures could be making some reptiles smarter. In a study published in the journal "Biology Letters," researchers incubated the eggs of *Bassiana duperreyi*, a mountain-dwelling Australian skink, at warmer temperatures, finding that the reptile grew up to perform well on a learning task. After incubating two different sets of eggs at different temperatures, researchers tested the hatchings, sending each lizard running by touching its tail, then measuring the time it took for each to find the open shelter and how often it tried to enter a blocked door. The results showed that the warm-incubated lizards learned to find the open shelter much more readily than the cool-incubated lizards. January 11, 2012, http://www.wired.com/wiredscience/2012/01/warmer-lizard-intelligence/.

March 2012

***ScienceDaily*, "Earliest Horses Show Past Global Warming Affected Body Size of Mammals."** A group of scientists have discovered a correlation between temperature and body size in mammals from approximately 56 million years ago. In a study published in the journal "Science," researchers analyzed the evolution of the earliest horses, the Sifrhippus sandrae, and found that as temperatures increased, their body size decreased. During the Paleocene-Eocene Thermal Maximum – a 175,000-year climate event in which increased concentrations of CO_2 in the atmosphere and oceans led to an average global temperature increase of approximately 10 to 20 degrees – researchers traced the evolution of the Sifrhippus. They found that during a 130,000-year period, the mammals shrank approximately 30 percent, from 12 pounds to 8.5 pounds. Over the next 45,000 years, they increased to approximately 15 pounds. Researchers also analyzed the correlations with aridity and CO_2 levels, but found temperature

to be the most likely factor in determining body size. February 23, 2012, http://www.sciencedaily.com/releases/2012/02/120223142634.htm.

***Oak Ridge National Laboratory News Release*, "ORNL-Led Team Advances Science of Carbon Accounting."** A team of researchers at ORNL have developed a method to determine the carbon balance of North America. Using inventory records from the United States, Canada, and Mexico that track changes in the amount of carbon in various reservoirs, such as plants, soils, and wood, the researchers generated estimates of the current rate of atmospheric CO_2 storage over North America, which then allowed them to calculate the state of the science in determining North America's carbon balance. The data showed that storage is neither permanent nor fixed, and that much of the current carbon storage in North America is associated with the forest sector in the Northwest and Southeast. The research paper, titled, "Reconciling estimates of the contemporary North American carbon balance among terrestrial biosphere models, atmospheric inversions, and a new approach for estimating net ecosystems exchange from inventory-based data," is available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2011.02627.x/abstract. March 6, 2012, http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20120306-00.

April 2012

***ScienceMag.org*, "Climate Change Sends Beetles Into Overdrive."** According to a new study conducted by researchers at the University of Colorado, mountain pine beetles could see a boost in reproduction in the Colorado region due to potential climate change. The pine beetles, which travel from New Mexico north into Canada, normally reproduce once per year, beginning in late summer along high-altitude sites where they swarm to individual lodgepole pines or related trees. Females dig deep burrows inside the trees' trunks and drop their eggs, depositing a special fungus that the larvae feed on throughout the winter before leaving their burrows the following August. The fungus, however, also destroys the trees. Researchers began tracking the growth of the pine beetles in 2009 and discovered that the insects developed into adults beginning in mid-June or even earlier, which they attributed to warmer weather. In addition, the beetles, upon emerging from the burrows, immediately began attacking nearby pines and laying their own eggs. The cycle would repeat, adding a second season of reproduction. As a result, the pine beetle population has expanded across the region; in British Canada alone, the insects gutted and killed approximately 13 million hectares of trees in about a decade. March 16, 2012, http://news.sciencemag.org/sciencenow/2012/03/climate-change-sends-beetles-int.html?ref=hp.

***MIT News Release*, "MIT Research: Study Finds Room to Store CO_2 Underground."** A study released by researchers at the Massachusetts Institute of Technology (MIT) suggests that the United States has the ability to store at least a century's worth of its CO_2 emissions in saline formations. In the study, the researchers modeled how the CO_2 would move through the rock, accounting for the capacity of the formations as well as the rate of injection that could be sustained over time. March 20, 2012, http://web.mit.edu/press/2012/greenhouse-gas-in-aquifers.html.

May 2012

***Phys.Org*, "Global Change Puts Plankton Under Threat."** According to a study published in the journal "Nature Climate Change," changes in seawater pH levels, due to carbon acid formed as a result of increased CO_2 emissions, could lead to poor growth or the eventual death of marine plankton. The research claims that approximately half of human-generated CO_2 emissions dissolves in the ocean, forming carbon acid and leading to a decrease in seawater pH levels. Coupled with potential climate change, researchers believe the ocean acidification-induced changes could pose a concern to the survival of plankton. The research team used mathematical modeling and cellular physiology to reveal that marine plankton will eventually experience a more acidic environment than previously thought. The

research will be further developed on key Australian phytoplankton species. May 4, 2012, http://phys.org/news/2012-05-global-plankton-threat.html.

***Reuters*, "New Antarctic Ice Shelf Threatened by Warming."** According to new research from the Alfred Wegener Institute for Polar and Marine Research, the Filchner-Ronne Ice Shelf, which borders the Weddell Sea on the eastern side of Antarctica, may melt by the end of the century due to potential climate change and accelerate rising sea levels. The 450,000-km^2 ice shelf acts as a buffer against warming waters, eroding the base of the larger glaciers currently located on land. Researchers predict that the melting of the Filchner-Ronne shelf could add up to 4.4 mm per year to rising global sea levels. According to the latest estimates based on remote sensing data, and in addition to the estimated 1.7-mm annual rise due to the expansion of the oceans as the water warmed, melting glaciers and ice shelves contributed 1.5 mm a year to rising global sea levels from 2003 to 2010. Research for this study was funded by the European Union's (EU) "Ice2sea" Program, which was set in the wake of the 2007 Intergovernmental Panel on Climate Change (IPCC) report highlighting ice sheets as a remaining uncertainty in rising sea level projections. May 9, 2012, http://www.reuters.com/article/2012/05/09/us-antarctica-global-warming-idUSBRE84811E20120509.

June 2012

***AG Professional*, "Rising CO_2 Levels Impact Rice Gene Flow."** Research conducted by the U.S. Department of Agriculture (USDA) shows that rising levels of atmospheric CO_2 facilitate the flow of genes from wild or weedy rice plants to domesticated rice varieties, resulting in domesticated plants taking on characteristics that could affect future rice production. Researchers documented how atmospheric CO_2 concentrations affected growth by conducting a two-year combination growth chamber and field study and observing the exchange of genetic material between the two plant types. Twenty-four-hour CO_2 concentrations in the chambers were set at 300, 400, and 600 parts per million (ppm), and were then approximated to the atmospheric CO_2 values present during the end of the 19th century, the current value, and projected values for the end of the 21st century, respectively. A genetic analysis of the two rice varieties' hybrid seed offspring was then conducted. The results indicated that the transfer of wild genetic material to the domesticated rice line resulted in the production of seed with weedy characteristics that would affect domesticated rice production. May 24, 2012, http://www.agprofessional.com/news/Links-between-weedy-domesticated-rice-to-rising-CO2-levels-153570545.html.

***GlobalPost*, "Climate Change Threatens Baby Sea Turtles, Study Says."** According to a study conducted by Drexel University, leatherback baby sea turtles are at risk of being baked inside their nests due to potential climate change. Researchers studied six nesting seasons (2004 to 2010) in which leatherback mothers planted their eggs in holes in the sand, with the babies hatching approximately two months later. By analyzing the hatched and spoiled eggs, the researchers found that the turtles had the highest mortality rate during seasons governed by El Niño, which are hot and dry. Using the region's model of potential climate change, which shows increased temperatures and conditions relative to El Niño, it was concluded that the turtles could be affected. May 24, 2012, http://www.globalpost.com/dispatch/news/science/120524/climate-change-threatens-baby-sea-turtles-study-says.

***New York Times*, "Butterfly Species Expands Range With Climate Change."** A study conducted by University of York researchers showed that a warming climate has led to brown argus butterflies spreading into England approximately 50 miles northward over the past 20 years to allow for its caterpillars to feed of the countryside's wild geranium plant population. The researchers determined the shift in the butterflies' range was due to potential climate change by studying data on their locations and populations over four decades. Uncommon in England in the 1980s, the brown argus has also seen an increase in population. The butterflies' typical diet is the rock rose, abundant in the south of England, but the caterpillars have since developed a taste for geraniums as the summer temperatures have

increased, leading them to expand their range northward. May 24, 2012, http://www.nytimes.com/2012/05/29/science/butterfly-species-expands-range-with-climate-change.html?_r=4.

July 2012

"Induced Seismicity Potential in Energy Technologies (2012)." The following is a brief background on this National Academy of Sciences Report: "In the past several years, some energy technologies that inject or extract fluid from the Earth, such as oil and gas development and geothermal energy development, have been found or suspected to cause seismic events, drawing heightened public attention. Although only a very small fraction of injection and extraction activities among the hundreds of thousands of energy development sites in the United States have induced seismicity at levels noticeable to the public, understanding the potential for inducing felt seismic events and for limiting their occurrence and impacts is desirable for state and [Federal] agencies, industry, and the public at large. To better understand, limit, and respond to induced seismic events, work is needed to build robust prediction models, to assess potential hazards, and to help relevant agencies coordinate to address them." The complete version is available for download at: http://dels.nas.edu/Report/Induced-Seismicity-Potential-Energy-Technologies/13355. In addition, PTRC has released a statement regarding seismic risk of geological storage of CO_2; it is available at: http://www.ptrc.ca/siteimages/PTRC%20Response%20to%20Zoback%20%20Gorelick_21June12_draft.pdf.

***Msnbc.com*, "Melting Sea Ice Could Decimate Emperor Penguins."** According to biologists at the Woods Hole Oceanographic Institution, potential climate change could result in the melting of sea ice surrounding Antarctica that the emperor penguin species depends on for survival. The emperor penguins raise their young on the sea ice during the winter; in addition, krill, a shrimplike animal on which the emperor penguins feeds, consume algae that grow on the underside of the sea ice. By observing emperor penguins at Terre Adélie in East Antarctica every winter since 1962, researchers developed a mathematical model describing the population dynamics of emperor penguins; factored in the effects of sea ice; and, by using a series of climate models, analyzed how potential climate change might affect the species' numbers. A wide range of results were produced and the median projection estimated a decline from 3,000 breeding pairs to 575 by 2100. June 20, 2012, http://www.msnbc.msn.com/id/47894638.

August 2012

***NY Daily News*, "Nepal Snow Leopard Threatened by Climate Change."** According to scientists from the World Wildlife Fund, the habitat of Nepal's snow leopards is under threat due to potential climate change. By using computer climate models and on-the-ground tracking of snow leopards' movements, the scientists discovered that the changing weather patterns are pushing forests further into the leopard's territory, which could potentially reduce their hunting grounds by approximately 40 percent by the end of the century. The species live in high alpine areas (above the tree line, but generally below 16,500 feet) where they are able to track their prey. Experts believe that as few as 500 adults currently inhabit Nepal's Himalayas. Under a "worst-case" scenario, scientists also predicted the leopards' 7,700 square-mile territory would be reduced to 4,500 square-miles by the end of the century. July 17, 2012, http://india.nydailynews.com/newsarticle/50057c86c3d4cacd35000002/nepal-snow-leopard-threatened-by-climate-change.

***ScienceDaily*, "Humpback Whales Staying in Antarctic Bays Later Into Autumn."** A new study conducted by Duke University researchers has found that a large number of humpback whales are remaining in bays along the Western Antarctic Peninsula long after their annual migrations to distant breeding grounds were believed to begin. According to the study, the humpback whales are staying in the Antarctic bays to feast on shrimp-like krill late into the austral autumn due to the increasingly delayed

arrival and reduced extent of annual winter sea ice cover, believed to be a result of potential climate change. Published in the journal "Endangered Species Research," the study provides the first density estimates for humpback whales in both open and enclosed habitats along the peninsula in late autumn. The highest densities of whales were found in narrow, enclosed sections of Wilhelmina Bay, Andvord Bay, and the Errera Channel. The lowest densities (as low as .02 whales per square kilometer) were found in the open water of the adjacent Gerlache Strait. July 30, 2012, http://www.sciencedaily.com/releases/2012/07/120730155059.htm.

Policy

September 2011

***Platts*, "Canada Calls for Gradual Phase Out of Coal-Fired Plants Starting in 2015,"** and ***Calgary Herald*, "Ottawa Unveils New Coal Power Regulations."** Canada's Environment Minister unveiled draft regulations on Friday, August 19, 2011, that call for the country to begin phasing out coal-fired power plants beginning in 2015 in an effort to reduce greenhouse gas (GHG) emissions from the power sector. Under the new rules, which are open to comment for 60 days after officially being, new plants will be required to be as clean as natural gas-fired generators and emit no more than 375 tonnes of CO_2 per GW-hour of power produced. In addition, coal plants would have to cut nearly 70 percent of emissions; existing coal facilities will have to meet new performance standards. August 19, 2011, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Coal/6392742, and August 20, 2011, http://www.calgaryherald.com/technology/Ottawa+unveils+coal+power+regulations/5282911/story.html.

"The environmental impact and risk assessment of CO_2 capture, transport and storage – An evaluation of the knowledge base." The following is the Abstract of this article: "In this study, [the authors] identify and characterize known and new environmental consequences associated with CO_2 capture from power plants, transport by pipeline and storage in geological formations. [The authors] have reviewed (analogous) environmental impact assessment procedures and scientific literature on CCS options. Analogues include the construction of new power plants, transport of natural gas by pipelines, underground natural gas storage (UGS), natural gas production, and enhanced oil recovery (EOR) projects. It is investigated whether crucial knowledge on environmental impacts is lacking that may postpone the implementation of CCS projects. This review shows that the capture of CO_2 from power plants results in a change in the environmental profile of the power plant. This change encompasses both increase and reduction of key atmospheric emissions, being: [nitrogen oxide (NO_X), sulfur dioxide (SO_2), ammonia (NH_3), particulate matter, mercury (Hg), hydrogen fluoride (HF) and hydrogen chloride (HCl)]. The largest trade-offs are found for the emission of NO_X and NH_3 when equipping power plants with post-combustion capture. Synergy is expected for SO_2 emissions, which are low for all power plants with CO_2 capture. An increase in water consumption ranging between 32 [percent] and 93 [percent] and an increase in waste and by-product creation with tens of kilotonnes annually is expected for a large-scale power plant (1 GW_e), but exact flows and composition are uncertain. The cross-media effects of CO_2 capture are found to be uncertain and to a large extent not quantified. For the assessment of the safety of CO_2 transport by pipeline at high pressure an important knowledge gap is the absence of validated release and dispersion models for CO_2 releases. [The authors] also highlight factors that result in some (not major) uncertainties when estimating the failure rates for CO_2 pipelines. Furthermore, uniform CO_2 exposure thresholds, detailed dose–response models and specific CO_2 pipeline regulation are absent. Most gaps in environmental information regarding the CCS chain are identified and characterized for the risk assessment of the underground, non-engineered, part of the storage activity. This uncertainty is considered to be larger for aquifers than for hydrocarbon reservoirs. Failure rates are found to be heavily based on expert opinions and the dose–response models for ecosystems or target species are not yet developed. Integration and validation of various sub-models describing fate and transport of CO_2 in various compartments of the geosphere is at an infant stage. In conclusion, it is not possible to execute a quantitative risk assessment for the non-engineered part of the storage activity with

high confidence." **Joris Koornneef, Andrea Ramírez, Wim Turkenburg, and André Faaij**, *Progress in Energy and Combustion Science*, Available online August 25, 2011, doi:10.1016/j.pecs.2011.05.002, http://www.sciencedirect.com/science/article/pii/S0360128511000402. (Subscription may be required.)

"The potential impacts of climate-change policy on freshwater use in thermoelectric power generation." The following is the Abstract of this article: "Climate change policy involving a price on carbon would change the mix of power plants and the amount of water they withdraw and consume to generate electricity. [The authors] analyze what these changes could entail for electricity generation in the United States under four climate policy scenarios that involve different costs for emitting CO_2 and different technology options for reducing emissions out to the year 2030. The potential impacts of the scenarios on the U.S. electric system are modeled using a modified version of the U.S. National Energy Modeling System and water-use factors for thermoelectric power plants derived from electric utility data compiled by the U.S. Energy Information Administration. Under all the climate-policy scenarios, freshwater withdrawals decline 2–14 [percent] relative to a business-as-usual (BAU) scenario of no U.S. climate policy. Furthermore, water use decreases as the price on CO_2 under the climate policies increases. At relatively high carbon prices (>$50/tonne CO_2), however, retrofitting coal plants to capture CO_2 increases freshwater consumption compared to BAU in 2030. [The authors'] analysis suggests that climate policies and a carbon price will reduce both electricity generation and freshwater withdrawals compared to BAU unless a substantial number of coal plants are retrofitted to capture CO_2." **Munish K. Chandel, Lincoln F. Pratson, and Robert B. Jackson**, *Energy Policy*, Available online August 6, 2011, doi:10.1016/j.enpol.2011.07.022, http://www.sciencedirect.com/science/article/pii/S0301421511005465. (Subscription may be required.)

October 2011

***Carbon Capture Journal*, "IEA Reports Progress on CCS Regulation."** The International Energy Agency (IEA) released the second edition of the IEA Carbon Capture and Storage Legal and Regulatory Review, providing an up-to-date snapshot of global CCS regulatory developments. The second edition reflects the ongoing progress toward comprehensive CCS legal and regulatory frameworks at national and regional levels. Examples of progress discussed in the review include: in the United States, the Environmental Protection Agency (EPA) finalized two Federal rules related to geologic storage; in Canada, Alberta became the first Canadian jurisdiction to finalize its regulatory framework; in Europe, four guidance documents have been released by the European Commission in addition to the European Union (EU) CCS Directive; and in Australia, the Federal government finalized secondary legislation to support offshore geologic CO_2 storage. The review also reflects progress being made in other countries that are implementing or considering CCS regulation, including Malaysia, South Africa, Vietnam, Mexico, and Indonesia. In addition to providing national-level updates of progress, the review also addresses long-term liability for stored CO_2, developments made by the international CCS community in advancing CCS deployment through amendments to international marine treaties and in the context of the United Nations Framework Convention on Climate Change (UNFCCC) framework, and the process behind developing CCS regulatory frameworks. October 9, 2011, http://www.carboncapturejournal.com/displaynews.php?NewsID=850.

"Managing private and public adaptation to climate change." The following is from the Abstract of this article: "Adaptation to climate change is already being delivered by public and private actors, yet there has been little analysis of the relationships between the providers and beneficiaries of adaptation. This paper reviews the type of actors that are supplying adaptation services and their motivations. [The authors] then focus on a specific, under-explored case of adaptation: that of privately provided adaptation public goods and services, the realization of which is contingent on the individual management of private goods and private risks. Following the work of Olson (1965) [the authors] find that the benefits of the privately provided adaptation public good do not necessarily accrue back to the (same) individuals who are the providers. The characteristics of this particular form of public good pose specific institutional challenges. In this paper [the authors]: (1) explore the characteristics and defining

features of these privately provided adaptation public goods; (2) argue that this form of adaptation provisioning is increasingly recognized as a feature in climate change adaptation (and/or social transformation) problems; (3) review existing cases of effective/ineffective management of these public goods; and (4) outline the institutions that may be required to facilitate the management of these public goods for adaptation." **Emma L. Tompkins and Hallie Eakin**, *Global Environmental Change*, Available online October 12, 2011, doi:10.1016/j.gloenvcha.2011.09.010, http://www.sciencedirect.com/science/article/pii/S0959378011001452. (Subscription required.)

November 2011

***New York Times*, "California Adopts Limits on Greenhouse Gases,"** and ***Los Angeles Times*, "California Becomes First State to Adopt Cap-and-Trade Program."** On October 20, 2011, the California Air Resources Board (CARB) voted unanimously to adopt the first state-administered cap-and-trade regulations in the Nation, setting limits on greenhouse gas (GHG) emissions and creating a market for industries within the state to trade carbon credits. Cap-and-trade is the centerpiece of California's AB 32, which mandates a reduction in CO_2 emissions to 1990 levels by 2020. Starting in 2013, California's largest CO_2 emitters will be required to meet the caps or buy carbon credits to offset their emissions in a carbon trading market that will be operated by CARB. The second phase of compliance, which will begin in 2015, is expected to include 85 percent of California's emissions sources. By 2016, approximately $10 billion in carbon allowances are expected to be traded through the statewide market, making it the second-largest carbon market in the world behind the EU. If successful, the program could serve as a model for future markets in other states. October 20, 2011, http://www.nytimes.com/2011/10/21/business/energy-environment/california-adopts-cap-and-trade-system-to-limit-emissions.html?_r=1, and October 21, 2011, http://www.latimes.com/news/local/la-me-cap-trade-20111021,0,1125437.story.

***IPAC-CO_2 News Release*, "Public Review Begins of World's First Standard for Geologic Storage of CO_2."** A draft of a standard for geologic storage of CO_2, developed by CSA Standards and the International Performance Assessment Centre for Geologic Storage of Carbon Dioxide (IPAC-CO_2), is now available for public review on a clause-by-clause basis through the CSA Standards online public review system. When completed, the new standard will be submitted to the Standards Council of Canada and the American National Standards Institute (ANSI) in the United States for bilateral recognition. In addition to providing guidelines for regulators, industry, and others involved with scientific and commercial CCS projects, the new standard will also provide the basis for development of the international standards by the International Organization for Standardization (ISO). November 4, 2011, http://www.ipac-co2.com/images/stories/files/ipac-2011-news%20release-standard-final.pdf.

"Communicating CCS: Applying communications theory to public perceptions of carbon capture and storage." The following is the Abstract of this article: "Although prior studies provide some insight into the effects of communication factors such as source credibility and argument strength on public perceptions of CCS, comparisons and integration of insights from these studies is complicated by the multitude of different and interdependent factors that influence communication outcomes. Here [the authors] provide an overview of these factors, structured in terms of a communications matrix and drawing on experience with CCS projects and studies to date. Using the matrix [the authors] organize empirical findings of the effects of four major communication input factors (source, message, channel, receiver) on communication output factors such as, attention, interest, understanding, and attitudes. The resulting 'map' of opinion shapers may guide development of public communication, engagement, and participation in CCS projects. The key message to communicators is that by knowing how input factors influence output factors, it can be decided which features are useful to achieve an intended communication outcome. Obtaining knowledge of input–output interactions requires early public engagement to explore public needs and concerns. Critical to the communication outcome is the extent to which CCS communication is an informed, open and objective public discussion process in which different views on the technology are acknowledged." **S. Brunsting, P. Upham, E. Dütschke, M. De**

Best Waldhober, C. Oltra, J. Desbarats, H. Riesch, and D. Reiner, *International Journal of Greenhouse Gas Control*, Available online October 22, 2011, doi:10.1016/j.ijggc.2011.09.012, http://www.sciencedirect.com/science/article/pii/S1750583611001824. (Subscription may be required.)

December 2011

***Western Climate Initiative*, "Quebec Adopts Cap-and-Trade Regulation."** Quebec has adopted a regulation for a cap-and-trade system for GHG emission allowances, according to the Minister of Sustainable Development, Environment, and Parks. Industries that emit 25,000 tonnes or more of CO_2 equivalent per year will be subject to the system, which will begin a transition year on January 1, 2012, allowing emitters to familiarize themselves with how the system works and make the necessary adjustments. The system will be officially enforced on January 1, 2013, at which point all emitters will be required to meet their new obligations for capping and reducing GHG emissions. Beginning in 2015, companies that import or distribute fuels in Quebec that are used in the transportation and building sectors, and whose emissions exceed the 25,000-tonne threshold, will also be subject to capping and reducing emissions. For more information, visit: http://www.mddep.gouv.qc.ca/changements/carbone/Systeme-plafonnement-droits-GES-en.htm. December 15, 2011, http://www.westernclimateinitiative.org/news-and-updates/139-quebec-adopts-cap-and-trade-regulation.

"Development of a CO_2 network for industrial emissions." The following is the Abstract of this article: "The application of Carbon Capture and Storage (CCS) technology to energy-intensive processes is starting to attract attention, presenting an opportunity for developing multi-user CO_2 transportation networks. Recognizing that most industrial facilities have not been designed with CCS in mind, this paper begins by looking at the practical issues associated with retrofitting CCS to industrial facilities. It then explores the technical and legal issues associated with building a CO_2 network. This is followed by an analysis of the costs involved. Having identified the key issues, a case study from North East England is presented as an example of what is possible in an area of high CO_2 emissions. The paper concludes by considering the issues involved in sizing a CO_2 network which can evolve to meet future needs and linking that to the development of policy." **Dermot J. Roddy**, *Applied Energy*, Available online November 9, 2011, doi:10.1016/j.apenergy.2011.10.016, http://www.sciencedirect.com/science/article/pii/S0306261911006672. (Subscription may be required.)

January 2012

***PRWeb*, "World Bank's New Greenhouse Gas Accounting Methodology Approved by SCS."** Scientific Certification Systems (SCS), a global leader in providing third-party environmental and sustainability certification, auditing, testing, and standards, has approved the World Bank's new GHG accounting methodology under the Verified Carbon Standard (VCS). Based on the Western Kenya Smallholder Agriculture Carbon Finance project, which focuses on helping farmers adopt practices that increase carbon in soil and biomass on agricultural lands, the new methodology will allow project developers to estimate GHG reductions of sustainable land management practices (SALM). January 6, 2012, http://www.prweb.com/releases/2012/1/prweb9082681.htm.

"Effectiveness of setting cumulative carbon dioxide emissions reduction targets." The following is the Abstract of this article: "In current policies, targets for GHG and more specifically CO_2 emissions are set on the basis of annual emissions. However, warming effects associated with global average temperature rise depend on accumulation of GHG in the atmosphere. Due to the quantity and longevity of CO_2 in the atmosphere there is increasing awareness that taking into account cumulative CO_2 emissions in defining targets for restraining the growth of CO_2 emissions would be particularly effective. The notion of effectiveness is linked to measuring the degree of achievement of the objectives. Considering CO_2 emissions targets set over a few decades, the path of emissions reduction contains

relevant information that cannot be captured by a classical measure like the distance to the target. The main contribution of this paper is the definition of an original measure of [CO_2] reduction effectiveness, which allows comparison of specified CO_2 reduction paths expressed in deterministic or probabilistic ways. Appropriate metrics are used to illustrate the proposed measure which in particular captures the importance of early action. The χ_0 measure is applied to simple what-if scenarios for the EU27 electricity and heat sector to 2050, evaluating the impact of each scenario with respect to a reference case." **Gianfranco Chicco and Paule M. Stephenson**, *Energy*, Available online December 17, 2011, doi:10.1016/j.energy.2011.11.024, http://www.sciencedirect.com/science/article/pii/S0360544211007420. (Subscription may be required.)

February 2012

"A Policy Strategy for Carbon Capture and Storage." The following is from the Executive Summary of this document: "This guide for policy makers aims to assist those involved in designing national and international policy related to CCS. Covering both conventional fossil-fuel CCS and bioenergy with CCS (BECCS), it explores development of CCS from its early pilot and demonstration project stages through to wide-scale deployment of the technology. The report concentrates on the economic and political economy perspective, leaving legal, safety, environmental and regulatory issues to be addressed by other analysis…The IEA's *Energy Technology Perspectives* indicates that CCS is an essential part of the portfolio of technologies needed to achieve substantial global GHG emissions reduction in the most cost-effective manner. The technology could - if governments commit to specific policies - account for nearly one-fifth of the emissions reduction required to cut GHG emissions from energy use in half by 2050. The scale of potential future deployment of CCS is enormous, spanning manufacturing, power generation and hydrocarbon extraction worldwide." The complete International Energy Agency (IEA) report is available for download at: http://iea.org/papers/2012/policy_strategy_for_ccs.pdf.

"Public acceptance of CCS system elements: A conjoint measurement." The following is the Abstract of this article: "The aim of the present study is to examine public preferences regarding the characteristics of the three elements of CCS: capture, pipeline, and storage. A random sample of 139 Swiss citizens received basic information about CCS online and then participated in an experiment. A conjoint measurement of CCS acceptance and analysis of variance was used to examine respondents' preferences for characteristics of CCS elements. This approach allowed respondents to make trade-offs by expressing preferences for complete CCS systems instead of evaluating single elements in isolation. [The authors'] results show that people put most emphasis on pipelines near their homes and on the type of plant the CO_2 originates from. A 'Not in my backyard [NIMBY] effect' was found both for pipelines and storage. This NIMBY effect, however, disappears when CO_2 from a biogas-fired plant is used for the injection. [The authors] conclude that it may be possible to avoid the NIMBY effect for geological storage field trials by using BECCS." **Lasse Wallquist, Selma L'Orange Seigo, Vivianne H.M. Visschers, and Michael Siegrist**, *International Journal of Greenhouse Gas Control*, Available online December 30, 2011, doi:10.1016/j.ijggc.2011.11.008, http://www.sciencedirect.com/science/article/pii/S1750583611002180. (Subscription may be required.)

"A socio-technical framework for assessing the viability of carbon capture and storage technology." The following is the Abstract of this article: "CCS is seen as a key technology to tackle climate change. The principal idea of CCS is to remove carbon from the flue gases arising from burning fuels for electricity generation or industrial applications and to store the carbon in geological formations to prevent it from entering the atmosphere. Policy makers in several countries are supportive of the technology, but a number of uncertainties hamper its further development and deployment. The paper makes three related contributions to the literatures on socio-technical systems and technology assessment: (1) it systematically develops an interdisciplinary framework to assess the main uncertainties of CCS innovation. These include technical, economic, financial, political and societal issues; (2) it identifies important linkages between these uncertainties; and (3) it develops qualitative and

quantitative indicators for assessing these uncertainties. This framework aims to help decision making on CCS by private and public actors and is designed to be applicable to a wider range of low carbon technologies. The paper is based on a systematic review of the social science literature on CCS and on insights from innovation studies, as well as on interviews about assessment of new technologies with experts from a range of organizations and sectors." **Nils Markusson, Florian Kern, Jim Watson, Stathis Arapostathis, Hannah Chalmers, Navraj Ghaleigh, Philip Heptonstall, Peter Pearson, David Rossati, and Stewart Russell**, *Technical Forecasting and Social Change*, Available online January 4, 2012, doi:10.1016/j.techfore.2011.12.001, http://www.sciencedirect.com/science/article/pii/S0040162511002769. (Subscription may be required.)

March 2012

***Dubai Chronicle*, "Dubai to Reduce Carbon Dioxide and Greenhouse Gas Emissions."** Dubai announced plans to develop a strategy to reduce GHG emissions and implement a carbon trading scheme. The Dubai Supreme Council of Energy (DSCE) signed an MOU with the Dubai Carbon Centre of Excellence (DCCE) to verify preliminary studies on CO_2 emissions. The initiative, part of the Dubai Integrated Energy Strategy 2030, will include research on GHG emissions and the development of frameworks for introducing a comprehensive CO_2 abatement program. In addition, DCCE will complete a detailed inventory of Dubai's GHG emissions in line with International Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC) requirements, as well as recommend viable targets for reducing CO_2 and GHGs and a methodology to monetize emissions. The strategy would also examine the best options to build a "Clean Energy Fund" linked to CO_2 reduction and dedicated to new investment in energy-related projects in Dubai. February 26, 2012, http://www.dubaichronicle.com/2012/02/26/dubai-carbon-dioxide-greenhouse-gas-emissions/.

"Overall environmental impacts of CCS technologies – A life cycle approach." The following is the Abstract of this article: "In the last decade the environmental performance of climate effective CCS considering also other environmental effects has become focus of several studies. With various technological CCS options under development, the field of possible technical solutions is hardly covered yet. This paper identifies technologies whose environmental effects have been [analyzed] from a life cycle perspective. Life Cycle Assessment (LCA) has proved to be a helpful tool to investigate the environmental consequences associated with the introduction of CCS. Even though, big differences in underlying assumptions of existing studies make comparison difficult, some general effects can be described. In general the intended reduction in [global warming potential (GWP)] by introducing CO_2 capture (up to – 85 [percent] hard coal oxyfuel, – 95 [percent] lignite oxyfuel, – 80 [percent] natural gas post-combustion) is combined with an increase of other environmental effects, regardless of capture technology, time horizon or fuel considered. Performing the [normalization] step shows that acidification and human toxicity potential have to be watched as well. Additionally, three parameter sets have been identified, which have a significant impact on the effects: (a) development of plant efficiencies and energy penalties; (b) capture efficiency; (c) fuel origin and composition." **Petra Zapp, Andrea Schreiber, Josefine Marx, Mike Haines, Jurgen-Friedrich Hake, and John Gale**, *International Journal of Greenhouse Gas Control*, Available online February 24, 2012, doi:10.1016/j.ijggc.2012.01.014, http://www.sciencedirect.com/science/article/pii/S175058361200028X. (Subscription may be required.)

"[Characterizing] CCS learning: The role of quantitative methods and alternative approaches." The following is the Abstract of this article: "A number of energy scenario studies have suggested that CCS could make a significant contribution to reducing global CO_2 emissions. This would require efforts to ensure rapid development and deployment. Since there is limited experience of CCS systems, it is hard to define 'business as usual' development. This leads to significant uncertainty for policy makers and other stakeholders with regard to [characterizing] potential CCS pathways and assessing the scope for and risks of acceleration. Quantitative analytical approaches to projecting costs and other parameters typically depend on best current estimates of critical input data, as well as implicit or explicit assumptions about technology development pathways and contextual factors such as evolving regulatory

requirements. There are significant limitations in current quantitative (and qualitative) data on CCS that lead to significant difficulties in identifying robust assumptions. One way to handle this is to develop multiple scenarios to illustrate the uncertainty. Another strategy is to make more use of qualitative methods for [analyzing] CCS innovation processes. This latter approach could help to avoid some of the issues associated with CCS cost uncertainty and instead re-focus attention on understanding critical aspects of innovation processes." **Nils Markusson and Hannah Chalmers**, *Technological Forecasting and Social Change*, Available online February 28, 2012, doi:10.1016/j.techfore.2011.12.010, http://www.sciencedirect.com/science/article/pii/S0040162511002885. (Subscription may be required.)

April 2012

***Bloomberg*, "Scotland to Fit Carbon Capture at Existing Coal Plants by 2025."** In a draft document on power generation plans, the Scottish government announced tentative plans to retrofit all existing coal plants with CCS technology by 2025, which they state would generate $5.6 billion over the next decade. The government will complete a review by 2018 and, according to the document, all coal plant applications must demonstrate CCS on at least 300 MW of capacity; from 2020, coal plant applications will require CCS for all their capacity. The document also states that successful demonstration of CCS technology in Scotland could generate as many as 5,000 jobs. March 5, 2012, http://www.bloomberg.com/news/2012-03-05/scotland-to-fit-carbon-capture-at-existing-coal-plants-by-2025.html.

"Providing adequate economic incentives for bioenergies with CO_2 capture and geological storage." The following is the Abstract of this article: "Knowing that CCS could play an important role in reducing emissions, it is important to have a good understanding of this role and the importance of environmental policies to support carbon capture and geological storage from bioenergies (BECCS). To date CCS technologies are not deployed on a commercial level, and policy instruments should be used to provide incentives to firms to use these technologies to reduce pollution. The aim of this paper is to compare the cost-efficiency of several incentive-based instruments (a fossil fuel tax, an emissions tax, a cap and trade system, and a subsidy on captured emissions) needed to spur the adoption of CCS and BECCS, using a dynamic general equilibrium model. This type of model has become the standard for assessing economy-wide impacts of environmental and technological policies. The study shows that BECCS will be deployed only if a specific subsidy per unit of biomass emissions captured with a CCS technology is available. [The authors] show also that the two most cost-efficient instruments for achieving a given emissions reduction target are a specific subsidy that rewards captured emissions and a carbon tax whose revenues are recycled to subsidize BECCS." **Olivia Ricci**, *Energy Policy*, Available online February 28, 2012, doi:10.1016/j.enpol.2012.01.066, http://www.sciencedirect.com/science/article/pii/S0301421512000948. (Subscription may be required.)

"The evolving perception of risk during reservoir evaluation projects for geological storage of CO_2." The following is the Abstract of this article: "If [CO_2] is to be stored in geological strata other than depleted hydrocarbon reservoirs (e.g. in saline [formations]), relatively little information will typically be available about the potential reservoirs. Significant risk associated with such projects therefore derives from uncertainty in reservoir evaluation. This paper describes a risk elicitation exercise carried out during geological reservoir evaluation for two exemplar CCS projects. A project-specific Features, Events and Processes (FEPs) register was developed through a structured elicitation process and discussions with experts. The register was used to elicit experts' perception of risk early in each project and thereafter at regular intervals, finding that the risk was moderate or low for the majority of FEPs. Where FEPs were perceived as high risk, lack of information and uncertainty tended to be the most influential factor. The results of the risk assessments were instrumental in identifying key project activities aimed at reducing uncertainty and addressing the highest areas of risk. Using the relatively inexpensive techniques of reprocessing legacy seismic data and conducting a hydrogeological study of the region around the storage site, uncertainty was reduced and the experts' perception of risk was lowered by the new information. However the risk assessment results also showed changes occurring in the absence of new

information and where experts declared no change to their perception of risk. It is therefore vital to understand the uncertainty in the risk assessment results which can clearly be affected by factors other than information related to the storage formations." **Debbie Polson, Andrew Curtis, Claudia Vivalda**, *International Journal of Greenhouse Gas Control*, Available online March 28, 2012, doi:10.1016/j.ijggc.2012.02.010, http://www.sciencedirect.com/science/article/pii/S1750583612000503. (Subscription may be required.)

May 2012

***Reuters*, "Mexican Senate Clears Way for Climate Bill,"** and ***AFP*, "Mexico's Senate Passes Climate Change Bill."** Mexico's Senate unanimously passed a climate change bill encouraging a voluntary carbon emissions trading market that would reduce carbon emissions by 50 percent by 2050. The measure, which still needs signed by the Mexican President to become a law, would promote policies and incentives to reduce carbon emissions, decrease the use of fossil fuels, and make renewable power more competitive. The legislature sets out that participants in the future emissions market can trade CO_2 permits with partner countries. In addition, a centralized agency, called the National Institute of Ecology and Climate Change, would be created, coordinating efforts from various ministries. April 19, 2012, http://www.reuters.com/article/2012/04/19/us-mexico-carbon-idUSBRE83I1N020120419, and April 20, 2012, http://www.google.com/hostednews/afp/article/ALeqM5iybWYXT1WghY2tz3TRI5eGoxSyyQ?docId=CNG.ee083f962dddb1d71cc981938aad89d5.431.

***Bloomberg*, "U.K. Pledges $97 Million for Carbon Capture in Emerging Markets,"** and ***The Guardian*, "U.K. to Give [$97 Million] to Developing Countries to Build CCS Plants."** At a meeting in London among energy ministers from 23 countries, the United Kingdom (U.K.) agreed to provide as much as ~$97 million to encourage the development of CCS technology in emerging markets. The money, which will be drawn from the previously announced International Climate Financing funding, will be used to boost projects and develop new partnerships. According to the Carbon Capture, Use, and Storage Action Group, the U.K. funds will contribute to the $200 million that should be allocated globally to speed up the deployment of CCS technology. In addition, the meeting also resulted in the energy ministers forming a partnership to foster collaboration between the public and private sectors in 16 countries. April 25, 2012, http://www.bloomberg.com/news/2012-04-25/u-k-pledges-97-million-for-carbon-capture-in-emerging-markets.html, and April 26, 2012, http://www.guardian.co.uk/environment/2012/apr/26/carbon-capture-storage-developing-countries?newsfeed=true.

***Reuters*, "Peru is Latest Developing Nation to Adopt Climate Change Initiative."** Peru has adopted a resolution to lower carbon emissions. The long-term climate change initiative aims to include more renewable fuels in Peru's energy matrix, switch to a low-carbon economy, and curb illegal logging in the Amazon rain forest. Peru emits approximately .4 percent of the world's greenhouse gas (GHG) emissions. In last year's U.N. talks in Durban, South Africa, Peru backed a goal for an international climate change deal by 2015 that would come into force by 2020. April 26, 2012, http://www.reuters.com/article/2012/04/26/us-peru-climate-idUSBRE83P1H820120426.

***SouthAfrica.info*, "South Africa Approves CO_2 Capture Plan."** South Africa's Cabinet announced the approval of a plan to capture and store CO_2 in deep geologic formations. According to the Performance Monitoring and Evaluation Minister, South Africa voluntarily committed to reduce its CO_2 emissions by 34 percent by 2020 and by 45 percent by 2025, on the condition that the necessary technological and financial support was provided. Potential areas for CCS in South Africa were identified in a recently released Geological Storage Atlas; the next step will be a test injection of CO_2 into a suitable geologic formation to determine if the CO_2 can be stored safely. May 7, 2012, http://www.southafrica.info/news/business/1968687.htm.

"Assessment of strategies for CO_2 abatement in the European petroleum refining industry." The following is the Abstract of this article: "Petroleum oil refineries account for almost [eight percent] of the total CO_2 emissions from industry in the EU. In this paper, the European petroleum refining industry is investigated and the prospects for future CO_2 abatement in relation to associated infrastructure are assessed. A more efficient use of the adjacent infrastructure, e.g., district heating networks, natural gas grids, [neighboring] industries, and CO_2 transport and storage systems, could provide opportunities for additional CO_2 emissions reduction. It is shown that access to infrastructures that can facilitate CO_2 abatement varies significantly across countries and between individual refineries. The assessment shows that short-term mitigation options, i.e., fuel substitution and energy efficiency measures, could reduce CO_2 emissions by 9-40 $MtCO_2$/year (6-26 [percent] of the total refinery emissions). It is further shown that [CCS] offers the greatest potential for more significant emission reductions in the longer term. However, the potential for CO_2 capture varies significantly depending on the choice of technology, CO_2 source, and scope of implementation (5-80 [percent] of the total refinery emissions)." **Daniella Johansson, Johan Rootzén, Thore Berntsson, and Filip Johnsson**, *Energy*, Available online April 19, 2012, doi:10.1016/j.energy.2012.03.039, http://www.sciencedirect.com/science/article/pii/S0360544212002307. (Subscription may be required.)

June 2012

***Environmental Expert*, "Protocol for Community-Scale GHG Emissions Launched."** The C40 Cities Climate Leadership group and the International Council for Local Environmental Initiatives (ICLEI) have launched a "community protocol" to measure GHG emissions at the community level in an effort to establish a single standard for measuring emissions from cities. The protocol will replace previously published standards, such as the International Local Government GHG Emissions Analysis Protocol and the International Standard for Determining GHG Emissions for Cities. The protocol was developed in collaboration with the World Resources Institute and the Joint Work Programme of Cities Alliance. A draft edition of the protocol was released for public comment in March 2012, with more than 30 organizations providing comments. The global partners will next pilot the community protocol in selected cities around the world, based on expressions of interest. Results and feedback will be reflected in the first edition of the full community protocol, which is expected to be published in late 2012. To view the draft protocol, visit: http://www.ghgprotocol.org/files/ghgp/GPC_PilotVersion_1.0_May2012_20120514.pdf. May 15, 2012, http://www.environmental-expert.com/news/protocol-for-community-scale-ghg-emissions-launched-294649.

July 2012

"What about coal? Interactions between climate policies and the global steam coal market until 2030." The following is the Abstract of this article: "Because of economic growth and a strong increase in global energy demand the demand for fossil fuels and therefore also [GHG] emissions are increasing, although climate policy should lead to the opposite effect. The coal market is of special relevance as coal is available in many countries and often the first choice to meet energy demand. In this paper [the authors] assess possible interactions between climate policies and the global steam coal market. Possible market adjustments between demand regions through market effects are investigated with a numerical model of the global steam coal market: the 'COALMOD-World' model. This equilibrium model computes future trade flows, infrastructure investments and prices until 2030. [The authors] investigate three specific designs of climate policy: a unilateral European climate policy, an Indonesian export-limiting policy and a fast-roll out of CCS in the broader context of climate policy and market constraints. [The authors] find that market adjustment effects in the coal market can have significant positive and negative impacts on the effectiveness of climate policies." **C. Haftendorn, C. Kemfert, and F. Holz**, *Energy Policy*, Available online June 27, 2012, doi:10.1016/j.enpol.2012.05.032, http://www.sciencedirect.com/science/article/pii/S0301421512004442. (Subscription may be required.)

August 2012

***Carbon Capture Journal*, "CCS Roadmap for Romania Launched."** According to a report by the environmental non-governmental organization (NGO) Bellona Foundation, Romania has the potential to become CO_2 negative by generating CO_2 neutral electricity from biomass and absorbing already emitted CO_2 from the atmosphere. The report, titled "Our future is carbon negative – A CCS Roadmap for Romania," models the Romanian electricity system until 2050 by considering current energy plans, with more or less CCS added. In addition, the report presents recommendations for policymakers and investors. To download the report, go to: http://bellona.org/ccs/ccs-news-events/publications/article/our-future-is-carbon-negative-a-ccs-roadmap-for-romania.html. June 26, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=965&PHPSESSID=9ajj2n8huu0brc2eckfo8eoju1.

"A literature review of economic studies on carbon pricing and Australian wholesale electricity markets." The following is the Abstract of this article: "With the ongoing development of Australian anthropogenic climate change mitigation policies, there has been a steady increase in modeling studies undertaken to estimate Australian carbon prices and their impact on existing electricity markets. This article summarizes some of the more prominent studies completed by many of Australia's foremost economic modeling firms. [The authors] developed a simple approach for testing the consistency of these studies and their findings in relation to carbon pass-through. Unfortunately, [the authors] have established that the studies are entirely inconsistent in their estimation of carbon pass-through. Furthermore, [the authors] were unable to establish why the estimation of carbon pass-through varies so significantly. This has important implications for policy makers given much of the compensation to be paid to households and businesses under the Clean Energy Future package is predicated on simple assumptions of carbon pass-through. Based upon [the authors'] analysis of these economic studies, [the authors'] conclusion is that Australian policy makers are best guided by relying upon the numerous a posteriori estimations of pass-through in the European Union Emissions Trading Scheme (ETS) rather than Australian a priori studies." **Tim Nelson, Simon Kelley, and Fiona Orton**, *Energy Policy*, Available online July 11, 2012, doi:10.1016/j.enpol.2012.05.075, http://www.sciencedirect.com/science/article/pii/S0301421512004880. (Subscription may be required.)

"Informed public opinion in the Netherlands: Evaluation of CO_2 capture and storage technologies in comparison with other CO_2 mitigation options." The following is the Abstract of this article: "In this study, 995 respondents in a representative sample of the Dutch general population are set in the situation of policymakers: they are faced with the issue of fulfilling the Dutch demand for energy in 2030 in such a way that emissions of [CO_2] will be reduced by 50 [percent]. In the Information-Choice Questionnaire (ICQ) that was developed for this, respondents evaluated information from experts on seven options for CO_2 emission reduction and their consequences. Two CCS options were compared to two energy efficiency options, a wind energy option, a biomass energy option, and a nuclear energy option. Results show that people are not that enthusiastic regarding the two CCS options. These are evaluated 5.3 and 5.9 on average on a scale of 1–10 and not often chosen as one of the three preferred options, but they are also rarely rejected. Most of the other options in the questionnaire were evaluated rather positively, except nuclear energy and the more ambitious efficiency option. Analysis shows that the evaluation of the information regarding consequences moderately influences how options are evaluated overall. The results further indicate that the CCS options are evaluated less positively due to the comparison with other options." **Marjolein de Best-Waldhober, Dancker Daamen, Andrea Ramirez Ramirez, André Faaij, Chris Hendriks, and Erika de Visser**, *International Journal of Greenhouse Gas Control*, Available online July 9, 2012, doi:10.1016/j.ijggc.2012.05.023, http://www.sciencedirect.com/science/article/pii/S1750583612001260. (Subscription may be required.)

Geology

September 2011

"Contact angle measurements of CO_2-water-quartz/calcite systems in the perspective of carbon sequestration." The following is the Abstract of this article: "This work presents contact angle measurements for CO_2-water-quartz/calcite systems at general sequestration pressure and temperature conditions (200-3000 [pounds per square inch gauge (psig)] and 77°F-122°F). The effect of drop volume, repeated exposure of the substrates to dense water saturated CO_2, pressure and temperature on the contact angles is examined. In the first measurement cycle, the contact angles for the quartz substrate varied from 46° to 48° and 47° to 46° for gaseous (water saturated) CO_2 and liquid (water saturated) CO_2 respectively, at 77°F. For calcite substrate, these values varied from 45° to 48° and 42° to 40°, respectively. Remarkably, this work highlights a characteristic permanent shift in the contact angle data with repeated exposure to dense, water saturated, CO_2. The contact angle data trends after repeated exposure to the dense, water saturated CO_2 varied from 89° to 91° and 85° to 80° for the quartz substrate for gaseous (water saturated) CO_2 and liquid (water saturated) CO_2 respectively, at 77°F. For calcite substrates, these values varied from 60° to 59° and 54° to 48°, respectively. This important observation has serious implications towards the design and safety issues, as a permanent positive contact angle shift indicates lower CO_2 retention capabilities of sequestration sites due to a reduction in the capillary pressure. It is further confirmed that the permanent shift in the contact angle is due to surface phenomena. With an increase in temperature (from 77°F to 122°F), the contact angle shift is reduced from about 45° to about 20° for quartz substrates. Other observations in the contact angle data with respect to pressure are in good agreement with the trends reported in the literature." **Prem Kumar Bikkina**, *International Journal of Greenhouse Gas Control*, Available online July 27, 2011, doi:10.1016/j.ijggc.2011.07.001, http://www.sciencedirect.com/science/article/pii/S1750583611001241. (Subscription may be required.)

"Effect of the Pore Length on CO_2 Adsorption over Amine-Modified Mesoporous Silicas." The following is the Abstract of this article: "Carbon dioxide adsorption was investigated in the presence of polyethylenimine (PEI)-impregnated mesoporous silicas with different pore lengths, namely, pore-expanded MCM-41, conventional SBA-15 with different pore diameters (7.2 and 10.5 nm), and SBA-15 with platelet morphology. The pore lengths of the silica supports were ca. 25, 1.5, and 0.2 μm, respectively. Under comparable conditions, the adsorption performance was found to be strongly dependent upon the pore length. The materials with the shortest channels showed the highest capacity and fastest adsorption. These findings were associated with diminished diffusion resistance and enhanced amine accessibility inside the pores." **Aliakbar Heydari-Gorji, Yong Yang, and Abdelhamid Sayari,** *Energy Fuels*, Available online August 4, 2011, doi:10.1021/ef200765f, http://pubs.acs.org/doi/abs/10.1021/ef200765f. (Subscription may be required.)

"Subarctic Weathering of Mineral Wastes Provides a Sink for Atmospheric CO_2." The following is the Abstract of this article: "The mineral waste from some mines has the capacity to trap and store CO_2 within secondary carbonate minerals via the process of silicate weathering. Nesquehonite [$MgCO_3 \cdot 3H_2O$] forms by weathering of Mg-silicate minerals in kimberlitic mine tailings at the Diavik Diamond Mine, Northwest Territories, Canada. Less abundant [sodium (Na)]- and [calcium (Ca)]-carbonate minerals precipitate from sewage treatment effluent deposited in the tailings storage facility. Radiocarbon and stable carbon and oxygen isotopes are used to assess the ability of mine tailings to trap and store modern CO_2 within these minerals in the arid, subarctic climate at Diavik. Stable isotopic data cannot always uniquely identify the source of carbon stored within minerals in this setting; however, radiocarbon isotopic data provide a reliable quantitative estimate for sequestration of modern carbon. At least 89 [percent] of the carbon trapped within secondary carbonate minerals at Diavik is derived from a modern source, either by direct uptake of atmospheric CO_2 or indirect uptake though the biosphere. Silicate weathering at Diavik is trapping 102-114 g C/m^2/y within nesquehonite, which corresponds to a

[two] orders of magnitude increase over the background rate of CO_2 uptake predicted from arctic and subarctic river catchment data." **Siobhan A. Wilson, Gregory M. Dipple, Ian M. Power, Shaun L. L. Barker, Stewart J. Fallon, and Gordon Southam**, *Environ. Sci. Technol.*, Available online August 20, 2011, doi:10.1021/es202112y, http://pubs.acs.org/doi/abs/10.1021/es202112y. (Subscription may be required.)

October 2011

"The effects of sub-critical and super-critical carbon dioxide adsorption-induced coal matrix swelling on the permeability of naturally fractured black coal." The following is from the Abstract of this article: "Swelling of the coal matrix with the adsorption of CO_2 is one of the leading problems for CO_2 [storage] in deep coal seams as it causes coal seam permeability to be significantly reduced. The main objective of this study was to investigate the effect of coal mass swelling on the permeability of naturally fractured black coal. A series of permeability tests were conducted using a newly developed tri-axial apparatus on 38 mm by 76 mm naturally fractured black coal specimens. These tests were carried out for CO_2 and N_2 injections at 2-20 MPa injection pressures under 10 to 24 MPa confining pressures at 33 °C. Each coal specimen was then allowed to swell under sub-critical and super-critical CO_2 adsorption and the corresponding effects on CO_2 and N_2 permeabilities were examined. Results indicate that the permeability of naturally fractured black coal is significantly reduced due to matrix swelling, which starts as quickly as within 1 h of CO_2 injection. A further reduction is then observed, and the maximum swelling rate occurs within the first 3-4 h of CO_2 adsorption. The amount of coal matrix swelling due to CO_2 adsorption clearly depends on the phase condition of the CO_2, and super-critical CO_2 adsorption-induced swelling is about two times higher than that induced by sub-critical CO_2 adsorption. Interestingly, although a fractured coal specimen which has already fully swelled under sub-critical CO_2 adsorption can swell significantly more under super-critical CO_2 adsorption, after swelling under super-critical CO_2 adsorption, no further swelling effect occurs under any CO_2 pressure or phase condition. Moreover, the swelling process continues longer under super-critical CO_2 adsorption. It is concluded that super-critical CO_2 adsorption can induce more matrix swelling than sub-critical CO_2 adsorption under the same adsorption pressure." **M.S.A. Perera, P.G. Ranjith, S.K. Choi, D. Airey**, *Energy*, Available online October 13, 2011, doi:10.1016/j.energy.2011.09.023, http://www.sciencedirect.com/science/article/pii/S0360544211006207. (Subscription required.)

"Parameters affecting mineral trapping of CO_2 sequestration in brines." The following is from the Abstract of this article: "Carbon dioxide [storage] using brines has emerged as a promising technology to mitigate the adverse impacts of climate change due to its large storage capacity and favorable chemistries. However, the permanent storage of CO_2 in brines takes significantly long periods of time as the formation of carbonates is slow. This review focuses on the four main parameters (brine composition, brine pH, system temperature, and pressure) that have been reported to have a major effect on mineral trapping of CO_2 [storage] in brines. These parameters are difficult to control for *in situ* underground CO_2 [storage]. However, understanding the effects of these main parameters is useful for both aboveground and underground carbonation reactions. Brine pH is the most important parameter. The precipitation of carbonate minerals is favored over a basic pH of 9.0. In order to promote the formation of carbonates, brine pH could be enhanced by using additives. System temperature has a greater effect than pressure." **Qi Liu and M. Mercedes Maroto-Valer**, *Greenhouse Gases: Science and Technology*, Available online September 2011, DOI:10.1002/ghg.29, http://onlinelibrary.wiley.com/doi/10.1002/ghg.29/abstract. (Subscription may be required.)

"Deterioration of a fractured carbonate caprock exposed to CO_2-acidified brine flow." The following is from the Abstract of this article: "A flow-through experiment was performed to investigate evolution of a fractured carbonate caprock during flow of CO_2-acidified brine. A core was taken from the Amherstburg limestone, a caprock formation overlying the Bois Blanc and Bass Islands formations, which have been used to demonstrate CO_2 storage in the Michigan basin. The inlet brine was representative of deep saline brines saturated with CO_2, resulting in a starting pH of 4.4. Experimental

conditions were 27 °C and 10 MPa. X-ray computed tomography and scanning electron microscopy were used to observe evolution of fracture geometry and to investigate mineralogical changes along the fracture surface. The initial brine flow corresponded to an average fluid velocity of 110 cm hr^{-1}. After one week, substantial mineral dissolution caused the average cross-sectional area of the fracture to increase from 0.09 cm^2 to 0.24 cm^2. This demonstrates that carbonate caprocks, if fractured, can erode quickly and may jeopardize sealing integrity when hydrodynamic conditions promote flow of CO_2-acidified brine. However, changes to fracture permeability due to mineral dissolution may be offset by unaltered constrictions along the flow path and by increases in surface roughness. In this experiment, preferential dissolution of calcite over dolomite led to uneven erosion of the fracture surface and an increase in roughness. In areas with clay minerals, calcite dissolution left behind a silicate mineral-rich microporous coating along the fracture wall. Thus, the evolution of fracture permeability will depend in a complex way on the carbonate content, as well as the heterogeneity of the minerals and their spatial patterning." Brian **Ellis, Catherine Peters, Jeffrey Fitts, Grant Bromhal, Dustin McIntyre, Robert Warzinski, Eilis Rosenbaum**, *Greenhouse Gases: Science and Technology*, Available online September 2011, DOI:10.1002/ghg.25, http://onlinelibrary.wiley.com/doi/10.1002/ghg.25/abstract. (Subscription may be required.)

November 2011

"Effects of saturation medium and pressure on strength parameters of Latrobe Valley brown coal: Carbon dioxide, water and nitrogen saturations." The following is the Abstract of this article: "Adsorption of CO_2 into coal matrix causes significant change in its chemical and physical structure, resulting in negligible permeability values and overall strength reduction. The main objective of this study is to investigate the effects of water, nitrogen (N_2) and CO_2 saturations at different saturation pressures on the strength of brown coal using uniaxial experiments. A series of uniaxial experiments was conducted on 38 mm diameter by 76 mm height Latrobe Valley brown coal samples with different saturation media (water, N_2, CO_2) and pressures (1, 2, and 3 MPa). According to the test results, water and CO_2 saturations cause the uniaxial compressive strength (UCS) of brown coal to be reduced by about 17 [percent] and 10 [percent] respectively. In contrast, N_2 saturation causes it to increase by about [two percent]. Moreover, Young's modulus of brown coal is reduced by about [eight percent] and 16 [percent] due to water and CO_2 saturations respectively, and is increased up to 5.5 [percent] due to N_2 saturation. It can be concluded that CO_2 and water saturations cause the strength of brown coal to be reduced while improving its toughness, and N_2 saturation causes the strength of brown coal to increase while reducing its toughness. The fracture propagation pattern of each sample was then observed using advanced acoustic emission (AE). Findings indicate that CO_2 saturation causes early crack initiation due to the CO_2 adsorption-induced swelled layer and early crack damage and failure points due to lower surface energy. In contrast, N_2 saturation causes delays in crack initiation, damage and failure due to the removal of both water and naturally available CO_2 from the coal mass during the saturation." **M.S.A. Perera, P.G. Ranjith, and M. Peter**, *Energy*, Available online October 28, 2011, doi:10.1016/j.energy.2011.09.026, http://www.sciencedirect.com/science/article/pii/S0360544211006232. (Subscription may be required.)

"CO_2 sequestration through mineral carbonation of iron oxyhydroxides." The following is the Abstract of this article: "Carbon dioxide sequestration via the use of sulfide reductants and mineral carbonation of the iron oxyhydroxide polymorphs lepidocrocite, goethite and akaganeite with supercritical CO_2 ($scCO_2$) was investigated using in situ attenuated total reflection Fourier transform infrared spectroscopy (ATR-FTIR), X-ray diffraction (XRD) and transmission electron microscopy (TEM). The exposure of the different iron oxyhydroxides to aqueous sulfide in contact with $scCO_2$ at ~70-100°C resulted in the partial transformation of the minerals to siderite ($FeCO_3$) and sulfide phases such as pyrite (FeS_2). The relative yield of siderite to iron sulfide bearing mineral product was a strong function of the initial sulfide concentration. The order of mineral reactivity with regard to the amount of siderite formation in the $scCO_2$/sulfide environment for a specific reaction time was goethite < lepidocrocite ≤ akaganeite. Given the presence of goethite in sedimentary formations, this conversion reaction may have

relevance to the subsurface sequestration and geologic storage of [CO_2]." **Kristin D. Lammers, Riley T. Murphy, Amber Riendeau, Alexander Smirnov, Maartin Schoonen, and Daniel Russell Strongin**, *Environ. Sci. Technol.*, Available online November 8, 2011, doi: 10.1021/es202571k, http://pubs.acs.org/doi/abs/10.1021/es202571k. (Subscription may be required.)

"Seal evaluation and confinement screening criteria for beneficial carbon dioxide storage with enhanced coal bed methane recovery in the Pocahontas Basin, Virginia." The following is the Abstract of this article: "The geological storage of [CO_2] in Appalachian basin coal seams is one possible sink for sequestration of [GHGs], with the added benefit of enhanced-coal bed methane (ECBM) recovery. The Pocahontas Basin (part of the central Appalachian Basin) of southwestern Virginia is a major coal bed methane (CBM) province with production mostly from coal beds in the Lower Pennsylvanian Pocahontas and New River formations. As part of the Southeast Regional Carbon Sequestration Partnership's Phase II research program, a CO_2-injection demonstration well was installed into Lower Pennsylvanian [CBM] producing strata in southwest Virginia. Samples of siliciclastic lithologies above coal beds in this Oakwood Field well, and from several other cores in the Nora Field were taken to establish a baseline of the basic confinement properties of overlying strata to test seal competency at local and regional scales. Strata above CBM-producing coal beds in the Pocahontas and New River formations consist of dark-gray shales; silty gray shales; heterolithic siltstones, sandstones, and shales; lithic sandstones, and quartzose sandstones. Standard measurements of porosity, permeability and petrography were used to evaluate potential [release] hazards and any possible secondary storage potential for typical lithologies. Both lithic- and quartz-rich sandstones exhibit only minor porosity, with generally low permeability (< 0.042 md). Interconnected porosity and permeability are strongly impacted by diverse cementation types and compaction. Analyzed siliciclastic lithologies are considered tight, with limited primary matrix permeability risks for [release], providing an ensemble of redundant CO_2-ECBM traps. One of the most promising confining intervals above the major [CBM] producing interval is the Hensley Shale Member. Analyses of 1500 geophysical logs in southwest Virginia indicate that this unit is moderately thick (> 50 ft, 15 m), laterally continuous (> 3000 km^2), and a homogenous shale, which coarsens upward into siltstone and sandstone, or is truncated by sandstone. Calculations from two mercury injection capillary porosimetry tests of the shale indicate that a displacement entry pressure of 207 [pounds per square inch absolute (psia)] (1427 kPa) would generate an estimated seal capacity of 1365 ft (416 m) of CO_2 before buoyant [release]. Scanning electron microscopy indicates a microfabric of narrow pore throats between quartz grains floating in a clay matrix. Modeled median pore throat size between micro-fabric matrix grains for the shale is estimated at 0.26 µm. These characteristics indicate that the shale, where fractures and joints are limited, would be an adequate regional confining interval for deeper CO_2 storage with ECBM." **Ryan P. Grimm, Kenneth A. Eriksson, Nino Ripepi, Cortland Eble, and Stephen F. Greb**, *International Journal of Coal Geology*, Available online November 17, 2011, doi: 10.1016/j.coal.2011.11.002, http://www.sciencedirect.com/science/article/pii/S016651621100245X. (Subscription may be required.)

December 2011

"Contribution of iron to the energetic of CO_2 sequestration in Mg-silicates-based rock." The following is the Abstract of this article: "The main purpose of this paper is to investigate the contribution of iron to the energy requirements of a process for producing magnesium hydroxide ($Mg[OH]_2$) from alkaline-earth Mg–silicate rock that contains iron, such as serpentinite. Once produced $Mg(OH)_2$ could be used to [store] carbon either by direct mineralization at a power plant or from the air, or as a means to deliver alkalinity to the ocean thus tending to restore oceanic pH and sequester atmospheric carbon. [Iron (Fe)]-containing by-products obtained from producing $Mg(OH)_2$ are considered to be beneficial as secondary raw materials for iron-and steel-making industries. It has been proposed that this could further reduce CO_2 emissions as well as raw material costs. However, this study hypothesized that the extent of this benefit, if any, would depend on energy intensity of reactions involving iron compounds. Using Aspen Plus® software, the contribution of iron to the energy input requirement of CO_2 [storage] was modeled. Results obtained showed that the extraction of iron from Mg–silicate minerals could present a significant

energy penalty to the mineralization process. Exergy analysis shows that at the experimental optimal temperature of 400°C, the energy penalties of having iron oxide (FeO), hematite (Fe_2O_3) and magnetite (Fe_3O_4) as dominant iron compounds results are (for 10 wt.% Fe in the rock) an increase of 0.3 GJ/t CO_2 ([seven percent]), 0.7 GJ/t CO_2 (20 [percent]) and 2.2 GJ/t CO_2 (60 [percent]) respectively when compared to an iron-free base case. Recovery of input raw material, ammonium sulfate (AS) by evaporative crystallization is a major energy intensive step in this process. However, [the authors'] model applied mechanical vapor recompression (MVR), which resulted in a significant reduction in energy demand. It can be concluded that the benefit of producing useful Fe by-products comes with an energy penalty, the extent of which varies with the form of Fe compound in the mineral. The findings in this paper are useful in determining which Mg–silicate-based rocks would be energy efficient for use." **Experience Nduagu, Johan Fagerlund, and Ron Zevenhoven**, *Energy Conversion and Management*, Available online December 2, 2011, doi:10.1016/j.enconman.2011.10.023, http://www.sciencedirect.com/science/article/pii/S0196890411003049. (Subscription may be required.)

"Carbon capture and storage using alkaline industrial wastes." The following is the Abstract of this article: "CCS is gaining momentum as a means for combating climate change. It is viewed as an important bridging technology, allowing emission targets to be met during fossil fuel dependence while sufficient renewable energy generation is installed. Mineral carbon [storage] is the only known form of permanent carbon storage and has the potential to capture and store CO_2 in a single step. It is based on the geologic process of natural rock weathering where CO_2 dissolved in rain water reacts with alkaline rocks to form carbonate minerals. While the reactions are thermodynamically [favorable], in nature the process occurs over thousands of years. The challenge of mineral carbon [storage] is to accelerate carbonation and exploit the heat of reaction with minimal energy and material losses. Minerals commonly selected for carbonation include calcium and magnesium silicates. These minerals require energy-intensive pre-treatments, such as fine grinding, heat treatment, and chemical activation with strong acids, to provide adequate conversions and reaction kinetics. Industrial waste residues present alternative sources of mineral alkalinity that are more reactive than primary minerals and are readily and cheaply available close to CO_2 sources. In addition, the carbonation of waste residues often improves their environmental stability. This paper provides an overview of the types of industrials wastes that can be used for mineral carbon [storage] and the process routes available." **Erin R. Bobicki, Qingxia Liu, Zhenghe Xu, and Hongbo Zeng**, *Progress in Energy and Combustion Science*, Available online November 26, 2011, doi:10.1016/j.pecs.2011.11.002, http://www.sciencedirect.com/science/article/pii/S0360128511000554. (Subscription may be required.)

"Putting It All Together: The Real World of Fully Integrated CCS Projects." The following is the Abstract of this article: "This study examines the legal, regulatory and financial issues encountered in nine planned commercial-scale CCS research, development and demonstration (RD&D) projects under Phase III of the U.S. Department of Energy's RCSP Program. In Phase III of the RCSP, financial issues dominated the outcomes in these projects, directly causing termination of three of the projects and contributing to termination in two others. Long-term liability and lack of coordination among regulatory authorities also posed significant barriers." **Craig Hart**, *Belfer Center for Science and International Affairs*, Available online July 2011, http://belfercenter.ksg.harvard.edu/files/Hart%20Putting%20It%20All%20Together%20DP%20ETIP%202011%20web.pdf.

January 2012

"The Impact of Geologic Variability on Capacity and Cost Estimated for Storing CO_2 in Deep-Saline Aquifers." The following is the Abstract of this article: "While numerous studies find that deep-saline sandstone aquifers in the United States could store many decades worth of the [Nation's] current annual CO_2 emissions, the likely cost of this storage (i.e. the cost of storage only and not capture and transport costs) has been harder to constrain. [The authors] use publically available data of key reservoir properties to produce geo-referenced rasters of estimated storage capacity and cost for regions within 15

deep-saline sandstone aquifers in the United States. The rasters reveal the reservoir quality of these aquifers to be so variable that the cost estimates for storage span three orders of magnitude and average > $100/tonne CO_2. However, when the cost and corresponding capacity estimates in the rasters are assembled into a marginal abatement cost curve (MACC), [the authors] find that ~ 75 [percent] of the estimated storage capacity could be available for < $2/tonne. Furthermore, ~ 80 [percent] of the total estimated storage capacity in the rasters is concentrated within just two of the aquifers – the Frio Formation along the Texas Gulf Coast, and the Mt. Simon Formation in the Michigan Basin, which together make up only ~ 20 [percent] of the areas analyzed. While [the authors'] assessment is not comprehensive, the results suggest there should be an abundance of low-cost storage for CO_2 in deep-saline aquifers, but a majority of this storage is likely to be concentrated within specific regions of a smaller number of these aquifers." **Jordan K. Eccles, Lincoln Pratson, Richard G. Newell, and Robert B. Jackson**, *Energy Economics*, Available online December 14, 2011, doi:10.1016/j.eneco.2011.11.015, http://www.sciencedirect.com/science/article/pii/S0140988311002891. (Subscription may be required.)

"Predicting CO_2-water interfacial tension under pressure and temperature conditions of geologic CO_2 storage." The following is the Abstract of this article: "Storage in subsurface geologic formations, principally saline aquifers, is currently under development as a major approach to counter anthropogenic CO_2 emissions. To ensure the stability and long-term viability of geologic carbon storage, injected CO_2 must be kept in place by an overlying cap rock of very low permeability. Capillary forces in the cap rock act to prevent upward migration and escape of the stored supercritical fluid, with interfacial tension (IFT) between the aqueous brine phase and the CO_2 phase being the primary control. However, published experimental CO_2-water IFT data vary widely, mainly because of inadequate experimental protocols or inappropriate use of bulk-fluid properties in computing IFT from experimental observations. Only two published data sets were found to meet all criteria of merit for an accurate measurement of IFT over the entire range of pressure (5-45 MPa) and temperature (298-383 K) pertinent to geologic carbon storage. In such circumstances, molecular simulations can enhance the utility of limited data when used to validate assumptions made in their interpretation, resolve discrepancies among data, and fill gaps where data are lacking. Simulations may also be used to provide insight into the relationship between IFT and fundamental properties, such as the strength of the CO_2-H_2O interaction. Through molecular dynamics simulations, [the authors] compared the quality of three CO_2 models and two H_2O models (SPC/E and TIP4P2005) in predicting IFT under the pressure and temperature conditions relevant to geologic CO_2 [storage]. Interfacial tension at fixed temperature simulated via molecular dynamics decreased strongly with increasing pressure below the critical CO_2 pressure of 7 MPa, then leveled off, in agreement with experiment, whereas increasing temperature from 300 to 383 K at fixed pressure had little effect on IFT, which is also consistent with experimental data. [The authors'] results demonstrated that the strength of the short-range portion of the CO_2-H_2O interaction exerts a major influence on IFT. The CO_2 model that best represented the attractive part of this interaction for randomly-oriented water molecules also best captures the experimental pressure dependence of IFT when combined with either water model. When combined with the SPC/E water model, this CO_2 model underestimated IFT by ~10 mN/m, which approximately equals the amount by which the SPC/E water model underestimates the surface tension of pure water. When combined with the TIP4P2005 water model, this model accurately captured the pressure dependence of the CO_2-H_2O IFT at 383 K over the entire pressure range examined. These pressure variations will have the dominant effect on IFT – especially at pressures lower than the CO_2 critical pressure (~7 MPa) – and, therefore, on the CO_2 storage capacity and sealing integrity of a subsurface reservoir." **Laura C. Nielsen, Ian C. Bourg, and Garrison Sposito**, *Geochimica et Cosmochimica Acta*, Available online December 19, 2011, doi:10.1016/j.gca.2011.12.018, http://www.sciencedirect.com/science/article/pii/S0016703711007393. (Subscription may be required.)

"Pore Size Effects on the Sorption of Supercritical CO_2 in Mesoporous CPG-10 Silica." The following is the Abstract of this article: "Excess sorption isotherms of supercritical [CO_2] in mesoporous CPG-10 silica glasses with nominal pore sizes of 7.5 and 35 nm were measured gravimetrically at 35 and 50°C and pressures of 0–200 bar. Formation of broad maxima in the excess sorption was observed

at fluid densities below the bulk critical density. Positive values of excess sorption were measured at bulk densities below 0.7 g/cm^3, i.e., the interfacial fluid is denser than the bulk fluid at low pressures. Zero and negative values were obtained at higher densities, i.e., the adsorbed fluid becomes equal to and eventually less dense than the corresponding bulk fluid. Pronounced confinement effects on sorption behavior have been found and further analyzed by normalizing the excess sorption to the adsorbent surface area and pore volume, yielding new insight into supercritical fluid adsorption in this range of pore sizes and *P*, *T* conditions. If normalized to the specific surface area, the excess sorption is higher for the 35 nm pore size material, but the pore volume normalized excess sorption is higher for the 7.5 nm pore size material. With increasing pore width, the excess sorption peak position shifts to higher pressure. Both CPG-10 materials exhibit regions of constant mean pore fluid density as a function of bulk CO_2 density at 35°C but not at 50°C. This region is located between the excess sorption peak maximum and the adsorption/depletion transition point. Applied to the situation of CO_2 [storage] in dry sandstone formations, the results of this study indicate that carbon storage capacity is enhanced by sorption effects, particularly at low temperature and in narrow pores with high surface to volume ratios." **Gernot Rother, Elizabeth G. Krukowski, Dirk Wallacher, Nico Grimm, Robert J. Bodnar, and David R. Cole**, *J. Phys. Chem. C*, Available online December 27, 2011, doi:10.1021/jp209341q, http://pubs.acs.org/doi/abs/10.1021/jp209341q. (Subscription may be required.)

February 2012

"Relationships between CO_2 sorption capacity by coals as measured at low and high pressure and their swelling." The following is the Abstract of this article: "From a comparison of high and low pressure sorption behavior of 28 bituminous and subbituminous coals for [CO_2], the sorption capacity calculated at high pressure is always substantially greater than that estimated from low pressure sorption measurements. The difference between maximum sorption capacity from high pressure measurements and that from low pressure measurements increases with decreasing rank. This difference can be quantitatively explained by swelling of the coal at high pressure that does not occur during low pressure measurements. When expressed as volume [percent], the maximum sorption capacity calculated from high pressure measurements was found to equal the sum of the maximum sorption capacity calculated from low pressure measurements and the volumetric swelling the coal undergoes on exposure to high pressure. This relationship implies that the volume occupied by the coal molecules is constant when it swells: the greater apparent coal volume that occurs on swelling in gases is entirely taken up completely by increased pore volume. Moreover, this relationship provides a natural explanation for the finding that when a coal that is swollen with gas is compressed, the coal releases it. If so, low pressure sorption measurements may provide a more direct estimation of coal sorption capacity in constrained coal seams, provided a robust method of predicting maximum sorption capacity from low pressure sorption [behavior] can be established." **Richard Sakurovs**, *International Journal of Coal Geology*, Available online December 8, 2011, doi:10.1016/j.coal.2011.11.012, http://www.sciencedirect.com/science/article/pii/S0166516211002552. (Subscription may be required.)

"Swelling of coal in carbon dioxide, methane and their mixtures." The following is the Abstract of this article: "Swelling of coal, especially in the presence of CO_2, may reduce the permeability of coal seams thus affecting the viability of enhanced coalbed methane production or CO_2 [storage] operations. In this paper [the authors] report laboratory measurements of swelling in four Australian bituminous and sub-bituminous coals in CO_2, methane and various mixtures of the two gases. Measurements were made on unconstrained monolithic samples at 55°C and at pressures up to about 15 MPa. Volumetric swelling at 15 MPa ranged from about 1.9 [percent] to 5.5 [percent] in CO_2 and 1.0 [percent] to 2.5 [percent] in [methane (CH_4)] depending on the rank of coal and the proportion of CO_2 in the gas mixture. Swelling measurements made at a constant pressure of 15 MPa but with varying gas composition showed that even CO_2 with a high affinity for coal could be completely displaced by helium, which does not adsorb, causing the coal sample to shrink to its original dimensions. Similarly, CH_4 was displaced by injecting CO_2 into the system which then caused the coal to swell to the same level as if it had been exposed to pure CO_2. The results of these experiments show that there is no enhanced swelling in

mixed gases above that would be observed in the pure CO_2 at the same total pressure. As well, the swelling behavior of coal in mixed gases was determined solely by the partial pressure of the sorbing gas so that weakly or non-sorbing gases are effective at displacing strongly adsorbed gases." **Stuart Day, Robyn Fry, and Richard Sakurovs**, *International Journal of Coal Geology*, Available online January 31, 2012, doi:10.1016/j.coal.2012.01.008, http://www.sciencedirect.com/science/article/pii/S0166516212000171. (Subscription may be required.)

"Process intensification routes for mineral carbonation." The following is the Abstract of this article: "Mineral carbonation is a realistic route for capture and storage of [CO_2]. The principal advantages of this approach are the chemical stability and storage safety of mineral carbonates, the opportunities for process integration available, and the potential for conversion of low-value materials into useful products. In this work, the valorization of alkaline waste materials from thermal processes by mineral carbonation utilizing intensified and integrated mineral carbonation routes is explored. Process intensification aims at providing the paradigm-shifting techniques needed to revolutionize the chemical engineering industry in the twenty-first century, particularly focusing on improvements toward process efficiency, yield, and sustainability. The combination of process intensification and process integration strategies has the potential to produce economically feasible and industrially acceptable carbonation technologies that can soon be implemented large scale, several examples of which are already proven at laboratory scale and are herein discussed." **Rafael M. Santos and Tom Van Gerven**, *Greenhouse Gases: Science and Technology*, Available online December 2011, doi:10.1002/ghg.36, http://onlinelibrary.wiley.com/doi/10.1002/ghg.36/abstract. (Subscription may be required.)

March 2012

"Studies of pH buffer systems to promote carbonate formation for CO_2 [storage] in brines." The following is the Abstract of this article: "Carbon dioxide [storage] using brines is significantly dependent on pH for the formation of carbonates. This study evaluated a series of buffer solutions and then selected the optimal one to promote the precipitation of mineral carbonates (mainly calcium carbonates) for above-ground and to help to understand the pH effect on both above-ground and underground carbonation. Five organic or inorganic buffer solutions (pH > 9.0) were selected in this study. pH stability studies were conducted to compare the buffering ability amongst those five buffer solutions for 15 days in both closed and open atmospheres. Buffer solution Bf 1 (boric buffer solution, pH = 10.0) and Bf 2 (0.3 M Tris buffer solution) were selected as the optimal buffers to conduct carbonation experiments due to their strong buffering ability to maintain the pH above 9.0. Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) analysis showed that the concentration of Ca decreased considerably after each carbonation experiments with buffer Bf 1 or Bf 2. The results from X-ray diffraction (XRD) analysis of the precipitates formed from carbonation reactions confirmed the predominant presence of calcite ($CaCO_3$). Finally, the buffers studied here were compared to biocatalysts previously reported for rising pH of brines." **Qi Liu and M. Mercedes Maroto-Valer**, *Fuel Processing Technology*, Available online February 20, 2012, doi:10.1016/j.fuproc.2012.01.023, http://www.sciencedirect.com/science/article/pii/S0378382012000409. (Subscription may be required.)

"The effect of mechanical rock properties on CO_2 storage capacity." The following is the Abstract of this article: "One of the most important issues when estimating CO_2 storage capacity, especially in the case of the storage into deep saline aquifers, is the mechanical integrity of rock, i.e. estimate of cap rock fracture pressure. In the case of storage into mature oil and gas reservoirs, reservoir pressure should not present an issue since it was significantly decreased due to hydrocarbon production, so it is reasonable to assume that the rock integrity would not be disturbed by injecting CO_2 to the initial reservoir pressure. Because estimates of fracture pressure are necessary, but not convenient for regional aquifers, the analysis of pore volume changes due to pressure buildup for the chosen CO_2 site in Croatia has been made. Pressure buildup depends on reservoir fluid (brine) compressibility, CO_2 compressibility at given reservoir conditions before CO_2 injection and on rock compressibility i.e. pore compressibility. Implementing the simple method for analysis of pressure buildup considering elastic properties of fluids

and rock, larger CO_2 storage capacity estimate was achieved than by using storage efficiency coefficient (*E*), as defined by U.S. DOE and which was used for estimating storage capacities in regional deep saline aquifers in Croatia as the part of EU GeoCapacity project." **Domagoj Vulin, Tomislav Kurevija, Iva Kolenkovic**, *Energy*, Available online February 23, 2012, doi:10.1016/j.energy.2012.01.059, http://www.sciencedirect.com/science/article/pii/S0360544212000643. (Subscription may be required.)

"Ensemble based co-optimization of carbon dioxide [storage] and enhanced oil recovery." The following is the Abstract of this article: "[Storage] of CO_2 in depleted or partially depleted oil reservoirs is a plausible option to reduce CO_2 emissions into the atmosphere. Carbon dioxide has been used as the injection fluid in EOR operations. The goal of such projects is to improve the profitability by maximizing the oil production (to increase the revenue) and minimizing the CO_2 injection (to decrease the costs). However, in [storage] projects, subsurface storage of the injected CO_2 needs to be maximized. The objective of this study is to develop a framework to co-optimize the oil extraction and CO_2 [storage]. In [the authors'] work, factors such as the cost of capturing the produced CO_2, CO_2 transportation and recycling are taken into account. In the proposed framework, the net present value (NPV) of the project is selected as the optimization objective function. The ensemble-based optimization (EnOpt) algorithm has been chosen as the optimization algorithm and the well injection patterns and rates as the controlling variables. A synthetic case is used to demonstrate the applicability of the developed technique. [The authors'] results show that the oil recovery and the NPV can be increased significantly. The proposed methodology is fairly robust as it does not require adjoint programming and can be readily used with any reservoir simulator. The workflow presented in this work can be used to design and co-optimize the coupled CO_2 [storage] and EOR." **Hamid Reza Jahangiri and Dongxiao Zhang**, *International Journal of Greenhouse Gas Control*, Available online February 24, 2012, doi:10.1016/j.ijggc.2012.01.013, http://www.sciencedirect.com/science/article/pii/S1750583612000278. (Subscription may be required.)

April 2012

"Hydrogeochemical processes in clastic sedimentary rocks, South Korea: A natural analogue study of the role of dedolomitization in geologic carbon storage." The following is the Abstract of this article: "For long-term mineral trapping of [stored] CO_2 in deep saline [formations], base cations such as Ca^{2+} and Mg^{2+} are essential. As a natural analogue study of geologic carbon storage in deep [formations] hosted in sedimentary formations, [the authors] examined the hydrochemistry of sulfate-rich (up to 1140 mg/l SO_4^{2-}) and moderately high P_{CO2} ($10^{-1.1}$ to $10^{-2.4}$ atm) groundwater in a Cretaceous non-marine sedimentary basin in South Korea with the objective to elucidate water-rock interactions controlling the concentrations and behavior of base cations. Principal component analysis of the acquired hydrochemical data indicated that dissolution of carbonates (calcite and dolomite) and evaporite minerals (halite and gypsum) controls the chemical composition of groundwater, resulting in substantial increases of the concentration s of Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-} and total dissolved solids (TDS) in deep groundwater. Na^{+} versus Cl^{-} and Ca^{2+}+ Mg^{2+} versus HCO_3^{-} + SO_4^{2-} plots provided evidence for dissolution of halite and gypsum. Progressively increasing $\delta^{34}S$ values of dissolved SO_4^{2-} (from 15.1 to 19.2‰) with increasing sulfate concentrations indicated gypsum dissolution. Ion-ion plots (esp., Mg^{2+}/Ca^{2+}, Ca^{2+}/SO_4^{2-} and Mg^{2+}/SO_4^{2-}) and saturation indices of calcite, dolomite and gypsum suggest that the groundwater chemistry (esp., the concentrations of Ca^{2+} and Mg^{2+}) is controlled by dedolomitization driven by gypsum dissolution. Groundwater in the study area does not reach complete equilibrium with respect to calcite and dolomite because of gypsum dissolution, which controls the Mg^{2+}/Ca^{2+} ratios of groundwater. Continued calcite precipitation triggered by an excess Ca supply from gypsum dissolution reduces the concentrations of dissolved inorganic carbon (DIC) in groundwater. The increase of $\delta^{13}C_{DIC}$ values from − 11.1 to − 6.5‰ concomitantly with increasing sulfate concentration was explained via geochemical modeling by dedolomitization under the rate constant ratio of about 0.038 between dolomite and calcite. The model results agree well with the observed Mg^{2+}/Ca^{2+} ratios and further suggest a potential increase of the void volume in the [formation] through dedolomitization by about 0.72 cm^3/l. Based on this analogue, [the authors] suggest that dedolomitization in concert with dissolution of gypsum may constitute an important process releasing base cations for mineral trapping of

injected CO_2 in non-marine clastic sedimentary strata containing carbonates and gypsum in South Korea and elsewhere." **Byoung-Young Choi, Seong-Taek Yun, Bernhard Mayer, So-Young Hong, Kyoung-Ho Kim, Ho-Young Jo**, *Chemical Geology*, Available online March 8, 2012, doi:10.1016/j.chemgeo.2012.03.002, http://www.sciencedirect.com/science/article/pii/S0009254112001192. (Subscription may be required.)

"Microfracturing of coal due to interaction with CO_2 under unconfined conditions." The following is the Abstract of this article: "Laboratory experiments conducted in the past century have shown that exposure of coal to CO_2 under unconfined, hydrostatic conditions leads to reversible adsorption and swelling. However, several authors also report irreversible changes in sorption capacity, sample volume, equilibration time and brittle failure strength. Some relate these effects to the formation of microfractures, while others consider 'structural rearrangements' in the macromolecular structure of coal to be responsible. In this study, [the authors] investigate the magnitude of irreversible swelling effects and changes in equilibration time in high volatile bituminous coal (Brzeszcze, Seam 364, Poland), and attempt to explain the results in terms of the operative microphysical processes. [The authors] also assess the implications for Enhanced Coalbed Methane (ECBM) operations. [The authors'] approach involves detailed dilatometry experiments conducted on fresh, unconfined, mm-scale coal matrix cylinders at CO_2 pressures up to 100 MPa, and at 40.0°C. Exposure of [the authors'] samples to CO_2 produced reversible and irreversible strains resulting predominantly from competition between adsorption-induced swelling and elastic compression. During the first or second cycle of exposure, substantial hysteresis was observed in volumetric behavior, notably at CO_2 pressures above 35-40 MPa. After two or three upward and downward CO_2 pressure cycles, the measured strain response became fully reversible. Equilibration with CO_2 took about four times longer during the first CO_2 pressurization cycle than in subsequent CO_2 pressurization cycles. Microstructural analysis and comparison showed that microfractures formed in the coal during first exposure to CO_2. From the microstructural and mechanical data, [the authors] infer that microfracturing was responsible for enhanced CO_2 penetration into the present samples. This, in turn allowed more homogeneous access of CO_2, and caused adsorption-induced swelling of matrix material not previously accessed by CO_2. [The authors] further infer that the enhanced penetration, sorption and swelling, in turn, resulted in the observed hysteresis in dimensional response and in the decrease in equilibration time seen in subsequent exposure cycles. Since most microfractures developed parallel to the bedding, roughly following maceral–maceral and bedding/layer interfaces, and because the largest permanent strains and strain hysteresis were measured perpendicular to the bedding, [the authors] infer that the formation of microfractures was caused by heterogeneous swelling, in combination with differential accessibility of the coal microstructure. No evidence was found that CO_2-induced plasticization of the macromolecular structure of the coal matrix played any role in the behavior observed. Simple mechanical considerations indicate that at *in situ* stresses corresponding to a depth of 1000-1500 m, *i.e.* effective stresses in the range 25-35 MPa, adsorption-induced microfractures are unlikely to form. This means that improved access of CO_2 to coal matrix material for ECBM production can probably be achieved only by inducing damage into coal seams, either by injection of solvents/solutes, or by performing active mining of the coal and/or the over- or underlying strata." **Sander Hol, Christopher J. Spiers, Colin J. Peach**, *Fuel*, Available online March 12, 2012, doi:10.1016/j.fuel.2012.02.030, http://www.sciencedirect.com/science/article/pii/S0016236112001536. (Subscription may be required.)

May 2012

"Variations in the mechanical behavior of Illinois bituminous coals." The following is the Abstract of this article: "Unmineable coalbeds are being considered as one of the geological [storage] options for storing CO_2. The storage mechanisms and potential risks associated with the effects of CO_2 on the coal structure are not yet understood and must be evaluated. The mechanical properties of the coal are expected to play an important role in the coal seams' stability, especially under external perturbations. Typically, the mechanical characteristics of coal are investigated as a bulk material, which averages the

effects of various structural in homogeneities as well as of face and butt cleat fractures present in the coal. In this paper, [the authors] attempt to establish baseline mechanical characteristics of Illinois bituminous coals while minimizing the fracture effects. Rectangular coal strips (length <20 mm), which showed no visible macro-defects, from two different Illinois bituminous coal seams, were subjected to three-point bending tests. [The authors'] results suggest there are significant variations in the flexural modulus (ranging from 0.7 GPa to 3.4 GPa) of the coal samples even though the coal rectangular strips originated from the same coal chunk. Vibrational spectroscopic analysis on the samples, which underwent mechanical testing, indicates a correlation between the flexural strength and modulus with the intensity of aliphatic groups. However, the mineral content of the coal seems not to influence the mechanical behavior of Illinois bituminous coals." **Richard D. West, Gediminas Markevicius, Vivak M. Malhotra, and Stephen Hofer**, *Fuel*, Available online April 5, 2012, doi:10.1016/j.fuel.2012.03.042, http://www.sciencedirect.com/science/article/pii/S0016236112002517. (Subscription may be required.)

"CO_2 [storage] into the Wyodak coal seam of Powder River Basin – Preliminary reservoir characterization and simulation." The following is the Abstract of his article: "Injection of [CO_2] captured from flue gas into coalbeds is regarded as one of the value-added options of CO_2 [storage] as the cost of injection can be partially or fully offset by the revenue generated through release of additional methane. The Powder River Basin is one of the major coalbed methane producing areas in the world. The paper presents findings of a preliminary reservoir simulation study on the feasibility of CO_2 [storage] over a nine-section area (4.8 km × 4.8 km) of the Powder River Basin into the thick Wyodak coal seam, one of the two major coal seams in the highly productive Fort Union formation. The reservoir model was built on the basis of information available in the public domain. Gamma ray logs from 60 wells were utilized for developing a 3-D geological model of the coal seam and overlying rocks in the area by employing geostatistical techniques. Considerable variability in gas and water production was observed in the 65 wells. This variability was utilized for capturing the reservoir heterogeneity by Gaussian geostatistical simulation, which produced realizations of fracture porosity and permeability distribution throughout the reservoir. Results of fluid flow simulation indicated that it would not be feasible to place more than one injector per 1.6 km × 1.6 km (1 mile × 1 mile) section of the area due to geomechanical constraint. As a preliminary estimate, it may be feasible to inject 0.658 million tons of CO_2 through such injector over a period of 20 years. [Twelve percent] more CO_2 can be injected over the same period by using a horizontal well but the loss of injectivity may be substantial due to reduction of permeability by coal matrix swelling. The loss of permeability can partially be overcome by intermittent injection for [six] months followed by a similar soak period. Placing one vertical injector each into all the nine sections would result in a scaled-up volume of 5.5 million tons of CO_2 injection. However, the nature of overlying rock could play a vital role in retention of injected CO_2 and up to 20 [percent] of the gas may migrate up by buoyancy." **Pratik Dutta and Mark D. Zoback**, *International Journal of Greenhouse Gas Control*, Available online April 21, 2012, doi:10.1016/j.ijggc.2012.03.004, http://www.sciencedirect.com/science/article/pii/S175058361200062X. (Subscription may be required.)

"Relationships between the sorption [behavior] of methane, carbon dioxide, nitrogen and ethane on coals." The following is the Abstract of this article: "[Storage] of [CO_2] in coal seams can reduce emissions of [CO_2] to the atmosphere. If such [storage] simultaneously results in enhanced coal bed methane (ECBM) production, some of the [storage] costs can be recovered by the value of the methane produced. This requires knowledge of both the [CO_2] and methane sorption [behavior] of coal at high pressures. In order to elucidate the connection between them, [the authors] investigated the sorption of [CO_2], methane, ethane and nitrogen at 55°C at pressures up to 20 MPa for a number of coals. Sorption isotherms were fitted by a modified Dubinin-Radushkevich model. The maximum sorption capacities of the coals for the different gases were found to be highly correlated. The relationship between maximum sorption capacity of a coal for a gas and its critical temperature was approximately proportional. The relationship between methane and nitrogen maximum sorption capacity was particularly close: on a volume basis, the maximum sorption capacity of all coals examined for methane was twice that of nitrogen. The ratio of maximum sorption capacity of [CO_2] and methane decreased linearly with increasing carbon content. The ethane/methane sorption ratio also tended to decrease with increasing

rank though to a smaller extent, indicating that the proportionally greater sorption at low rank coals is not unique to [CO_2]. The heat of sorption tends to increase with increasing vitrinite reflectance; this may reflect the greater polarizability of higher rank coals (which also determines their reflectance)." **Richard Sakurovs, Stuart Day, and Steve Weir**, *Fuel*, Available online March 20, 2012, doi:10.1016/j.fuel.2012.03.014, http://www.sciencedirect.com/science/article/pii/S0016236112002232. (Subscription may be required.)

June 2012

"*In Situ* Molecular Spectroscopic Evidence for CO_2 Intercalation into Montmorillonite in Supercritical Carbon Dioxide." The following is the Abstract of this article: "The interaction of anhydrous supercritical CO_2 ($scCO_2$) with both kaolinite and ~1W (i.e., close to but less than one layer of hydration) calcium-saturated montmorillonite was investigated under conditions relevant to geologic carbon [storage] (50°C and 90 bar). The CO_2 molecular environment was probed *in situ* using a combination of three novel high-pressure techniques: X-ray diffraction, magic angle spinning nuclear magnetic resonance spectroscopy, and attenuated total reflection infrared spectroscopy. [The authors] report the first direct evidence that the expansion of montmorillonite under $scCO_2$ conditions is due to CO_2 migration into the interlayer. Intercalated CO_2 molecules are rotationally constrained and do not appear to react with waters to form bicarbonate or carbonic acid. In contrast, CO_2 does not intercalate into kaolinite. The findings show that predicting the seal integrity of caprock will have complex dependence on clay mineralogy and hydration state." **John S. Loring, Herbert T. Schaef, Romulus V.F. Turcu, Christopher J. Thompson, Quin R.S. Miller, Paul F. Martin, Jianzhi Hu, David W. Hoyt, Odeta Qafoku, Eugene S. Ilton, Andrew R. Felmy, and Kevin M. Rosso**, *Langmuir*, Available online April 25, 2012, doi:10.1021/la301136w, http://pubs.acs.org/doi/abs/10.1021/la301136w. (Subscription required.)

"Direct Nanoscale Observations of CO_2 [Storage] during Brucite [$Mg(OH)_2$] Dissolution." The following is the Abstract of this article: "The dissolution and carbonation of brucite on (001) cleavage surfaces was investigated in a series of in situ and ex situ atomic force microscopy (AFM) experiments at varying pH (2–12), temperature (23–40°C), aqueous $NaHCO_3$ concentration (10^{-5}–1 M), and PCO_2 (0–1 atm). Dissolution rates increased with decreasing pH and increasing $NaHCO_3$ concentration. Simultaneously with dissolution of brucite, the growth of a Mg–carbonate phase (probably dypingite) was directly observed. In $NaHCO_3$ solutions (pH 7.2–9.3,), precipitation of Mg–carbonates was limited. Enhanced precipitation was, however, observed in acidified $NaHCO_3$ solutions (pH 5, DIC ≈ 25.5 mM) and in solutions that were equilibrated under a CO_2 atmosphere (pH 4, DIC ≈ 25.2 mM). Nucleation predominantly occurred in areas of high dissolution such as deep step edges suggesting that the carbonation reaction is locally diffusion-transport controlled. More extensive particle growth was also observed after ex situ experiments lasting for several hours. This AFM study contributes to an improved understanding of the mechanism of aqueous brucite carbonation at low temperature and pressure conditions and has implications for carbonation reactions in general." **J. Hövelmann, C.V. Putnis, E. Ruiz-Agudo, and H. Austrheim**, *Environ. Sci. Technol.*, Available online April 13, 2012, doi:10.1021/es300403n, http://pubs.acs.org/doi/abs/10.1021/es300403n. (Subscription required.)

"Stable carbon isotope techniques to quantify CO_2 trapping under pre-equilibrium conditions and elevated pressures and temperatures." The following is the Abstract of this article: "Flow-through experiments in the laboratory were conducted to monitor the fate of CO_2 using stable carbon isotopes ($\delta^{13}C$) techniques in dynamic, pre-equilibrium conditions. Such conditions are typical, for instance in CCS, in the initial stages of CO_2 injection, near injection well regions of the reservoir. For this purpose, a reactive percolation bench (ICARE 4) was used, injecting a CO_2-saturated brine at supercritical conditions (pCO_2 = 84 bar, T = 60°C) through quartzitic limestone at an average flow rate of 2×10^{-9} m^3 s^{-1}. Calcium (Ca^{2+}) and dissolved inorganic carbon (DIC) concentration data and pH were used to aid analytical interpretations. During CO_2 injection, $\delta^{13}C_{DIC}$ values decreased from about -11‰ to those of the injected CO_2 (-29.3‰), indicating CO_2 sourced carbon dominance over a carbonate sourced one in

the system. Simultaneously DIC and Ca^{2+} concentrations increased from 1 mmol L^{-1} to a maximum of 71 mmol L^{-1} and 31 mmol L^{-1}, respectively. Isotope and mass balances were used to quantify the amount of DIC originating from either the injected CO_2 or carbonates. At the end of the experiments, between 71 and 98 [percent] of the total DIC originated from CO_2 dissolution, the remaining amount is attributed to carbonate dissolution. Furthermore, the total amount of injected C_{CO2} trapped as DIC ranged between 9 and 17 [percent] and between 83 and 91 [percent] was in free phase. The state of carbonate equilibrium of the host fluid, under the high pressure-temperature conditions after CO_2 injection was identified, verifying pre-equilibrium conditions. Results confirm observations made in reported field data. This [emphasizes] that the combination of CO_2 monitoring, the development of a thorough understanding of carbonate equilibrium, as well as the quantification of CO_2-trapping, is essential for a solid assessment of reservoir performance and safety considerations during CO_2 injection. These are equally important for understanding water-rock-CO_2 dynamics in natural subsurface environments." **A. Myrttinen, E. Jeandel, O. Ukelis, V. Becker, R. van Geldern, P. Blum, and J.A.C. Barth**, *Chemical Geology*, Available online May 19, 2012, doi:10.1016/j.chemgeo.2012.05.008, http://www.sciencedirect.com/science/article/pii/S0009254112002276?v=s5. (Subscription may be required.)

"Measurement of accessible reactive surface area in a sandstone, with application to CO_2 mineralization." The following is the Abstract of this article: "A new characterization approach is employed in this study that enables the measurement of the surface area of each reactive mineral located within the connected pore network of a sandstone from a carbon [storage] pilot site in Cranfield, Mississippi. The mineral distribution is measured in 2D by chemical mapping using Energy Dispersive X-ray Spectroscopy-Scanning Electron Microscopy (SEM-EDX) coupled with an image segmentation technique. The pore structure is mapped at high resolution using a pixel contrast thresholding technique applied to 2D Backscattered Electron Microscopy (BSE-SEM) images. After merging the mineral distribution and porosity maps, the accessibilities of each mineral present in the rock sample are quantified. These quantifications require characterizing in advance the connected pore network in the merged maps, which is done considering the permeability of chlorite measured at the nano-scale in three dimensions by Focus Ion Beam-Scanning Electron Microscopy (FIB-SEM). The accessible surface area of each reactive mineral is finally determined by multiplying the fraction of each reactive mineral next to the connected pore network, measured in 2D, with the surface area of the connected pore network in the rock, which is measured in 3D from X-ray based micro tomography (μ-CT) images and subsequently refined with a correction factor that accounts for the missing pore connectivity. This is necessary since μ-CT voxel resolution (880 nm) is lower than the pixel resolution achieved with BSE-SEM (330 nm). The accessible surface areas of the reactive minerals present in the sandstone rock can be used to accurately scale the rate constants for quantitative prediction and ultimately control of CO_2 injection in the subsurface at the Cranfield pilot site." **Gautier Landrot, Jonathan B. Ajo-Franklin, Li Yang, Stefano Cabrini, and Carl I. Steefel**, *Chemical Geology*, Available online May 23, 2012, doi:10.1016/j.chemgeo.2012.05.010, http://www.sciencedirect.com/science/article/pii/S000925411200229X?v=s5. (Subscription may be required.)

July 2012

"Tracers – Past, Present and Future Applications in CO_2 Geosequestration." The following is the Abstract of this article: "Chemical tracers have been used in various CCS projects worldwide primarily to provide information regarding subsurface migration of CO_2 and to verify CO_2 containment. Understanding the movement and interactions of CO_2 in the subsurface is a challenging task considering the variety of states in which it exists (i.e. gas, liquid, supercritical, dissolved in water) and the range of possible storage mechanisms (i.e. residual or capillary trapping, dissolved in water, structural trapping or incorporation into minerals). This paper critically reviews several chemical tracer applications and case studies for CCS projects. In many instances, there are parallels (e.g. tracer classes and applications)

between tracers in the oil and gas industry and in CCS. It has been shown that chemical tracers can complement geophysical measurements (e.g. seismic) in understanding the formation [behavior] of CO_2. Although tracers have been successfully used in many CCS projects, some fundamental information, for example partitioning and adsorption, about the [behavior] of tracers is still lacking and this can be an issue when interpreting tracer data (e.g. determining leakage rates). In this paper the deployment and recovery of chemical tracers and their use on various CCS projects are described." **Matthew Myers, Linda Stalker, Bobby Pejcic, and Andrew Ross**, *Applied Geochemistry*, Available online June 15, 2012, doi:10.1016/j.apgeochem.2012.06.001, http://www.sciencedirect.com/science/article/pii/S0883292712001485?v=s5. (Subscription may be required.)

"Reaction of Water-Saturated Supercritical CO_2 with Forsterite: Evidence for Magnesite Formation at Low Temperatures." The following is the Abstract of this article: "The nature of the reaction products that form on the surfaces of nanometer-sized forsterite particles during reaction with H_2O saturated supercritical CO_2 ($scCO_2$) at 35°C and 50°C were examined under in situ conditions and ex situ following reaction. The in situ analysis was conducted by X-ray diffraction (XRD). Ex situ analysis consisted of scanning electron microscopy (SEM) examination of the surface phases and chemical characterization of precipitates using a combination of confocal Raman spectroscopy, ^{13}C and ^{29}Si NMR spectroscopy, and energy-dispersive X-ray Spectroscopy (EDS). The results show that the forsterite surface is highly reactive with the primary reaction products being a mixture of nesquehonite and magnesite at short reaction times ([approximately three to four] days) and then magnesite and a highly porous amorphous silica phase at longer reaction times (14 days). After 14 days of reaction most of the original forsterite transformed to reaction products. Importantly, the formation of magnesite was observed at temperatures much lower (35°C) than previously thought needed to overcome its well known sluggish precipitation kinetics. The conversion of nesquehonite to magnesite liberates H_2O which can potentially facilitate further metal carbonation, as postulated by previous investigators, based upon studies at higher temperature (80°C). The observation that magnesite can form at lower temperatures implies that water recycling may also be important in determining the rate and extent of mineral carbonation in a wide range of potential CO_2 storage reservoirs." **Andrew R. Felmy, Odeta Qafoku, Bruce W. Arey, Jian Zhi Hu, Mary Hu, H. Todd Schaef, Eugene S. Ilton, Nancy J. Hess, Carolyn I. Pearce, Ju Feng, and Kevin M. Rosso**, *Geochimica et Cosmochimica Acta*, Available online June 12, 2012, doi:10.1016/j.gca.2012.05.026, http://www.sciencedirect.com/science/article/pii/S0016703712003225?v=s5. (Subscription may be required.)

"Monitoring groundwater flow and chemical and isotopic composition at a demonstration site for carbon dioxide storage in a depleted natural gas reservoir." The following is the Abstract of this article: "Between March 2008 and August 2009, 65,445 tonnes of ~75 mol% CO_2 gas were injected in a depleted natural gas reservoir approximately 2000 m below surface at the Otway project site in Victoria, Australia. Groundwater flow and composition were monitored biannually in two overlying [formations] between June 2006 and March 2011, spanning the pre-, syn- and post-injection periods. The shallower (~0–100 m), unconfined, porous and karstic [formation] of the Port Campbell Limestone and the deeper (~600–900 m), confined and porous [formation] of the Dilwyn Formation contain valuable fresh to brackish water resources. Groundwater levels in either [formation] have not been affected by the drilling, pumping and injection activities that were taking place, or by the rainfall increase during the project. In terms of groundwater composition, the Port Campbell Limestone groundwater is brackish (electrical conductivity = 801–3900 μS cm^{-1}), cool (temperature = 12.9–22.5°C), and near-neutral (pH = 6.62–7.45), whilst the Dilwyn [formation] groundwater is fresher (electrical conductivity = 505–1473 μS cm^{-1}), warmer (temperature = 42.5–48.5°C), and more alkaline (pH = 7.43–9.35). Carbonate dissolution, evapotranspiration and cation exchange control the composition of the groundwaters. Comparing the chemical and isotopic composition of the groundwaters collected before, during and after injection shows no statistically significant changes; even if they were statistically significant, they are mostly not consistent with those expected if CO_2 addition had taken place. The monitoring program reveals no

impact on the groundwater resources attributable to the C storage demonstration project." **Patrice de Caritat, Allison Hortle, Mark Raistrick, Charlotte Stalvies, and Charles Jenkins**, *Applied Geochemistry*, Available online May 16, 2012, doi:10.1016/j.apgeochem.2012.05.005, http://www.sciencedirect.com/science/article/pii/S0883292712001230. (Subscription may be required.)

"Experimental study of crossover from capillary to viscous fingering for supercritical CO_2 – water displacement in a homogeneous pore network." The following is the Abstract of this article: "Carbon [storage] in saline [formations] involves displacing brine from the pore space by supercritical CO_2 ($scCO_2$). The displacement process is unstable due to the unfavorable viscosity ratio between the invading $scCO_2$ and the resident brine. The mechanisms that affect $scCO_2$-water displacement under reservoir conditions (41°C, 9 MPa) were investigated in a homogeneous micromodel. A large range of injection rates, expressed as the dimensionless capillary number (Ca), was studied in two sets of experiments: discontinuous-rate injection, where the micromodel was saturated with water before each injection rate was imposed, and continuous-rate injection, where the rate was increased after quasi-steady conditions were reached for a certain rate. For the discontinuous-rate experiments, capillary fingering and viscous fingering are the dominant mechanisms for low (logCa <= -6.61) and high injection rates (logCa >= -5.21), respectively. Crossover from capillary to viscous fingering was observed for logCa = -5.91~-5.21, resulting in a large decrease in $scCO_2$ saturation. The discontinuous-rate experimental results confirmed the decrease in nonwetting fluid saturation during crossover from capillary to viscous fingering predicted by numerical simulations by Lenormand et al. (1988).1 Capillary fingering was the dominant mechanism for all injection rates in the continuous-rate experiment, resulting in monotonic increase in $scCO_2$ saturation." **Ying Wang, Changyong Zhang, Ning Wei, Mart Oostrom, Thomas W. Wietsma, Xiaochun Li, and Alain Bonneville**, *Environ. Sci. Technol.*, Available online June 5, 2012, doi:10.1021/es3014503, http://pubs.acs.org/doi/abs/10.1021/es3014503. (Subscription required.)

August 2012

"Hydrogeochemical numerical simulation of impacts of mineralogical compositions and convective fluid flow on trapping mechanisms and efficiency of carbon dioxide injected into deep saline sandstone aquifers." The following is the Abstract of this article: "A series of numerical simulations, which consider density-dependent (convective) groundwater and CO_2 flow, is performed using a multiphase hydrogeochemical reactive transport numerical model to evaluate impacts of mineralogical compositions on the trapping mechanisms and efficiency of CO_2 injected into a deep saline sandstone [formation] (reservoir rock). The results of the numerical simulations show that the mineralogical compositions of the sandstone [formation] have significant impacts on hydrogeochemical behavior of injected CO_2 and thus its trapping mechanisms and efficiency. Injected CO_2 is accumulated as a free fluid phase beneath the caprock (i.e., hydrodynamic trapping), then dissolved as aqueous phases such as bicarbonate and carbonate anions into groundwater (i.e., solubility trapping), and finally precipitated as carbonate minerals (i.e., mineral trapping). Mineral trapping of injected CO_2 takes places as precipitation of a primary carbonate mineral such as calcite and secondary carbonate minerals such as dawsonite, siderite, ankerite, and magnesite. The patterns of hydrogeochemical reactions depend significantly on the initial presence and absence of chlorite in the sandstone [formation]. For mineral trapping of injected CO_2, ankerite is the most dominant mineral when chlorite is initially present, whereas dawsonite is the most dominant mineral when chlorite is initially absent in the sandstone aquifer. Mg^{2+} and Fe^{2+}, which are essential chemical components of such secondary carbonate minerals (i.e., siderite, ankerite, and magnesite) for mineral trapping of injected CO_2, are mainly supplied by dissolution of chlorite. As a result, the precipitation amounts of the secondary carbonate minerals and thus the efficiency of mineral trapping of injected CO_2 increase significantly as the volume fraction of chlorite increases in the sandstone [formation]. A series of additional numerical simulations, which consider density-independent (non-convective) multiphase fluid flow, is also performed using the same numerical model, and then its results are compared with those of the above-mentioned numerical simulations,

which consider density-dependent (convective) multiphase fluid flow, to evaluate impacts of convective fluid flow on the trapping mechanisms and efficiency of injected CO_2. The comparison of the results of both numerical simulations shows that convective fluid flow also has significant impacts on hydrogeochemical behavior of injected CO_2 and thus its trapping mechanisms and efficiency. Convective fluid flow reduces the free fluid phase of CO_2 (i.e., hydrodynamic trapping) and thus enhances the aqueous and solid phases of CO_2 (i.e., initially solubility trapping and then mineral trapping)." **Jung-Hwi Kihm, Jun-Mo Kim, Sookyun Wang, and Tianfu Xu**, *Journal of Geophysical Research*, Available online June 12, 2012, doi:10.1029/2011JB008906, http://www.agu.org/pubs/crossref/2012/2011JB008906.shtml. (Subscription may be required.)

"Hydro-mechanical analysis of CO_2 storage in porous rocks using a critical state model." The following is the Abstract of this article: "A numerical model is presented to simulate the hydro-mechanical [behavior] of the porous rocks that form the deep saline [formations] which are currently being considered as potential CO_2 storage reservoirs. The model has taken into account the equations of state regulating the [behavior] of CO_2, in both the supercritical state in which will be injected, and under atmospheric conditions. Whilst the flow model is founded on a 'conventional' advective/diffusive formulation, the geomechanical constitutive model used is a critical state model that includes a non-linear hypoelastic law, and a brittle/ductile yield which takes into account mechanical degradation and the effect of partial saturation caused by the CO_2 flow. With this model, it will be possible to analyze the [localization] of the deformation which may occur when a dilatant brittle yield is reached, and thus to analyze the role played by the preferential flow paths associated with this localization. A partial differential equation solver based on the finite element method, which adopts a multiphysics simulation environment, has been used. After some examples of validation, the simulation of a synthetic example that highlights the capacities of the model is presented." **J. Alonso, V. Navarro, B. Calvo, and L. Asensio**, *International Journal of Rock Mechanics and Mining Sciences*, Available online June 7, 2012, doi:10.1016/j.ijrmms.2012.05.016, http://www.sciencedirect.com/science/article/pii/S1365160912000962. (Subscription may be required.)

Technology

September 2011

"Economics of CCS for coal plants: Impact of investment costs and efficiency on market diffusion in Europe." The following is the Abstract of the article: "In this paper, [the authors] analyze how the development of the CCS technology used in coal-fired power plants affects its market diffusion. Specifically, [the authors] (1) show the significant variance in expectations about the economics of commercial-grade CCS hard coal power plants observed in the literature; (2) analyze the impact of CCS economics on electricity generation costs; and (3) investigate the expected deployment of CCS in the European power sector, depending on the variance of two main factors, efficiency and investment cost, using the bottom-up electricity sector model HECTOR. Simulation results show that investment costs strongly influence the market deployment of coal-fired CCS power plants, leading to a share of 16 [percent] in European generation capacity by 2025 with the lowest observed investment costs of [~1,884 $/kW], but only 2 [percent] with the highest of [~4,037 $/kW]. A variation of conversion efficiency between 37 [percent] and 44 [percent], the minimum and maximum observed values, only leads to a 13-15 [percent] share of CCS-equipped power plants. These findings are robust for the Base Case with a CO_2 price of [~58 $/t] and also for sensitivities with [~40 and ~27 $/t CO_2], but with a lower effect, as the overall share of CCS is significantly reduced at these prices." **Richard Lohwasser and Reinhard Madlener**, *Energy Economics*, Available online August 6, 2011, doi:10.1016/j.eneco.2011.07.030, http://www.sciencedirect.com/science/article/pii/S0140988311001605. (Subscription may be required.)

"Precipitation of Calcium Carbonate by Carbon Dioxide Microbubbles." The following is the Abstract of this article: "The microbubble generator (MBG)—an apparatus in which tiny micron-sized gas

bubbles are produced in the aqueous phase—has been widely used in water purification systems. In this study, the feasibility of utilizing the MBG to precipitate calcium carbonate along the carbonation route was examined. The effects of the calcium hydroxide concentration and the injection flow rate of [CO_2] on the precipitation process were evaluated. Changes in pH, temperature of the suspension, and residual calcium ion concentration in the suspension were monitored to evaluate the proposed process. In addition, the process was compared with that based on a conventional bubble generator. This revealed a two-fold improvement in the acquisition time required for calcium carbonate precipitation as well as an increase in the conversion efficiency of [CO_2] to carbonate minerals. The proposed process should be helpful for practical applications of a carbon sequestration method." **Jun-Hwan Bang, Young Nam Jang, Wonbaek Kim, Kyung Sun Song, Chi Wan Jeon, Soo Chun Chae, Seung-Woo Lee, So-Jin Park, and Myung Gyu Lee**, *Chemical Engineering Journal*, Available online September 10 , 2011, doi:10.1016/j.cej.2011.09.021, http://www.sciencedirect.com/science/article/pii/S1385894711010795. (Subscription may be required.)

"**Greening Coal: Breakthroughs and Challenges in Carbon Capture and Storage."** The following is the Abstract of this article: "This paper reviews the state-of-the-art of science and technology related to CO_2 capture, storage, and system-wide integration. Each of these areas is covered in a separate section, with emphasis on strategies and technologies suitable for making CCS happen in the near future. Substantial short-term effort in CCS is currently being directed toward reducing capture costs from industrial sources, mainly power plants, and ensuring that geologic sequestration can be done safely; however [the authors] include brief discussions of future directions in other areas within each section. The capture section outlines the three primary approaches currently being pursued for capture from power plants (post-combustion, oxy-combustion, and pre-combustion capture), then focuses on challenges faced by incorporating capture into existing coal-fired power plants, specifically, work on solvents, solid sorbents, and membranes that can reduce capture costs. The storage section begins with a brief review of potential storage options, including mineralization, ocean storage and others. [The authors] next focus on geologic sequestration in deep saline aquifers, with discussion of subsurface trapping mechanisms, coupled flow and transport processes, and an example of thermo-hydro-chemical-mechanical simulation that illustrates the interrelationships of these processes in CO_2 repositories. [The authors] finish this section with discussion of new research directions in reservoir pressure management and the role of risk analysis in sequestration projects. The system-wide integration section discusses relationships between sources, storage sites, and the connecting transportation infrastructure. Efficient design of CCS infrastructure that considers the intersection of science, policy, and industry is critical for effective and economically viable CCS development. An example is presented that demonstrates the usefulness of comprehensive system design for routing CO_2 to multiple storage sites. The section continues with discussion of recent developments in and implications of total system design." **Philip Stauffer, Gordon N. Keating, Richard S Middleton, Hari Selvi Viswanathan, Rajinder P Singh, Kathryn A. Berchtold, Rajesh J. Pawar, and Anthony Mancino**, *Environ. Sci. Technol.*, Available online September 9, 2011, doi:10.1021/es200510f, http://pubs.acs.org/doi/abs/10.1021/es200510f. (Subscription may be required.)

October 2011

"Pore-scale study of capillary trapping mechanism during CO_2 injection in geological formations." The following is from the Abstract of this article: "Geological [storage] of CO_2 gas has emerged as a promising solution for reducing the amount of greenhouse gases in atmosphere. A number of continuum scale models are available to describe the transport phenomena of CO_2 [storage]. These models rely heavily on a phenomenological description of subsurface transport phenomena and the predictions can be highly uncertain. "First-principle" pore-scale models provide a better understanding of fluid displacement processes. In this work [the authors] use a Smoothed Particle Hydrodynamics (SPH) model to study pore-scale displacement and capillary trapping mechanisms of super-critical CO_2 in the subsurface. Simulations are carried out to investigate the effects of gravitational, viscous, and capillary forces on the amount of trapped CO_2 in terms of non-dimensional numbers. [The authors] found that the

displacement patterns and the amount of trapped CO_2 depends mainly on Capillary and Gravity numbers. For large Gravity numbers, most of the injected CO_2 reaches the cap-rock due to gravity separation. A significant portion of CO_2 gets trapped by capillary forces when the Gravity number is small. When the Gravity number is moderately high, trapping patterns are heavily dependent on the Capillary number. If the Capillary number is very small, then capillary forces dominate the buoyancy forces and a significant fraction of injected CO_2 is trapped by the capillary forces. Conversely, if the Capillary number is high, trapping is relatively small since buoyancy dominates the capillary forces." **Uditha C. Bandara, Alexandre M. Tartakovsky, Bruce J. Palmer**, *International Journal of Greenhouse Gas Control*, Available online October 7, 2011, doi:10.1016/j.ijggc.2011.08.014, http://www.sciencedirect.com/science/article/pii/S1750583611001708. (Subscription required.)

"Storage of CO_2 hydrate in shallow gas reservoirs: pre- and post-injection periods." The following is from the Abstract of this article: "With the growing concern about climate change, interest in reducing CO_2 emissions has increased. Geological storage of CO_2 is perceived to be one of the most promising methods that could provide significant reductions in CO_2 emissions over the short and medium term. Since a major concern regarding geological storage is the possibility of leakage, trapping CO_2 in a solid form is quite attractive. Unlike mineral trapping, the kinetics of CO_2-hydrate formation is quite fast, providing the opportunity for long-term storage of CO_2. Thermodynamic calculations suggest that CO_2 hydrate is stable at temperatures that occur in a number of formations in Northern Alberta, in an area where there are significant CO_2 emissions associated with the production of oil sands and bitumen. In this paper, [the authors] study storage of CO_2 in hydrate form at conditions similar to those at depleted gas pools in Northern Alberta. Our numerical simulation results show that the CO_2 storage capacity of such pools is many times greater than their original gas-in-place. This provides a local option for storage of a portion of the CO_2 emissions from the oil sands operations in northeastern Alberta. In an earlier paper, [the authors] studied hydrate formation during a period of continued CO_2 injection. In this paper, [the authors] extend the duration of the investigation to include the period after injection has stopped. In particular, [the authors] study the storage capacity of such depleted gas pools and the fate of the hydrate over long periods of time when the injection of CO_2 has slowed down or ceased. [The authors] examine the effect of properties of the reservoir and cap/base rocks, as well as operating conditions. In particular, [the authors] investigate a shut-in case as the most realistic condition in CO_2 field [storage]." **Olga Ye Zatsepina and Mehran Pooladi-Darvish**, *Greenhouse Gases: Science and Technology*, Available online September 2011, DOI:10.1002/ghg.23, http://onlinelibrary.wiley.com/doi/10.1002/ghg.23/abstract. (Subscription may be required.)

"Strong and Reversible Binding of Carbon Dioxide in a Green Metal-Organic Framework." The following is from the Abstract of this article: "Although porous metal-organic frameworks (MOFs) have been shown to be very effective at adsorbing CO_2 selectively by dint of dipole-quadruple interactions and/or ligation to open metal sites, the gas is not usually trapped covalently. Furthermore, the vast majority of these MOFs are fabricated from nonrenewable materials, often in the presence of harmful solvents, most of which are derived from petrochemical sources. Herein [the authors] report the highly selective adsorption of CO_2 by CD-MOF-2, a recently described green MOF consisting of the renewable cyclic oligosaccharide γ-cyclodextrin and RbOH, by what is believed to be reversible carbon fixation involving carbonate formation and decomposition at room temperature. The process was monitored by solid-state ^{13}C NMR spectroscopy as well as colorimetrically after a pH indicator was incorporated into CD-MOF-2 to signal the formation of carbonic acid functions within the nanoporous extended framework." **Jeremiah J. Gassensmith, Hiroyasu Furukawa, Ronald A. Smaldone, Ross S. Forgan, Youssry Y. Botros, Omar M. Yaghi, and J. Fraser Stoddart**, *J. Am. Chem. Soc.*, Available online August 30, 2011, doi:10.1021/ja206525x, http://pubs.acs.org/doi/abs/10.1021/ja206525x. (Subscription required.)

November 2011

"An evaluation of ex situ, industrial-scale, aqueous CO_2 mineralization." The following is the Abstract of this article: "It is essential to objectively evaluate the many CO_2 mitigation strategies in order to prioritize investments of capital and research. Aqueous CO_2 mineralization is one potential strategy to permanently sequester CO_2, without the associated long-term monitoring and liability issues. Investigators are studying and optimizing aqueous CO_2 mineralization for the production of inorganic carbonates and are scaling up some of these processes. This paper adopts a life-cycle approach toward the evaluation of energy requirements and discusses other potential barriers for three CO_2 mineralization pathways: industrial caustics, naturally occurring minerals, and industrial wastes. This analysis is based on CO_2 capture from a 1 GW coal-fired power plant using one of the three mineral mineralization pathways. The investigators utilize consistent system boundaries and process-modeling assumptions, standard engineering calculations to estimate energy requirements, and publicly available data for upstream energy requirements and for the production of products/co-products. The results suggest that some industrial wastes show promise for CO_2 mineralization, but their availability is limited. The other pathways currently have large energy penalties and face other significant barriers, such as the production of large quantities of potentially hazardous waste and large-scale mining." **K.E. Kelly, G.D. Silcox, A.F. Sarofim, and D.W. Pershing**, *International Journal of Greenhouse Gas Control*, Available online October 20, 2011, doi:10.1016/j.ijggc.2011.09.005, http://www.sciencedirect.com/science/article/pii/S1750583611001757. (Subscription may be required.)

"Structural Integrity of CO_2 Transport Pipelines – A Review." The following is the Abstract of this article: "A recent trend in the development of CO_2 pipelines is the shift from the predominance of transport of CO_2 for EOR to the transportation of CO_2 as part of the [CCS] process for global warming mitigation. Among the processes of capture, transport, and storage, less attention has been paid to transport as it is assumed to be for granted, existing technology. This paper presents a focused analysis of the problem of structural integrity of CO_2 pipelines through reviewing the state-of-the-art literature and practice, and highlights the need for a unified code of practice for the modeling of integrity and, due to the potentially hazardous nature of CO_2, safety, in these pipelines." **Amir Chahardehi**, *Key Engineering Materials*, Available online September 1, 2011, doi:10.4028/www.scientific.net/KEM.488-489.779, http://www.scientific.net/KEM.488-489.779. (Subscription may be required.)

"Potential influence of CO_2 release from a carbon capture storage site on release of trace metals from marine sediment." The following is the Abstract of this article: "One of the main risks of CCS is CO_2 [release] from a storage site. The influence of CO_2 [release] on trace metals leaching from contaminated marine sediment in a potential storage area (Northern Spain) is addressed using standardized leaching tests. The influence of the pH of the leaching solution on the leachates is evaluated using deionized water, natural seawater and acidified seawater at pH = 5, 6 and 7, obtained by CO_2 bubbling. Equilibrium leaching tests were performed at different liquid–solid ratios and the results of ANC/BNC leaching test were modeled using Visual Minteq. Equilibrium tests gave values of the final pH for all seawater leachates between 7 and 8 due to the high acid neutralization capacity of the sediment. Combining leaching test results and geochemical modeling provided insight in the mechanisms and prediction of trace metals leaching in acidified seawater environment." **M. Cruz Payán, Bram Verbinnen, Berta Galan, Alberto Coz, Carlo Vandecasteele, and Javier R. Viguri**, *Environmental Pollution*, Available online November 10, 2011, doi:10.1016/j.envpol.2011.10.015, http://www.sciencedirect.com/science/article/pii/S0269749111005859. (Subscription may be required.)

December 2011

"A framework for environmental assessment of CO_2 capture and storage systems." The following is the Abstract of this article: "CCS is increasingly seen as a way for society to enjoy the benefits of fossil fuel energy sources while avoiding the climate disruption associated with fossil CO_2 emissions. A

decision to deploy CCS technology at scale should be based on robust information on its overall costs and benefits. LCA is a framework for holistic assessment of the energy and environmental footprint of a system, and can provide crucial information to policy-makers, scientists, and engineers as they develop and deploy CCS systems. [The authors] identify seven key issues that should be considered to ensure that conclusions and recommendations from CCS LCA are robust: energy penalty, functional units, scale-up challenges, non-climate environmental impacts, uncertainty management, policy-making needs, and market effects. Several recent life-cycle studies have focused on detailed assessments of individual CCS technologies and applications. While such studies provide important data and information on technology performance, such case-specific data are inadequate to fully inform the decision making process. LCA should aim to describe the system-wide environmental implications of CCS deployment at scale, rather than a narrow analysis of technological performance of individual power plants." **Roger Sathre, Mikhail Chester, Jennifer Cain, and Eric Masanet**, *Energy*, Available online November 29, 2011, doi:10.1016/j.energy.2011.10.050, http://www.sciencedirect.com/science/article/pii/S0360544211007171. (Subscription may be required.)

"Life cycle assessment of CO_2 sequestration in magnesium silicate rock – A comparative study." The following is the Abstract of this article: "This paper addresses the energy and environmental implications of [storing] CO_2 from a coal power plant using magnesium silicate rock. An accounting type life cycle assessment (LCA) of the mineralization method under development at Åbo Akademi University (ÅAU), Finland, is presented and the results are compared with the process developed at NETL, formerly Albany Research Council (ARC) in the [United States]. The ÅAU process is a multi-staged route where CO_2 is [stored] via a process that first produces magnesium hydroxide, $Mg(OH)_2$ from Mg silicate. The $Mg(OH)_2$ produced is later reacted with CO_2 in a high temperature gas/solid pressurized fluidized bed (FB) reactor, forming pure, stable and environmentally benign $MgCO_3$ product. This study addresses the following important issues; (a) the material and energy requirements of [storing] 1 ton of CO_2 (t-CO_2) in mineral silicate, (b) the overall environmental burdens associated with CO_2 [storage] using serpentinite mineral, (c) the priorities and opportunities for reduction of energy requirements and environmental impacts associated with mineralizing CO_2, and (d) comparison of LCA results of the ÅAU mineralization process route with that of the mineralization process developed by NETL. Exergy calculations show that with heat recovery mineralizing 1 t-CO_2 using the ÅAU process requires 3.6 GJ/t-CO_2 while that of the NETL needs 3.4 GJ/t-CO_2. Applying results of exergy analysis in the life cycle inventory (LCI) models of the ÅAU and the NETL processes leads to 517 kg CO_2e and 683 kg CO_2e of [GHG] emissions (in CO_2 equivalents) respectively, for every ton of CO_2 mineralized in serpentinite." **Experience Nduagu, Joule Bergerson, and Ron Zevenhoven**, *Energy Conversion and Management*, Available online November 29, 2011, doi:10.1016/j.enconman.2011.10.026, http://www.sciencedirect.com/science/article/pii/S0196890411003074. (Subscription may be required.)

January 2012

"Carbon dioxide capture with membranes at an IGCC power plant." The following is the Abstract of this article: "Integrated Gasification Combined Cycle (IGCC) power plants are being developed as an economical method of producing electricity from coal while simultaneously capturing CO_2 for [storage]. In these plants, conventional cold absorption processes are considered the baseline technology to separate CO_2 from gasified coal syngas. Separation and [storage] of the CO_2 by these methods increases the levelized cost of the electricity (LCOE) produced by approximately 30 [percent]. This paper describes the use of hydrogen-selective and CO_2-selective membranes used in various process designs to perform the same separation. The best design, using recently developed membranes, has 40 [percent] of the capital cost and uses 50 [percent] of the energy of cold absorption. The resulting increase in the LCOE to separate and [store] the CO_2 is then approximately 15 [percent]. If higher permeance, and especially more selective, membranes can be developed, the cost of the technology described will be reduced even further." **Tim C. Merkel, Meijuan Zhou, and Richard W. Baker**, *Journal of Membrane Science*, Available online November 12, 2011, doi:10.1016/j.memsci.2011.11.012, http://www.sciencedirect.com/science/article/pii/S0376738811008283. (Subscription may be required.)

"Influence of droplet mutual interaction on carbon dioxide capture process in sprays." The following is the Abstract of this article: "Sprays are an important tool for [CO_2] capture through absorption. To figure out CO_2 capture processes in sprays, the gas absorbed by a single droplet under droplet mutual interaction is investigated. In the study, the number density of droplet is in the range of 10^3–10^6 cm^{-3}. By conceiving a bubble as the influence distance of the droplet–droplet interaction, the predictions indicate that the mutual interaction plays an important role on the absorption process and uptake amount of CO_2 when the number density is as high as 10^6 cm^{-3} with droplet radius of 30 μm. Specifically, the absorption period and CO_2 uptake amount of a droplet are reduced by [seven percent] and 10 [percent], respectively, so that the absorption rate is decreased compared to the droplet without interaction. Though the droplet mutual interaction abates the CO_2 uptake amount of a single droplet, a higher number density is conducive to the total uptake amount of CO_2 from the gas phase to the liquid phase. With the number density of 10^6 cm^{-3} and increasing the droplet radius from 10 to 50 μm, CO_2 capture from the gas phase to the liquid phase is intensified from 0.35 [percent] to 47.8 [percent], even though the droplet–droplet interaction lessens the CO_2 uptake amount of a single droplet by a factor of 48 [percent]. In conclusion, a dense spray with larger droplet radii enhances the droplet–droplet interaction and thereby reduces CO_2 capture capacity of single droplets; but more solute can be removed from the gas phase." **Wei-Hsin Chen, Yu-Lin Hou, and Chen-I Hung**, *Applied Energy*, Available online November 29, 2011, doi:10.1016/j.apenergy.2011.10.035, http://www.sciencedirect.com/science/article/pii/S0306261911006891. (Subscription may be required.)

February 2012

"Pre-combustion carbon dioxide capture by gas-liquid absorption for Integrated Gasification Combined Cycle power plants." The following is the Abstract of this article: "Among various configurations of fossil fuel power plants with [CO_2] capture, this paper focuses on pre-combustion capture technology applied to an [IGCC] power plant using gas–liquid absorption. The paper proposes a detailed study and optimization of plant design (column height and packed dimensions) with CO_2 capture process using different solvents as: aqueous solutions of alkanolamine, dimethyl ethers of polyethylene glycol, chilled methanol and N-Methyl-2-pyrolidone. By developing simulations in Aspen Plus, the following performance results of these physical and chemical solvents, mentioned above, are discussed: overall energy consumption (power consumption, heating and cooling agent consumption), CO_2 specific emissions, net electric power output and plant efficiency. The paper presents as well, the total investment capital cost of an IGCC coal mixed with biomass (sawdust) power plant generating 425-450 MW net electricity with (70 [percent] CO_2 capture, 80 [percent] CO_2 capture and 90 [percent] CO_2 capture) and without pre-combustion CO_2 capture. Simulation results show that for evaluated solvents for CO_2 capture, the physical solvent, dimethyl ethers of polyethylene glycol, is more energy efficient that the other physical and chemical solvents investigated. Regarding the economic study, implementation of pre-combustion CO_2 capture on IGCC plant, using dimethyl ethers of polyethylene glycol, leads to an increase of the capital cost with about 19.55 [percent] for 70 [percent] CO_2 capture, 20.91 [percent] for 80 [percent] CO_2 capture and 22.55 [percent] for 90 [percent] CO_2 capture." **Anamaria Padurean, Calin-Cristian Cormos, and Paul-Serban Agachi**, *Industrial Journal of Greenhouse Gas Control*, Available online January 18, 2012, doi:10.1016/j.ijggc.2011.12.007, http://www.sciencedirect.com/science/article/pii/S1750583611002350. (Subscription may be required.)

"A methodology to estimate maximum probable leakage along old wells in a geological sequestration operation." The following is the Abstract of this article: "This study presents a computational methodology to estimate the maximum probable leakage of CO_2 along old wells in a geological [storage] operation. The methodology quantifies the maximum probable CO_2 leakage as a function of the statistical characterization of existing wells. [The authors] use a Monte Carlo approach based on a computationally efficient simulator to run many thousands of realizations. Results from the Monte Carlo simulations are used to determine maximum leakage rates at 95 [percent] confidence. Uncertainty in the analysis is due to leaky well parameters, which are known to be highly uncertain. [The

authors] consider a wide range of parameter values, with [their] focus on assignment of effective well permeability values and the correlation of those values along individual wells. [The authors] use a specific location in Alberta, Canada, to demonstrate the methodology using a hypothetical injection and an assumed probability structure for the well permeabilities. [The authors] show that for a wide range of parameter values, the amount of leakage is within the bounds suggested as acceptable for climate change mitigation." **Juan P. Nogues, Benjamin Court, Mark Dobossy, Jan M. Nordbotten, and Michael A. Celia**, *International Journal of Greenhouse Gas Control*, Available online January 20, 2012, doi:10.1016/j.ijggc.2011.12.003, http://www.sciencedirect.com/science/article/pii/S1750583611002313. (Subscription may be required.)

"Transient CO_2 leakage and injection in wellbore-reservoir systems for geologic carbon sequestration." The following is the Abstract of this article: "At its most basic level, the injection of CO_2 into deep reservoirs for geologic carbon [storage] (GCS) involves a system comprising the wellbore and the target reservoir, the wellbore being the only conduit available to emplace the CO_2. Wellbores in general have also been identified as the most likely conduit for CO_2 and brine leakage from GCS sites, especially those in sedimentary basins with historical hydrocarbon production. [The authors] have developed a coupled wellbore and reservoir model for simulating the dynamics of CO_2 injection and leakage through wellbores, and [they] have applied the model to situations relevant to geologic CO_2 storage involving upward flow (e.g. leakage) and downward flow (injection). The new simulator integrates a wellbore-reservoir system by assigning the wellbore and reservoir to two different sub-domains in which flow is controlled by appropriate laws of physics. In the reservoir, [the authors] model flow using a standard multiphase Darcy flow approach. In the wellbores, [the authors] use the drift-flux model and related conservation equations for describing transient two-phase non-isothermal wellbore flow of CO_2-water mixtures. Applications to leakage test problems reveal transient flows that develop into quasi-steady states within a day if the reservoir can maintain constant conditions at the wellbore. Otherwise, the leakage dynamics could be much more complicated than the simple quasi-steady-state flow, especially when one of the phases flowing in from the reservoir is near its residual saturation. A test problem of injection into a depleted (low-pressure) gas reservoir shows transient behavior out to several hundred days with sub-critical conditions in the well disappearing after 240 days." **Lehua Pan, Curtis M. Oldenburg, Karsten Pruess, and Yu-Shu Wu**, *Greenhouse Gases: Science and Technology*, Available online December 2011, doi:10.1002/ghg.41, http://onlinelibrary.wiley.com/doi/10.1002/ghg.41/abstract. (Subscription may be required.)

March 2012

"The Cost of Carbon Capture and Storage for Natural Gas Combined Cycle Power Plants." The following is the Abstract of this article: "This paper examines the cost of CCS for natural gas combined cycle (NGCC) power plants. Existing studies employ a broad range of assumptions and lack a consistent costing method. This study takes a more systematic approach to analyze plants with an amine-based [post-combustion] CCS system with 90 [percent] CO_2 capture. [The authors] employ sensitivity analyses together with a probabilistic analysis to quantify costs for plants with and without CCS under uncertainty or variability in key parameters. Results for new baseload plants indicate a likely increase in levelized cost of electricity (LCOE) of $20–32/MWh (constant 2007$) or $22–40/MWh in current dollars. A risk premium for plants with CCS increases these ranges to $23–39/MWh and $25–46/MWh, respectively. Based on current cost estimates, [the authors'] analysis further shows that a policy to encourage CCS at new NGCC plants via an emission tax or carbon price requires (at 95 [percent] confidence) a price of at least $125/t CO_2 to ensure NGCC-CCS is cheaper than a plant without CCS. Higher costs are found for [non-baseload] plants and CCS retrofits." **Edward S. Rubin and Haibo Zhai**, *Environ. Sci. Technol.*, Available online February 14, 2012, doi:10.1021/es204514f, http://pubs.acs.org/doi/abs/10.1021/es204514f. (Subscription required.)

"Potential restrictions for CO_2 [storage] sites due to shale and tight gas production." The following is the Abstract of this article: "[CCS] is the only available technology that both allows continued use of

fossil fuels in the power sector and reduces significantly the associated CO_2 emissions. Geological [storage] requires a deep permeable geological formation into which captured CO_2 can be injected, and an overlying impermeable formation, called a caprock, that keeps the buoyant CO_2 within the injection formation. Shale formations typically have very low permeability and are considered to be good caprock formations. Production of natural gas from shale and other tight formations involves fracturing the shale with the explicit objective to greatly increase the permeability of the shale. As such, shale gas production is in direct conflict with the use of shale formations as a caprock barrier to CO_2 migration. [The authors] have examined the locations in the United States where deep saline aquifers, suitable for CO_2 [storage], exist, as well as the locations of gas production from shale and other tight formations. While estimated [storage] capacity for CO_2 [storage] in deep saline aquifers is large, up to 80 [percent] of that capacity has areal overlap with potential shale-gas production regions and, therefore, could be adversely affected by shale and tight gas production. Analysis of stationary sources of CO_2 shows a similar effect: about two-thirds of the total emissions from these sources are located within 20 miles of a deep saline aquifer, but shale and tight gas production could affect up to 85 [percent] of these sources. These analyses indicate that co-location of deep saline aquifers with shale and tight gas production could significantly affect the sequestration capacity for CCS operations. This suggests that a more comprehensive management strategy for subsurface resource utilization should be developed." **Thomas Elliot and Michael Celia**, *Environ. Sci. Technol.*, Available online February 21, 2012, doi:10.1021/es2040015, http://pubs.acs.org/doi/abs/10.1021/es2040015. (Subscription required.)

April 2012

"Effects of Well Spacing on Geological Storage Site Distribution Costs and Surface Footprint." The following is the Abstract of this article: "Geological storage studies thus far have not evaluated the scale and cost of the network of distribution pipelines that will be needed to move CO_2 from a central receiving point at a storage site to injection wells distributed about the site. Using possible injection rates for deep-saline sandstone [formations, the authors] estimate that the footprint of a [storage] site could range from <100 km^2 - >100,000 km^2, and that distribution costs could be <$0.10/tonne - >$10/tonne. [The authors'] findings are based on two models for determining well spacing; one which minimizes spacing in order to maximize use of the volumetric capacity of the reservoir, and a second that determines spacing to minimize sub-surface pressure interference between injection wells. The interference model, which [the authors] believe more accurately reflects reservoir dynamics, produces wider well spacings and a counterintuitive relationship whereby total injection site footprint and thus distribution cost declines with decreasing permeability for a given reservoir thickness. This implies that volumetric capacity estimates should be reexamined to include well spacing constraints, since wells will need to be spaced further apart than void space calculations might suggest. [The authors] conclude that site selection criteria should include thick, low-permeability reservoirs to minimize distribution costs and site footprint." **Jordan Kaelin Eccles, Lincoln Pratson, and Munish Kumar Chandel**, *Environmental Science & Technology*, Available online March 21, 2012, doi:10.1021/es203553e, http://pubs.acs.org/doi/abs/10.1021/es203553e?prevSearch=carbon%2Bsequestration&searchHistoryKey=. (Subscription required.)

"Parameters influencing the flow performance of natural cleat systems in deep coal seams experiencing carbon dioxide injection and sequestration." The following is the Abstract of this article: "Carbon dioxide [storage] in deep, unmineable coal seams may provide an immediate and economically feasible solution for mitigation of anthropogenic CO_2 emissions. Coal contains natural cleats, which largely control fluid movement in coal seams. This study uses experimental and numerical methods to investigate the variables (i.e. injection pressure, injection depth, and coal temperature) that will influence cleat performance in the CO_2 [storage] process for black coal. The steady-state downstream pressure (and pressure differential from the injection value) that develops during undrained triaxial tests performed on fractured black coal, without deviatoric load, is taken as a measure of cleat performance. The results of tests show that increasing injection pressure has a significant detrimental effect on cleat performance, in accord with greater adsorption-induced swelling (and cleat closure) with

higher injection pressure. Testing also shows that increasing injection depth has a moderate (negative) effect on cleat performance and that temperature has a minor (positive) effect on cleat performance. The experimental results were used to validate a numerical model produced using the COMET 3 numerical simulator, which was used to further explore coupling between the variables that influence cleat performance in coal-seam CO_2 [storage]. The numerical results show that the influence of injection pressure on cleat performance is dependent on injection depth, whereby a given increase in injection pressure will have more detrimental effects on cleat performance at greater depths than it would at more shallow depths. The influence of injection depth on cleat performance is similarly dependent on the absolute depth range considered. Coupling was observed in the influence of temperature on cleat performance and both injection pressure and depth. Modeling shows that increasing temperature has a negative influence on cleat performance for low injection pressures (i.e. 6 MPa), but a positive influence on cleat performance for higher injection pressures (i.e. 12 MPa). Modeling shows that temperature will have an influence on the manner by which depth effects cleat performance if injection pressures are high (i.e. 12 MPa), but no such influence if injection pressures are low (i.e. 6 MPa)." **M.S.A. Perera, P.G. Ranjith, D.R. Viete, and S.K. Choi**, *International Journal of Coal Geology*, Available online April 5, 2012, doi:10.1016/j.coal.2012.03.010, http://www.sciencedirect.com/science/article/pii/S016651621200095X. (Subscription required.)

"**Cross-hole electromagnetic and seismic modeling for CO_2 detection and monitoring in a saline [formation]."** The following is the Abstract of this article: "The injection of CO_2 in saline [formations] and depleted hydrocarbon wells is one solution to avoid the emission of that greenhouse gas to the atmosphere. Carbon taxes can be avoided if geological [storage] can efficiently be performed from technical and economic perspectives. For this purpose, [the authors] present a combined rock-physics methodology of electromagnetic (EM) and seismic wave propagation for the detection and monitoring of CO_2 in crosswell experiments. First, [the authors] obtain the electrical conductivity and seismic velocities as a function of saturation, porosity, permeability and clay content, based on the CRIM and White models, respectively. Then, [the authors] obtain a conductivity-velocity relation. This type of relations is useful when some rock properties can be more easily measured than other properties. Finally, [the authors] compute crosswell EM and seismic profiles using direct modeling techniques. P- and S-wave attenuation is included in the seismic simulation by means of White's mesoscopic theory. The modeling methodology is useful to perform sensitivity analyses and it is the basis for performing traveltime EM and seismic tomography and obtain reliable estimations of the saturation of [CO_2]. In both cases, it is essential to correctly pick the first arrivals, particularly in the EM case where diffusion wavelength is large compared to the source-receiver distance. The methodology is applied to CO_2 injection in a sandstone [formation] with shale intrusions, embedded in a shale formation. The EM traveltimes are smaller after the injection due to the higher resistivity caused by the presence of [CO_2], while the effect is opposite in the seismic case, where water replaced by gas decreases the seismic velocity." **José M. Carcione, Davide Gei, Stefano Picotti, and Alberto Michelini**, *Journal of Petroleum Science and Engineering*, Available March 30, 2012, doi:10.1016/j.petrol.2012.03.018, http://www.sciencedirect.com/science/article/pii/S092041051200071X. (Subscription required.)

May 2012

"Modeling and Upscaling of Binary Gas Coal Interactions in CO_2 Enhanced Coalbed Methane Recovery." The following is the Abstract of this article: "When CO_2 injected into the unmineable coal seam, complicated binary gas [methane (CH_4])-CO_2 coal interactions affect coal porosity and permeability, which is one of the bottleneck scientific issues faced in enhancing production of coalbed methane and the geological [storage] of [CO_2]. The issue is addressed through the development and application of a novel fully coupled coal deformation, gas transport and gas adsorption/desorption finite element (FE) model with COMSOL Multiphysics. The COMSOL FE model considers the combined net effects on coal permeability among the coal matrix swelling/shrinking due to gas displacement, pore pressure and in-situ stress. These combined effects are quantified through solving a set of coupled field

equations which govern the coal deformation, prescribe the transport and interaction of gas flow in a similar way to poroelastic theory, and define CH_4-CO_2 counter diffusion and flow in a coal seam. Numerical models were verified with the experiment data. The established COMSOL FE simulator was applied to simulate the CO_2 injection performance in Qinshui Basin field under in-situ size and conditions, to address in-situ spatial-temporal evolutions of coal deformation and permeability. Simulation results suggest that net change of coal permeability accompanying binary gas dispersion is controlled competitively by the influence of effective stresses and differential swelling of coal. 1.75×10^4t CO_2 can be sequestrated in 300×300 m^2 area of Qinshui Basin within 10 years. During the simulation, coalbed methane recovery was promoted by 1.44 times." **Lai Zhou, Qiyan Feng, Zhongwei Chen, and Jishan Liu**, *Procedia Environmental Sciences*, Available online April 6, 2012, doi:10.1016/j.proenv.2012.01.368, http://www.sciencedirect.com/science/article/pii/S1878029612003696. (Subscription may be required.)

"Modeling and analysis of selected carbon dioxide capture methods in IGCC systems." The following is the Abstract of this article: "Carbon dioxide capture from energy systems will likely become a necessity as the European Union regulations are becoming increasingly more stringent. The greatest disadvantage of the existing methods of CO_2 separation is the high energy intensity. In the Integrated Gasification Combined Cycle (IGCC) system, the [CO_2] capture process is conducted before combustion, which facilitates the separation. In this paper, two methods of CO_2 capture are compared. The first is the most frequently considered, known as chemical absorption. The second is membrane CO_2 separation, which is not as commonly deployed but has the potential to be an even more efficient process. The models of CO_2 capture installations were built in Aspen software. The two processes used in the analyses were primarily compared with respect to the energy intensity of each method. The results of the analysis show that the use of membranes allows for a significant decrease in the energy intensity of the capture process compared with the absorption process. However, the purity of the separated CO_2 significantly depends on the type and surface of the membrane and on the process parameters. Nevertheless, it is clear that the development of membrane techniques will enable the most competitive CO_2 capture solutions, in terms of effectiveness and cost, compared with other methods." **Anna Skorek-Osikowska, Katarzyna Janusz-Szymańska, and Janusz Kotowicz**, *Energy*, Available online March 3, 2012, doi:10.1016/j.energy.2012.02.002, http://www.sciencedirect.com/science/article/pii/S0360544212000953. (Subscription may be required.)

June 2012

"Molecular modeling of carbon dioxide transport and storage in porous carbon-based materials." The following is the Abstract of this article: "To fundamentally study the molecular processes in porous carbon-based systems relevant to transport and storage of [CO_2], non-equilibrium molecular dynamics simulations have been carried out with an external driving force imposed on a carbon-based 3-D pore network. The purpose of this study is to investigate the transport properties of pure [CO_2], methane and nitrogen as well as binary mixtures nitrogen and [CO_2] and also methane and [CO_2] through modeled 3-D carbon-based systems representative of porous carbon-based materials. The 3-D pore network has been generated atomistically using the Voronoi tessellation method of a structure containing approximately 125,000 atoms. Simulations have been carried out to determine the effect of the pore structure, exposure to an external potential and composition mixture on phenomena such as fluid distribution in the system and permeability for broad ranges of conditions. The results indicate that the morphological characteristics and energetic effects play a dominant role in the flow and transport properties of fluids. As expected among these factors, the porosity of the structure strongly affect the permeability. In addition, [the authors'] simulation results indicate that the permeability is *zero* below a critical porosity of about 0.2 due to the low connectivity in the pore network." **Mahnaz Firouzi and Jennifer Wilcox**, *Microporous and Mesoporous Materials*, Available online March 7, 2012, doi:10.1016/j.micromeso.2012.02.045, http://www.sciencedirect.com/science/article/pii/S1387181112001382. (Subscription may be required.)

"The outlook for improved carbon capture technology." The following is the Abstract of this article: "CCS is widely seen as a critical technology for reducing atmospheric emissions of CO_2 from power plants and other large industrial facilities, which are major sources of [GHG] emissions linked to global climate change. However, the high cost and energy requirements of current CO_2 capture processes are major barriers to their use. This paper assesses the outlook for improved, lower-cost technologies for each of the three major approaches to CO_2 capture, namely, post-combustion, pre-combustion and oxy-combustion capture. The advantages and limitations of each of method are discussed, along with the current status of projects and processes at various stages in the development cycle. [The authors] then review a variety of 'roadmaps' developed by governmental and private-sector organizations to project the commercial roll-out and deployment of advanced capture technologies. For perspective, [the authors] also review recent experience with R&D programs to develop lower-cost technologies for [sulfur dioxide (SO_2) and nitrogen oxide (NO_X)] capture at coal-fired power plants. For perspective on projected cost reductions for CO_2 capture [the authors] further review past experience in cost trends for SO_2 and NO_X capture systems. The key insight for improved carbon capture technology is that achieving significant cost reductions will require not only a vigorous and sustained level of R&D, but also a substantial level of commercial deployment, which, in turn, requires a significant market for CO_2 capture technologies. At present such a market does not yet exist. While various incentive programs can accelerate the development and deployment of improved CO_2 capture systems, government actions that significantly limit CO_2 emissions to the atmosphere ultimately are needed to realize substantial and sustained reductions in the future cost of CO_2 capture." **Edward S. Rubin, Hari Mantripragada, Aaron Marks, Peter Versteeg, and John Kitchin**, *Progress in Energy and Combustion Science*, Available online May 11, 2012, doi:10.1016/j.pecs.2012.03.003, http://www.sciencedirect.com/science/article/pii/S0360128512000184. (Subscription may be required.)

"A parametric study of the transport of CO_2 in the near-surface." The following is the Abstract of this article: "Previous simulations of the behavior of a CO_2 plume from a discrete line source near the ground surface have generally assumed that the water-table, soil layering, and land surface were all horizontal. As might be expected, these conditions produce plumes with a high degree of symmetry. The three dimensional TOUGH2 simulations reported here begin to consider several complications: degree of soil heterogeneity, presence of a capillary barrier, water table depth, CO_2 [release] rate, sloping topography, and regional groundwater flow (sloping water-table). The results show that the ground surface CO_2 flux distribution can be significantly different due to variation in the aforementioned factors, e.g. presence of a capillary barrier. The plume affected by these factors can assume an irregular shape characterized by multiple pathways to the surface. These pathways make the detection of a CO_2 [release] by soil gas or surface flux measurements conditionally possible at tens of meters away from the initial [release] location. Such phenomena should be considered when designing CO_2 detection network design." **Egemen Ogretim, Everett Mulkeen, Donald D. Gray, and Grant S. Bromhal**, *International Journal of Greenhouse Gas Control*, Available online May 15, 2012, doi:10.1016/j.ijggc.2012.04.007, http://www.sciencedirect.com/science/article/pii/S1750583612000953. (Subscription may be required.)

July 2012

"NEMS-CCUS: A Model and Framework for Comprehensive Assessment of CCUS and Infrastructure." The following is the Abstract of this article: "NETL has funded development of a NEMS-CCUS (National Energy Modeling System) Model that enables modeling of CO_2 pipelines and pipeline networks across the [48] contiguous states. An existing NEMS-based analysis used by NETL to assess CCUS for existing coal-fired power plants was updated to include CO_2 capture from both existing coal-fired and new gas- and coal-fired plants, factor in plant specific variations in the costs of CO_2 capture and include regional variations in the costs of the transmission and storage of CO_2. Pipeline networks in the updated model are configured endogenously to be optimally consistent with the latest capacity and cost data for the U.S. storage resource base. The model enables analysis of various source, [formation], and pipeline combinations under different economic and policy scenarios. This paper presents a recent

application of the model to assess the role of [CCUS] in both carbon tax and clean energy standard Cases. Documentation is presented for key parts of the model, including: (1) capture costs – an update of the original generic model that includes corrections for other site specific details such as space constraints and location, based on the AEP Conesville Unit 5 CCUS retrofit study, which originally included corrections based on capacity, heat rate, and emission control configuration; (2) [storage] capacity and costs – NATCARB and other databases are used for storage capacity and formation properties which are combined with drilling, monitoring, and other cost estimates in various cost models; (3) transmission costs – pipeline cost data and [Geographic Information Systems (GIS)] data on siting constraints are combined in a General Algebraic Modeling System (GAMS) based optimizer that configures an evolving pipeline network ; (4) NEMS integration – the GAMS GDX utility is used to interface NEMS and the GAMS based optimizer (Capture Transportation Storage Module – CTS) such that the evolving pipeline network and its associated cost adders for transmission and [storage] are consistent with the penetration of CCUS in NEMS." **Rodney Geisbrecht, Charles A. Zelek, Tim Grant, L. A. Goudarzi, K. M. Callahan, and William Babiuch**, presented at the Carbon Management Technology Conference held in Orlando, Florida, USA, February 7–9, 2012 (CMTC-150377-PP), http://www.netl.doe.gov/energy-analyses/refshelf/PubDetails.aspx?Action=View&Source=Main&PubId=431.

"Monitoring CO_2 intrusion and associated geochemical transformations in a shallow groundwater system using complex electrical methods." The following is the Abstract of this article: "The risk of CO_2 [release] from a properly permitted deep geologic storage facility is expected to be very low. However, if [release] occurs it could potentially impact potable groundwater quality. Dissolved CO_2 in groundwater decreases pH, which can mobilize naturally occurring trace metals commonly contained in [formation] sediments. Observing such processes requires adequate monitoring strategies. Here, [the authors] use laboratory and field experiments to explore the sensitivity of time-lapse complex resistivity responses for remotely monitoring dissolved CO_2 distribution and geochemical transformations that may impact groundwater quality. Results show that electrical resistivity and phase responses correlate well with dissolved CO_2 injection processes. Specifically, resistivity initially decreases due to increase of bicarbonate and dissolved species. As pH continues to decrease, the resistivity rebounds toward initial conditions due to the transition of bicarbonate into non-dissociated carbonic acid, which reduces the total concentration of dissociated species and thus the water conductivity. An electrical phase decrease is also observed, which is interpreted to be driven by the decrease of surface charge density as well as potential mineral dissolution and ion exchange. Both laboratory and field experiments demonstrate the potential of field complex resistivity method for remotely monitoring changes in groundwater quality due to CO_2 [release]." **Baptiste Dafflon, Yuxin Wu, Susan S. Hubbard, Jens Birkholzer, Thomas M. Daley, John D. Pugh, John E. Peterson, and Robert Trautz**, *Environ. Sci. Technol.*, Available online June 7, 2012, doi:10.1021/es301260e, http://pubs.acs.org/doi/abs/10.1021/es301260e. (Subscription required.)

"In Situ Measurement of Magnesium Carbonate Formation from CO_2 Using Static High-Pressure and –Temperature ^{13}C NMR." The following is the Abstract of this article: "[The authors] explore a new in situ NMR spectroscopy method that possesses the ability to monitor the chemical evolution of supercritical CO_2 in relevant conditions for geological CO_2 [storage]. As a model, [the authors] use the fast reaction of the mineral brucite, $Mg(OH)_2$, with supercritical CO_2 (88 bar) in aqueous conditions at 80 °C. The in situ conversion of CO_2 into metastable and stable carbonates is observed throughout the reaction. After more than 58 h of reaction, the sample was depressurized and analyzed using in situ Raman spectroscopy, where the laser was focused on the undisturbed products through the glass reaction tube. Postreaction, ex situ analysis was performed on the extracted and dried products using Raman spectroscopy, powder X-ray diffraction, and magic-angle spinning ^{1}H-decoupled ^{13}C NMR. These separate methods of analysis confirmed a spatial dependence of products, possibly caused by a gradient of reactant availability, pH, and/or a reaction mechanism that involves first forming hydroxy-hydrated (basic, hydrated) carbonates that convert to the end-product, anhydrous magnesite. This carbonation reaction illustrates the importance of static (unmixed) reaction systems at sequestration-like conditions."

J. Andrew Surface, Philip Skemer, Sophia E. Hayes, and Mark S. Conradi, *Environ. Sci. Technol.*, Available online June 1, 2012, doi:10.1021/es301287n, http://pubs.acs.org/doi/abs/10.1021/es301287n. (Subscription required.)

"Scoping analysis of brine extraction/re-injection for enhanced CO_2 storage." The following is the Abstract of this article: "Brine extraction from the CO_2 injection interval and re-injection into overlying shallower [formations] have been described as an active management tool at [storage] sites. They improve injectivity and reduce risks, and are a potential cost-saving measure. In this study, using analytical equations, [the authors] show that brine re-injection from the deep [formation] into a shallower saline [formation] increases CO_2 storage capacity relative to direct CO_2 injection into the two saline aquifers as a result of the CO_2 density change. Using generic models, [the authors] compare three different scenarios for CO_2 injection: (i) injection of CO_2 into the deep [formation] without the re-injection program, (ii) injection of CO_2 into both the shallow and deep [formations], and (iii) injection of CO_2 into the deep [formation] and extraction/re-injection of the brine into the shallow [formation]. Volumetric calculations at different pressure and temperature conditions provide a simple analytical tool for studying CO_2 storage capacity in stacked saline [formations]. Numerical compositional simulations confirm results of the analytical derivations and prior assumptions. Depending on the size and depth of the shallower [formation], brine re-injection can increase storage capacity by 30 [percent] or more, given a comparison of scenario 3 with scenario 1. However, when scenario 3 is compared with scenario 2, storage gain is generally less than [five percent], although potential CO_2 [release] risks are reduced. Results of a sensitivity analysis to shallow-[formation] pore volume and geothermal-temperature gradient are also presented. In addition, brine re-injection from geopressured saline [formations], when compared with that of normally pressured reservoirs, is twice as efficient." **Seyyed Abolfazl Hosseini and Jean-Philippe Nicot**, *Greenhouse Gases: Science and Technology*, Available online May 22, 2012, doi:10.1002/ghg.1283, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1283/abstract. (Subscription may be required.)

August 2012

"Energy consumption reduction in CO_2 capturing and [storage] of an LNG plant through process integration and waste heat utilization." The following is the Abstract of this article: "Liquefied natural gas (LNG) plants are energy intensive. As a result, the power plants operating these LNG plants emit high amounts of CO_2. To mitigate global warming that is caused by the increase in atmospheric CO_2, CCS using amine absorption is proposed. However, the major challenge of implementing this CCS system is the associated power requirement, increasing energy consumption by about 15–20 [percent]. In order to reduce such energy consumption, innovative process integration and waste heat utilization is proposed. Four waste heat sources and six potential uses were uncovered. A new integrated CCS configuration is proposed, which integrates the APCI LNG plant and the driver cycle with the CCS plant. HYSYS simulation software was used to simulate the CO_2 capture cycle using monoethanolamine solvent, natural gas combined cycles, CO_2 compression cycle and CO_2 liquefaction cycles. The developed models were validated against experimental data from the literature with good agreement. Net available power enhancement in one of the proposed CCS configuration is 26.3 MW, which is 16.31 [percent] more than the conventional CCS configuration. Pinch analysis method was used to compare the utility cooling and utility heating of the proposed and conventional CCS configurations. The result of the pinch analysis shows that the proposed CCS configuration requires 23.86 [percent] less utility cooling than the conventional CCS configuration." **Abdullah Alabdulkarem, Yunho Hwang, and Reinhard Radermacher**, *International Journal of Greenhouse Gas Control*, Available online July 17, 2012, doi:10.1016/j.ijggc.2012.06.006, http://www.sciencedirect.com/science/article/pii/S1750583612001326 (Subscription may be required.)

"Imaging Wellbore Cement Degradation by Carbon Dioxide under Geologic Sequestration Conditions Using X-ray Computed Microtomography." The following is the Abstract of this article: "X-

ray microtomography (XMT), a nondestructive three-dimensional imaging technique, was applied to demonstrate its capability to visualize the mineralogical alteration and microstructure changes in hydrated Portland cement exposed to [CO_2] under geologic [storage] conditions. Steel coupons and basalt fragments were added to the cement paste in order to simulate cement-steel and cement-rock interfaces. XMT image analysis showed the changes of material density and porosity in the degradation front (density: 1.98 g/cm^3, porosity: 40 [percent]) and the carbonated zone (density: 2.27 g/cm^3, porosity: 23 [percent]) after reaction with CO_2-saturated water for [five] months compared to unaltered cement (density: 2.15 g/cm^3, porosity: 30 [percent]). Three-dimensional XMT imaging was capable of displaying spatially heterogeneous alteration in cement pores, calcium carbonate precipitation in cement cracks, and preferential cement alteration along the cement-steel and cement-rock interfaces. This result also indicates that the interface between cement and host rock or steel casing is likely more vulnerable to a CO_2 attack than the cement matrix in a wellbore environment. It is shown here that XMT imaging can potentially provide a new insight into the physical and chemical degradation of wellbore cement by CO_2 [release]." **Hun Bok Jung, Danielle Jansik, and Wooyong Um**, *Environ. Sci. Technol.*, Available online July 23, 2012, doi:10.1021/es3012707, http://pubs.acs.org/doi/abs/10.1021/es3012707. (Subscription required.)

"MCFC-based CO_2 capture system for small scale CHP plants." The following is the Abstract of this article: "Carbon dioxide emissions into the atmosphere are considered among the main reasons of the greenhouse effect. The largest share of CO_2 is emitted by power plants using fossil fuels. Nowadays there are several technologies to capture CO_2 from power plants' exhaust gas but each of them consumes a significant part of the electric power generated by the plant. The Molten Carbonate Fuel Cell (MCFC) can be used as concentrator of CO_2, due to the chemical reactions that occurs in the cell stack: [CO_2] entering into the cathode side is transported to the anode side via $CO_3^=$ ions and is finally concentrated in the anodic exhaust. MCFC systems can be integrated in existing power plants (retro fitting) to separate CO_2 in the exhaust gas and, at the same time, produce additional energy. The aim of this study is to find a feasible system design for medium scale cogeneration plants which are not considered economically and technically interesting for existing technologies for carbon capture, but are increasing in numbers with respect to large size power plants. This trend, if confirmed, will increase number of medium cogeneration plants with consequent benefit for both MCFC market for this application and effect on global CO_2 emissions. System concept has been developed in a numerical model, using AspenTech engineering software. The model simulates a plant, which separates CO_2 from a cogeneration plant exhaust gases and produces electric power. Data showing the effect of CO_2 on cell voltage and cogenerator exhaust gas composition were taken from experimental activities in the fuel cell laboratory of the University of Perugia, FCLab, and from existing CHP plants. The innovative aspect of this model is the introduction of recirculation to optimize the performance of the MCFC." **Umberto Desideri, Stefania Proietti, Paolo Sdringola, Giovanni Cinti, Filippo Curbis**, *International Journal of Hydrogen Energy*, Available online July 28, 2012, doi:10.1016/j.ijhydene.2012.05.048, http://www.sciencedirect.com/science/article/pii/S0360319912011913. (Subscription may be required.)

Terrestrial

September 2011

"Carbon accounting and the climate politics of forestry." The following is the Abstract of this article: "Many proposals have been made for the more successful inclusion of Land Use, Land-Use Change and Forestry (LULUCF) in the Kyoto framework. Though the positions of individual states or the goal of avoided deforestation guide many approaches, [the authors'] model sets cost-effective strategies for climate change mitigation and the efficient and balanced use of forest resources at its center. Current approaches to forest resource-based carbon accounting consider only a fraction of its potential and fail to adequately mobilize the LULUCF sector for the successful stabilization of atmospheric GHG concentrations. The presence of a significantly large 'incentive gap' justifies the urgency of reforming the

current LULUCF carbon accounting framework. In addition to significantly broadening the scope of carbon pools accounted under LULUCF, [the authors] recommend paying far greater attention to the troika of competing but potentially compatible interests surrounding the promotion of standing forests (in particular for the purposes of carbon sequestration, biodiversity protection and ecosystem promotion/preservation), harvested wood products (HWP) and bioenergy use. The successful balancing of competing interests, the enhancement of efficiency and effectiveness and the balanced use of forest resources require an accounting mechanism that weighs and rewards each component according to its real climate mitigation potential. Further, [the authors'] data suggest the benefits of such a broadly based carbon accounting strategy and the inclusion of LULUCF in national and international accounting and emission trading mechanisms far outweigh potential disadvantages. Political arguments suggesting countries could take advantage of LULUCF accounting to reduce their commitments are not supported by the evidence [the authors] present." **David Ellison, Mattias Lundblad, and Hans Petersson**, *Environmental Science & Policy*, Available online August 10, 2011, doi:10.1016/j.envsci.2011.07.001, http://www.sciencedirect.com/science/article/pii/S1462901111001079. (Subscription may be required.)

October 2011

"Carbon Sequestration, Optimum Forest Rotation and Their Environmental Impact." The following is the Abstract of this article: "Due to their large biomass forests assume an important role in the global carbon cycle by moderating the greenhouse effect of atmospheric pollution. The Kyoto Protocol recognizes this contribution by allocating carbon credits to countries which are able to create new forest areas. Sequestrated carbon provides an environmental benefit thus must be taken into account in cost–benefit analysis of afforestation projects. Furthermore, like timber output carbon credits are now tradable assets in the carbon exchange. By using British data, this paper looks at the issue of identifying optimum felling age by considering carbon [storage] benefits simultaneously with timber yields. The results of this analysis show that the inclusion of carbon benefits prolongs the optimum cutting age by requiring trees to stand longer in order to soak up more CO_2. Consequently this finding must be considered in any carbon accounting calculations." **Erhun Kula and Yavuz Gunalay**, *Environmental Impact Assessment Review*, Available online October 2, 2011, doi:10.1016/j.eiar.2011.08.007, http://www.sciencedirect.com/science/article/pii/S0195925511001004. (Subscription may be required.)

November 2011

"An investigation into the effects of an emissions trading scheme on forest management and land use in New Zealand." The following is the Abstract of this article: "An econometric-process simulation model was constructed to investigate the effects of an Emissions Trading Scheme (ETS) on forest management and land use in New Zealand. Profit maximizing agents which choose between forestry and agricultural land uses were simulated under carbon price scenarios of $20, $50 and $0 per tonne CO_2 equivalent. The model suggests that an ETS will lead to increased afforestation and rotation age, and decreased silviculture and deforestation. A $20 carbon price or higher led to an overall increase in carbon sequestration by the forestry sector, driven predominantly by afforestation on lower fertility sites. Higher carbon prices increase the range of available land for planting. Future carbon price expectancy was critical. Rising carbon price expectancy led to large scale afforestation, but also to significant deforestation. A falling expectancy prevented deforestation but also stifled afforestation. The most sustainable solution was a stable carbon price expectancy allowing land to consistently work towards an economically optimal use. The recommendation of this report is for policy which promotes a stable long-run carbon price and flexibility for change between land uses. Suggestions include a guaranteed maximum carbon price, or allowing a forest to be felled at reduced penalty if another is concurrently planted." **Thomas Adams and James A. Turner**, *Forest Policy and Economics*, Available online October 20, 2011, doi:10.1016/j.forpol.2011.09.010, http://www.sciencedirect.com/science/article/pii/S1389934111001651. (Subscription may be required.)

December 2011

"Application of eddy covariance to determine ecosystem-scale carbon balance and evapotranspiration in an agroforestry system." The following is the Abstract of this article: "The inclusion of belts of trees in the agricultural areas of south-western Australia is gaining popularity, through perceived benefits in water use, biodiversity and carbon [storage]. However, water use and carbon assimilation are difficult to quantify at the ecosystem scale. In this research, [the authors] investigate the application of eddy covariance in a 'belt and alley' system. Footprint [modeling] indicated that the proportion of the signal from the tree belts was similar to the proportion of tree belts in the ecosystem. Eddy covariance units were installed in two adjacent fields: one containing belts of four-year-old oil mallee Trees 10 m wide planted 60 m apart; and one containing agricultural crops. Tree belts had little impact on wind direction or its standard deviation for any measurement height, and stationarity, integral turbulence and energy balance closure were similar for the two fields. Persistent upward wind flows were observed for wind directions aligned with the tree belts, suggesting the possibility of advection. For [the authors'] experimental site, removal of data for winds aligned with the tree belts had a negligible impact on fluxes of [CO_2] and water. During summer and autumn, the field containing oil mallees used 27 mm more water, and assimilated 0.93 Mg CO_2/ha more than the field without trees. Both daytime and night time CO_2 fluxes were greater in magnitude for the oil mallee field than the control field during summer. Water use by the trees was lower than other fields in the region where herbaceous perennials had been grown, and also lower than other estimates based on sap flow measurements. Further research will be necessary to determine the impact of spatial variability of water use on groundwater recharge at the catchment scale. Extra carbon storage associated with tree belts may increase their economic attractiveness to farmers in the region, but the impact of respiration after summer rainfall requires further investigation." **P.R. Ward, S.F. Micin, and I.R.P Fillery**, *Agricultural and Forest Meteorology*, Available online October 19, 2011, doi:10.1016/j.agrformet.2011.09.016, http://www.sciencedirect.com/science/article/pii/S0168192311002929. (Subscription may be required.)

"Loblolly and slash pine control organic carbon in soil aggregates and carbon mineralization." The following is the Abstract of this article: "The influence of soil aggregation as a means to protect soil organic carbon (SOC) from mineralization is unclear in sandy soils. The dominant forest cover types in the Lower Coastal Plain of the [United States] where sandy surface soils prevail are loblolly pine (*Pinus taeda*) and slash pine (*Pinus elliottii var elliottii*). The purpose of this study was to investigate the role that aggregation plays in C incorporation and [storage] in sandy soils of the Lower Coastal Plain found under loblolly and slash pine ecosystems. Thirteen forest stands (seven loblolly pine; six slash pine) were used for this investigation. A sonic dismembrator was used to apply dispersive energy in order to destroy aggregates. The use of sonic energy was shown to be a valid tool for studying aggregates in sandy soils. The data showed that aggregates do not protect ASOC from mineralization in these sandy soils. Loblolly pine surface mineral horizons accumulated 131 [percent] more TSOC than slash pine soil horizons. Slash pine soils had a 27 [percent] higher specific mineralization rate than loblolly pine soils; and Diffuse Reflectance Fourier Transform spectra (DRIFTS) showed that soils under loblolly pine were more aromatic than those under slash pine – and became more aromatic as mineralization proceeded. Due to their dominance in the Lower Coastal Plain of the [United States], pine ecosystems play an important role in the conversion of atmospheric CO_2 into the TSOC pool. However, soil aggregation should not be considered a mechanism to protect SOC in these sandy soils when modeling soil carbon dynamics, even though slash pine systems show a slightly greater capacity to develop aggregates." **E.I. Azuaje, N.B. Comerford, W.G. Harris, J.B. Reeves III, and S. Grunwald**, *Forest Ecology and Management*, Available online October 21, 2011, doi:10.1016/j.foreco.2011.09.030, http://www.sciencedirect.com/science/article/pii/S0378112711005895. (Subscription may be required.)

January 2012

"Sustainable dynamics of size-structured forest under climate change." The following is the Abstract of this article: "The paper investigates the impact of global climate change on the sustainable growth of forest, namely, on its aggregated characteristics such as the number of trees, the basal area, and the amount of carbon [stored] in the stand. The forest dynamics is described by a nonlinear size-structured population model. The existence of a steady state regime is proven and explicit formulas for the aggregated characteristics are obtained. A numeric simulation on realistic data illustrates and extends the obtained analytic results." **Natali Hritonenko, Yuri Yatsenko, Renan-Ulrich Goetz, and Angels Xabadia**, *Applied Mathematics Letters*, Available online December 21, 2011, doi:10.1016/j.aml.2011.12.020, http://www.sciencedirect.com/science/article/pii/S089396591100615X. (Subscription may be required.)

"Changes in soil carbon sequestration, fraction and soil fertility in response to sugarcane residue retention are site-specific." The following is the Abstract of this article: "Sugarcane crop residues contain substantial quantities of C and plant nutrients, but there have been relatively few studies of how sugarcane residues enrich the soil and contribute to C [storage], and most studies have been undertaken at only one or a few sites. The purpose of this study was to address these knowledge gaps by determining the magnitude and time scale of changes in soil concentrations of total C, C fractions and plant nutrients following retention of sugarcane residues. C fractions were determined by two different methods. [The authors] sampled soils from five experiments, in contrasting environments, where sugarcane residues had been either retained or removed for between [one] and 17 years. Changes in the concentration of both soil C and plant nutrients were highly site-specific and not in proportion to the period that residues were retained: for example, soil C (0–250 mm) decreased by 0.9 g kg^{-1} and 0.5 g kg^{-1} at sites where residues had been retained for [one] and 17 years, respectively, but increased by 2.0 g kg^{-1} at a site with residues retained for [six] years. Soil C composition, defined by the $KMnO_4$ oxidation and particulate organic C-ultraviolet photo-oxidation fractionation (POC-UV) schemes, appeared to be a more sensitive indicator of changes in residue management, indicating that increases in readily-oxidizable C and particulate organic C, respectively, after [one] year of retaining instead of burning residues. The two methods provided different information that was complementary in understanding changes in soil C. The $KMnO_4$ method identified downward movement of C fractions in the profile to 250 mm, while the labile fractions measured by the POC-UV scheme appeared to be more sensitive to early changes in residue management (after [one] year). While recent studies have found that several concentrations of $KMnO_4$ reduced all C fractions by a similar magnitude and thus concentrated on the fraction oxidized by the 333 mM concentration of $KMnO_4$, [the authors] found that use of both this and the 33 mM concentration enabled a greater understanding of changes in C pools due to residue management." **P.J. Thorburn, E.A. Meier, K. Collins, F.A. Robertson**, *Soil and Tillage Research*, Available online December 22, 2011, doi:10.1016/j.still.2011.11.009, http://www.sciencedirect.com/science/article/pii/S016719871100208X. (Subscription may be required.)

February 2012

"Prediction of vertical soil organic carbon profiles using soil properties and environmental tracer data at an untilled site." The following is the Abstract of this article: "Soil organic carbon (SOC) has considerable spatial and temporal variability both at the hillslope and catchment scale as well as down the soil profile. In recent years the distribution of SOC down the soil profile has become an area of interest in the understanding of the carbon [storage] potential of soils. Most studies however have concentrated on highly disturbed agricultural sites with little data available for untilled locations. In this study the vertical distribution of SOC is examined at a grassland site in the Young River area of Western Australia that has remained undisturbed by human activity for 50 years. Soil physical properties (texture, rock content) as well as the distribution of the environmental tracers ^{137}Cs and ^{210}Pb were assessed with

the aim of better understanding the transport processes which produce the observed vertical distribution of SOC. While no consistent relationship was found between SOC and soil physical properties significant relationships were found between the distribution of SOC and the environmental tracers, ^{137}Cs and ^{210}Pb. Finite element simulations based on a diffusion/convection/decay model showed that the transport of ^{137}Cs and ^{210}Pb down the soil profile is likely to be driven by the same (primarily diffusive) processes. The same model used in conjunction with plant input and decay data generated from the RothC-26.3 soil carbon model revealed that transport of SOC down the soil profile, while also a diffusion process, was significantly slower indicating that different processes and/or pathways are involved in SOC transport at this site." **T. Wells, G.R. Hancock, C. Dever, and D. Murphy**, *Geoderma*, Available online December 27, 2011, doi:10.1016/j.geoderma.2011.11.006, http://www.sciencedirect.com/science/article/pii/S0016706111003247. (Subscription may be required.)

March 2012

***Oak Ridge National Laboratory News Release*, "Final FACE Harvest Reveals Increased Soil Carbon Storage Under Elevated Carbon Dioxide."** According to a 12-year free-air CO_2-enrichment (FACE) experiment at Oak Ridge National Laboratory (ORNL), elevated concentrations of CO_2 can increase carbon storage in soil, helping slow down rising atmospheric concentrations. The experiment, sponsored by DOE, ended in 2009, but the conclusion and final harvest provided researchers the opportunity to cut down trees and dig into the soil to quantify the effect of elevated CO_2 concentrations on plant and soil carbon; the effects were quantified by excavating soil from large pits that were approximately three feet deep. Researchers found an increase in soil carbon storage under elevated CO_2 concentrations – a finding different from other FACE experiments in forests. March 5, 2012, http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20120305-00.

"Long-and short-term precipitation effects on soil CO_2 efflux and total belowground carbon allocation." The following is the Abstract of this article: "Soil CO_2 efflux (E_{soil}), the main pathway of C movement from the biosphere to the atmosphere, is critical to the terrestrial C cycle but how precipitation and soil moisture influence E_{soil} remains poorly understood. Here, [the authors] irrigated a longleaf pine wiregrass savanna for six years; this increased soil moisture by 41.2 [percent]. [The authors] tested how an altered precipitation regime affected total belowground carbon allocation (TBCA), root growth, soil carbon, and E_{soil}. [The authors] used two methods to quantify E_{soil}: daytime biweekly manual measurements and automated continuous measurements for one year. [The authors] hypothesized that the low-frequency manual method would miss both short- and long-term (i.e., subdaily to annual, respectively) effects of soil moisture on E_{soil} while the high-frequency data from the automated method would allow the effects of soil moisture to be discerned. Root growth was significantly higher in irrigated plots, particularly at 0–20 cm depth. Irrigated annual E_{soil} was significantly greater than that of the control when estimated with the continuous measurements but not when estimated from biweekly measurements. The difference in annual E_{soil} estimates is likely due to (1) the delayed increase in E_{soil} following irrigation pulses of soil moisture (i.e., variation that the biweekly manual measurements missed) and (2) the diel timing of biweekly manual measurements (they were completed early to mid-day before peak efflux). With irrigation, estimates of TBCA increased almost two-fold with automated measurements but only 36 [percent] with intermittent measurements. Relative to controls, irrigated treatments stored almost 2 Mg C ha^{-1} $year^{-1}$ more in soils and 0.26 Mg C ha^{-1} $year^{-1}$ more in roots. High-frequency measurements of E_{soil} were essential to estimate total belowground carbon allocation. With irrigation, soil carbon pools were not at steady-state, so shifts in soil carbon storage must be considered in TBCA estimates." **Chelcy R. Ford, Jason McGee, Francesca Scandellari, Erik A. Hobbie, Robert J. Mitchell**, *Agricultural and Forest Meteorology*, Available online January 24, 2012, doi:10.1016/j.agrformet.2011.12.008, http://www.sciencedirect.com/science/article/pii/S0168192312000020. (Subscription may be required.)

"Responses of trees to elevated carbon dioxide and climate change." The following is the Abstract of this article: "The enhancement in photosynthesis at elevated concentration of [CO_2] level than the

ambient level existing in the atmosphere is widely known. However, many of the earlier studies were based on instantaneous responses of plants grown in pots. The availability of field chambers for growing trees, and long-term exposure studies of tree species to elevated [CO_2], has changed [many of the] views on [CO_2] acting as a [fertilizer]. Several tree species showed acclimation or even down-regulation of photosynthetic responses while a few of them showed higher photosynthesis and better growth responses. Whether elevated levels of [CO_2] can serve as a fertilizer in a changed climate scenario still remains an unresolved question. Forest-Air-Carbon dioxide-Enrichment (FACE) sites monitored at several locations have shown lately, that the acclimation or down regulation as reported in chamber studies is not as wide-spread as originally thought. FACE studies predict that there could be an increase of 23–28 [percent] productivity of trees at least till 2050. However, the increase in global temperature could also lead to increased respiration, and limitation of minerals in the soil could lead to reduced responses in growth. Elevated [CO_2] induces partial closure of leaf stomata, which could lead to reduced transpiration and more economical use of water by the trees. Even if the [CO_2] acts as a fertilizer, the responses are more pronounced only in young trees. And if there are variations in species responses to growth due to elevated [CO_2], only some species are going to dominate the natural vegetation. This will have serious implications on the biodiversity and the structure of the ecosystems. This paper reviews the research done on trees using elevated CO_2 and tries to draw conclusions based on different methods used for the study. It also discusses the possible functional variations in some tree species due to climate change." **Jose Kallarackal and T.J. Roby**, *Biodiversity and Conservation*, Available online February 1, 2012, doi:10.1007/s10531-012-0254-x, http://www.springerlink.com/content/qu694535138mj285/. (Subscription required.)

April 2012

"Influence of Soil and Climate Conditions on CO_2 Emissions from Agricultural Soils." The following is the Abstract of this article: "Many of the environmental problems related to agriculture will still be serious over the next 30 years. However, the seriousness of some of those problems may increase more slowly than in the past or even diminish in other cases. Agriculture plays two different roles in climate change; on one hand, it suffers from the impact of climate change, on the other hand, it is responsible for 14 [percent] of total greenhouse gases. Nevertheless, agriculture is also part of the solution, as it is capable of mitigating a significant amount of global emissions. This paper aims to study the influence of edapho-climate conditions on soil CO_2 emissions into the atmosphere. In order to do so, [the authors] conducted three field trials in different areas in southern Spain, which have different soil textures and different climate conditions. The results show how interaction between the temperature and rainfall recorded has a greater influence on emissions than each of the factors separately. However, at the same time, the texture of the soil at each of the locations was also found to be the most dominant variable in the gas emission process." **Rosa María Carbonell-Bojollo, Miguel Angel Repullo-Ruibérriz de Torres, Antonio Rodríguez-Lizana, and Rafaela Ordóñez-Fernández**, *Water, Air, & Soil Pollution*, Available online March 13, 2012, doi:10.1007/s11270-012-1121-9, http://www.springerlink.com/content/bl4244j9lx55773u/. (Subscription required.)

May 2012

"Mineral Carbonation as the Core of an Industrial Symbiosis for Energy-Intensive Minerals Conversion." The following is the Summary of this article: "The longer term sustainability of the minerals sector may hinge, in large part, on finding innovative solutions to the challenges of energy intensity and CO_2 management. This article outlines the need for large-scale 'carbon solutions' that might be shared by several colocated energy-intensive and carbon-intensive industries. In particular, it explores the potential for situating a mineral carbonation plant as a carbon [formation] at the heart of a minerals and energy complex to form an industrial symbiosis. Several resource-intensive industries can be integrated synergistically in this way, to enable a complex that produces energy and mineral products with low net CO_2 emissions. An illustrative hypothetical case study of such a system within New South Wales,

Australia, has been constructed, on the basis of material and energy flows derived from Aspen modeling of a serpentine carbonation process. The synergies and added value created have the potential to significantly offset the energy and emission penalties and direct costs of CO_2 capture and storage. This suggests that greenfield minerals beneficiation and metals refining plants should consider closer integration with the power production and energy provision plants on which they depend, together with a carbon solution, such as mineral carbonation, as a critical element of such integration. Other sustainability considerations are highlighted." **Geoffrey F. Brent, Daniel J. Allen, Brent R. Eichler, James G. Petrie, Jason P. Mann, and Brian S. Haynes**, *Journal of Industrial Ecology*, Available online February 2012, doi:10.1111/j.1530-9290.2011.00368.x, http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2011.00368.x/abstract;jsessionid=C5891EB4F3AFF606F61C46D3D3C5C5D4.d01t04. (Subscription may be required.)

June 2012

"Grassland carbon [storage] and emissions following cultivation in a mixed crop rotation." The following is the Abstract of this article: "Grasslands are potential carbon [formations] to reduce unprecedented increase in atmospheric CO_2. Effect of age ([one to four]-year-old) and management (slurry, grazing multispecies mixture) of a grass phase mixed crop rotation on carbon [storage] and emissions upon cultivation was compared with 17-year-old grassland and a pea field as reference. Aboveground and root biomass were determined and soils were incubated to study CO_2 emissions after soil disturbance. Aboveground biomass was highest in [one]-year-old grassland with slurry application and lowest in [four]-year-old grassland without slurry application. Root biomass was highest in [four]-year-old grassland, but all [one to four]-year-old grasslands were in between the pea field (0.81 ± 0.094 g kg^{-1} soil) and the 17-year-old grassland (3.17 ± 0.22 g kg^{-1} soil). Grazed grasslands had significantly higher root biomass than cut grasslands. There was no significant difference in the CO_2 emissions within [one to four]-year-old grasslands. Only the 17-year-old grassland showed markedly higher CO_2 emissions (4.9 ± 1.1 g CO_2 kg^{-1} soil). Differences in aboveground and root biomass did not affect CO_2 emissions, and slurry application did not either. The substantial increase in root biomass with age but indifference in CO_2 emissions across the age and management in temporary grasslands, thus, indicates potential for long-term [storage] of soil C." **Bharat Sharma Acharya, Jim Rasmussen, and Jørgen Eriksen**, *Agriculture, Ecosystems & Environment*, Available online March 26, 2012, doi:10.1016/j.agee.2012.03.001, http://www.sciencedirect.com/science/article/pii/S0167880912000849. (Subscription may be required.)

July 2012

"Early Public Impressions of Terrestrial Carbon Capture and Storage in a Coal-Intensive State." The following is the Abstract of this article: "While CCS is considered to be critical to achieving long-term climate-protection goals, public concerns about the CCS practice could pose significant obstacles to its deployment. This study reports findings from the first state-wide survey of public perceptions of CCS in a coal-intensive state, with an analysis of which factors predict early attitudes toward CCS. Nearly three-quarters of an Indiana sample (N=1,001) agree that storing carbon underground is a good approach to protecting the environment, despite 80 [percent] of the sample being unaware of CCS prior to participation in the two-wave survey. The majority of respondents do not hold strong opinions about CCS technology. Multivariate analyses indicate that support for CCS is predicted by a belief that humankind contributes to climate change, a preference for increased use of renewable energy, and egalitarian and individualistic worldviews, while opposition to CCS is predicted by self-identified political conservatism and by selective attitudes regarding energy and climate change. Knowledge about early impressions of CCS can help inform near-term technology decisions at state regulatory agencies, utilities, and pipeline companies, but follow-up surveys are necessary to assess how public sentiments evolve in response to image-building efforts with different positions on coal and CCS." **Sanya Carley, Rachel M. Krause,**

David C. Warren, John Rupp, and John Graham, *Environ. Sci. Technol.*, Available online June 7, 2012, doi:10.1021/es300698n, http://pubs.acs.org/doi/abs/10.1021/es300698n. (Subscription required.)

"Passive [Storage] of Atmospheric CO_2 through Coupled Plant-Mineral Reactions in Urban soils." The following is the Abstract of this Article: "Photosynthetic removal of CO_2 from the atmosphere is an important planetary [CO_2] removal mechanism. Naturally, an amount equivalent to all atmospheric carbon passes through the coupled plant–soil system within [seven] years. Plants cycle up to 40 [percent] of photosynthesized carbon through their roots, providing a flux of C at depth into the soil system. Root-exuded carboxylic acids have the potential to supply 4–5 micromoles C $hr^{-1}g^{-1}$ fresh weight to the soil solution, and enhance silicate mineral weathering. Ultimately, the final product of these root-driven processes is CO_2, present in solution as bicarbonate. This combines with Ca liberated by corrosion associated with silicate mineral weathering to enter the soil–water system and to produce pedogenic calcium carbonate precipitates. Combining understanding of photosynthesis and plant root physiology with knowledge of mineral weathering provides an opportunity to design artificial soils or to plan land use in ways that maximize removal and [storage] of atmospheric CO_2 through artificially enhanced pedogenic carbonate precipitation. This process requires relatively low energy and infrastructure inputs. It offers a sustainable [CO_2] removal mechanism analogous to the use of constructed wetlands for the passive remediation of contaminated waters, and is likely to achieve wide public acceptance." **David A. C. Manning and Phil Renforth**, *Environ. Sci. Technol.*, Available online May 22, 2012, doi:10.1021/es301250j, http://pubs.acs.org/doi/abs/10.1021/es301250j. (Subscription required.)

August 2012

"A sustainable agricultural landscape for Australia: A review of interlacing carbon sequestration, biodiversity and salinity management in agroforestry systems." The following is the Abstract of this article: "Transformation of the southwestern Australian landscape from deep-rooted woody vegetation systems to shallow-rooted annual cropping systems has resulted in the severe loss of biodiversity and this loss has been exacerbated by rising ground waters that have mobilized stored salts causing extensive dry land salinity. Since the original plant communities were mostly perennial and deep rooted, the model for sustainable agriculture and landscape water management invariably includes deep rooted trees. Commercial forestry is however only economical in higher rainfall (>700 mm yr^{-1}) areas whereas much of the area where biodiversity is threatened has lower rainfall (300–700 mm yr^{-1}). Agroforestry may provide the opportunity to develop new agricultural landscapes that interlace ecosystem services such as carbon mitigation via carbon [storage] and biofuels, biodiversity restoration, watershed management while maintaining food production. Active markets are developing for some of these ecosystem services, however a lack of predictive metrics and the regulatory environment are impeding the adoption of several ecosystem services. Nonetheless, a clear opportunity exists for four major issues – the maintenance of food and fiber production, salinization, biodiversity decline and climate change mitigation – to be managed at a meaningful scale and a new, sustainable agricultural landscape to be developed." **S.J. George, R.J. Harper, R.J. Hobbs, and M. Tibbett**, *Agricultural, Ecosystems & Environment*, Available online July 31, 2012, doi:10.1016/j.agee.2012.06.022, http://www.sciencedirect.com/science/article/pii/S0167880912002496. (Subscription may be required.)

Trading

September 2011

***RGGI News Release*, "10 States Complete Thirteenth Regional Auction for Carbon Dioxide Allowances."** The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI), the Nation's first market-based regulatory program to reduce GHG emissions, announced the results of their 13th quarterly auction of CO_2 allowances, held September 7, 2011. Of the

42,189,685 current control period (2009-2011) CO_2 allowances offered for sale, 7,487,000 (17.75 percent) were sold at the auction clearing price of $1.89 per allowance (the minimum reserve price for the auction); 94 percent of the allowances sold were purchased by electric generators and their corporate affiliates. Winning bids, ranging from $1.89 to $5.18, were submitted by 31 entities. According to Potomac Economics, an independent market monitor, power plants and their corporate affiliates have purchased 85 percent of allowances sold in Auctions 1 through 13 and hold 97 percent of the allowances in circulation. Proceeds from the auctions now total more than $900 million, approximately 80 percent of which is being invested in consumer benefits such as energy efficiency, renewable energy, direct assistance to consumers, and other programs. September 9, 2011, http://www.rggi.org/docs/Auction_13_Release_Report.pdf.

"Carbon trading: Current schemes and future developments." The following is the Abstract of this article: "This paper looks at the GHG emissions trading schemes and examines the prospects of carbon trading. The first part of the paper gives an overview of several mandatory GHG trading schemes around the world. The second part focuses on the future trends in carbon trading. It argues that the emergence of new schemes, a gradual enlargement of the current ones, and willingness to link existing and planned schemes seem to point towards geographical, temporal and sectoral expansion of emissions trading. However, such expansion would need to overcome some considerable technical and non-technical obstacles. Linking of the current and emerging trading schemes requires not only considerable technical fixes and [harmonization] of different trading systems, but also necessitates clear regulatory and policy signals, continuing political support and a more stable economic environment. Currently, the latter factors are missing. The global economic turmoil and its repercussions for the carbon market, a lack of the international deal on climate change defining the Post-Kyoto commitments, and [unfavorable] policy shifts in some countries, cast serious doubts on the expansion of emissions trading and indicate that carbon trading enters an uncertain period." **Slobodan Perdan and Adisa Azapagic**, *Energy Policy*, Available online August 4, 2011, doi:10.1016/j.enpol.2011.07.003, http://www.sciencedirect.com/science/article/pii/S030142151100526X. (Subscription may be required.)

October 2011

***RGGI News Release*, "RGGI States Initiate Bidding Process for December 2011 CO_2 Allowance Auction."** The Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice and application materials for CO_2 Allowance Auction 14, providing potential auction participants with the information required to submit a Qualification Application and indicate their intent to bid in the auction scheduled for December 7, 2011. The Northeast and Mid-Atlantic states participating in RGGI, the Nation's first market-based regulatory program to reduce greenhouse gas (GHG) emissions, will auction 42,983,482 CO_2 allowances for the current control period (2009 to 2011) and 1,864,951 CO_2 allowances for the future control period (2012 to 2014); a reserve price of $1.89 will be used for all allowances. Since its inception in September 2008, RGGI has auctioned more than 380 million CO_2 allowances. For more information about previous auction results, including prices, bids, and participation, visit: http://www.rggi.org/market/co2_auctions/results. October 7, 2011, http://www.rggi.org/docs/PR-20111007_Auction14BidderInitiation.pdf.

"Carbon sequestration and permit trading on the competitive fringe." The following is from the Abstract of this article: "This paper makes two contributions to the carbon-[storage] policy literature. First and foremost, [the authors] develop a theoretical framework in which [storage] and permit-trading markets are analyzed jointly in the context of a competitive fringe model. [The authors'] framework formalizes the linkage between regulatory policy changes (as they manifest themselves in the permit market) and subsequent equilibrium allocations in the [storage] market. Second, [the authors] perform a numerical analysis demonstrating the role market structure, or market power, might play in the determination of the equilibrium [storage] allocation and carbon price. Both [the authors'] analytical and numerical results demonstrate the importance of incorporating into empirical supply-side models demand-side information that is reflective of an underlying market structure." **Arthur J. Caplan**,

Economic Modeling, Available online September 28, 2011, doi:10.1016/j.econmod.2011.08.018, http://www.sciencedirect.com/science/article/pii/S0264999311002100. (Subscription may be required.)

November 2011

***The New York Times*, "Australian Senate Approves Emissions Trading Plan."** The upper house of Australia's Parliament approved the government's proposal to adopt an emissions trading program that will impose a carbon tax on the country's largest emitters beginning in July 2012. The package of 18 bills that make up the carbon trading legislation passed through the Senate by a vote of 36 to 32; the legislation passed through the lower house by a 74 to 72 vote in October. Under the new regulations, the nation's 500 biggest producers of CO_2 emissions will be subject to an initial fixed carbon tax of $24.70 per tonne; the regulations will become a market-based trading program in 2015, the size of which will be second only to that of the EU. November 7, 2011, http://www.nytimes.com/2011/11/08/world/asia/australian-senate-approves-emissions-trading-plan.html?_r=3.

December 2011

***Bloomberg*, "Japan Aims to Start Bilateral Carbon Offset Program in 2013."** Beginning in 2013, Japan will work with companies to reduce GHG emissions as part of a bilateral carbon offset program announced by the Ministry of Foreign Affairs of Japan (MOFA). The Japanese government has been preparing for the emission-cutting program by establishing energy management systems and forest protection projects with Japanese companies in developing countries. According to officials, feasibility studies to run the program in 28 countries have commenced, with plans to expand consultations with more nations in the future. For more details on the program, visit the MOFA website at: http://www.mofa.go.jp/policy/environment/warm/cop/lowcarbongrowth_vision_1111.html. November 29, 2011, http://www.bloomberg.com/news/2011-11-29/japan-aims-to-start-bilateral-carbon-offset-program-in-2013.html.

***RGGI News Release*, "RGGI Auction Sells 27 Million CO_2 Allowances, Proceeds to Benefit Northeast and Mid-Atlantic Regional Economy."** The Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) have announced the results of their 14th quarterly auction of CO_2 allowances. The final auction of the program's first three-year control period, a total of $51.5 million was generated from the sale of 27,293,000 CO_2 allowances. For the current control period (2009-2011), 63 percent of the 42,983,482 allowances offered were sold, ranging from $1.89 to $5.00 per allowance, with a clearing price of $1.89. Overall, the first three-year control period brought cumulative auction proceeds of $952 million, and, according to a recent report by an independent consulting firm, The Analysis Group, will result in $1.6 billion in net economic benefit to the region through RGGI-funded programs designed to reduce energy bills and support local jobs. For more information on the first control period, go to: http://www.rggi.org/docs/PR120911_Auction14Results.pdf. The next RGGI auction, which will be the first of the second control period, is scheduled for March 14, 2012. December 9, 2011, http://www.rggi.org/docs/PR120911_Auction14Results.pdf.

January 2012

***Western Climate Initiative*, "Final Offset Protocol Review and Recommendation Process Available."** The Western Climate Initiative (WCI) released a standard process to review offset protocols and recommend them for adoption into their partner jurisdictions' rules and regulations to help ensure an adequate supply of high-quality offsets. The WCI Design Recommendations (2008) advocate establishing an offset system to support the WCI cap-and-trade program. The Design for the WCI Regional Program (2010) recommends essential criteria for credible offsets, and that the standards and processes for approving offset projects should be developed in advance of the start of the cap-and-trade

program, and in an open and transparent manner. The final process provides a step-by-step description of how existing offset protocols will be reviewed by WCI Partner jurisdictions in regard to how they meet WCI offset criteria. According to WCI, consistent, transparent processes are expected to lower project development costs and support learning and sharing of experience among WCI Partner jurisdictions and offset protocol developers. To download the Final Offset Protocol Review and Recommendation Process, go to: http://www.westernclimateinitiative.org/document-archives/Offsets-Committee-Documents/Offset-Protocol-Review-and-Recommendation-Process/. December 19, 2011, http://www.westernclimateinitiative.org/news-and-updates/140-final-offset-protocol-review-and-recommendation-process-available.

"Carbon sequestration and permit trading on the competitive fringe." The following is the Abstract of this article: "This paper makes two contributions to the carbon-[storage] policy literature. First and foremost, [the authors] develop a theoretical framework in which [storage] and permit-trading markets are analyzed jointly in the context of a competitive fringe model. [The authors'] framework formalizes the linkage between regulatory policy changes (as they manifest themselves in the permit market) and subsequent equilibrium allocations in the [storage] market. Second, [the authors] perform a numerical analysis demonstrating the role market structure, or market power, might play in the determination of the equilibrium [storage] allocation and carbon price. Both [the authors'] analytical and numerical results demonstrate the importance of incorporating into empirical supply-side models demand-side information that is reflective of an underlying market structure." **Arthur J. Caplan**, *Economic Modeling*, Available online September 28, 2011, doi:10.1016/j.econmod.2011.08.018, http://www.sciencedirect.com/science/article/pii/S0264999311002100. (Subscription may be required.)

February 2012

***ANSI News Release*, "Ernst & Young Achieves ANSI Accreditation for Greenhouse Gas Emission Verification."** The American National Standards Institute (ANSI) announced the accreditation of Ernst & Young under their Accreditation Program for Greenhouse Gas Validation/Verification Bodies, which oversees the professional conduct of third-parties responsible for verifying the accuracy of emission assertions. Ernst & Young will verify GHG assertions related to GHG emissions and removals at the organizational level, and, as a third-party verification body, assess how organizations measure and quantify their GHG inventory, as well as how they report results against established protocol. ANSI, the coordinator of the U.S. standards and conformity assessment system, is a member of the International Accreditation Forum (IAF) and is the only U.S. body accrediting against ISO 14065:2007, "Greenhouse gases – Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition." January 23, 2012, http://www.ansi.org/news_publications/news_story.aspx?menuid=7&articleid=3126.

***Reuters*, "Global CO_2 Market Totals [$122.28 Billion] in 2011."** According to analysts at Thomson Reuters Point Carbon, worldwide carbon markets were valued at $122.28 billion in 2011, up four percent from 2010. In addition, the value of the European Union (EU) Emissions Trading System (ETS), the world's largest carbon market, grew by 6 percent, and overall traded volume in EU Allowances (EUAs), including options and auctions, increased by 17 percent. The ETS, the 27-nation bloc's main policy instrument to address potential climate change, caps CO_2 emissions on more than 10,000 power and industrial plants, covering approximately half of the bloc's GHG emissions. January 10, 2012, http://www.reuters.com/article/2012/01/10/us-carbon-value-pointcarbon-idUSTRE8091N720120110.

***Platts*, "California and Quebec Working on Joint Carbon Auction."** California and Quebec have tentatively agreed to host a joint auction to sell CO_2 allowances as part of a coordinated GHG cap-and-trade program set to begin in 2013. Quebec adopted its cap-and-trade regulations in December and plans on linking its program with California before the first quarterly auction, which is scheduled to take place August 15, 2012. Compliance entities falling under the cap are required to hold enough allowances to cover their respective GHG emissions. The Western Climate Initiative (WCI) is currently conducting a

search for a company to oversee the auction. January 12, 2012, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/ElectricPower/6854723.

March 2012

***Reuters*, "South Africa to Introduce Carbon Tax."** The South African Treasury announced plans to introduce a carbon tax next year to reduce GHG emissions. Under the plan, nearly two-thirds of emissions will be tax-exempt until 2020 in an attempt to lessen the impact on industry; in its 2012/2013 budget, the treasury proposed a 60 percent tax-free threshold on annual emissions for all sectors, who, with the exception of electricity, would be able to claim additional relief of at least 10 percent. In addition, the draft policy, which is expected to be published later this year, proposed a carbon tax of 120 rand per ton of CO_2 equivalent for emissions above the threshold; the levy would come into effect in 2013/2014, increasing by 10 percent each year until 2020. February 22, 2012, http://www.reuters.com/article/2012/02/22/safrica-budget-carbon-idAFL5E8DM4VA20120222.

***Reuters*, "UK to Auction Extra EU Carbon Permits in 2012."** Government officials announced that Britain will auction more EU carbon permits than planned this year due to a surplus of permits for the second phase (2008-2012) trading period of the EU ETS. Since November 2008, the UK government has raised $1.8 billion from the sale of 99 million permit sources from a new entrant reserve for Phase II. The last scheduled auction, conducted on March 8, 2012, sold 3.5 million EUAs; according to DECC, more Phase II auctions will be held this year. DECC also said they will auction 125-130 million EUAs annually from 2013 to 2020. The EU ETS, the world's largest cap-and-trade scheme, sets a cap on CO_2 emissions for approximately 12,000 power and industrial plants. February 24, 2012, http://www.reuters.com/article/2012/02/24/carbon-uk-idUSL5E8DO76720120224.

"Electric-power systems planning and greenhouse-gas emission management under uncertainty." The following is the Abstract of this article: "In this study, a multistage interval-stochastic integer programming model is formulated for managing GHG emissions and planning electric-power systems under uncertainty. The developed model can reflect dynamic, interactive, and uncertain characteristics of energy systems. Besides, the model can be used for answering questions related to types, times, demands and mitigations of energy systems planning practices, with the objective of minimizing system cost over a long-time planning horizon. The solutions can help generate electricity-generation schemes and capacity-expansion plans under different GHG-mitigation options and electricity-demand levels. Tradeoffs among system cost, energy security, and emission management can also be tackled. A high system cost will increase renewable energy supply and reduce GHG emission, while a desire for a low cost will run into risks of a high energy deficiency and a high GHG emission." **Y.P. Li and G.H. Huang**, *Energy Conversion and Management*, Available online January 31, 2012, doi:10.1016/j.enconman.2011.12.018, http://www.sciencedirect.com/science/article/pii/S0196890411003724. (Subscription may be required.)

April 2012

***RGGI News Release*, "RGGI Auction Sells 21.5 Million CO_2 Allowances."** The states participating in the second Regional Greenhouse Gas Initiative (RGGI) control period announced that 21,559,000 CO_2 allowances (62 percent of the 34,843,858 allowances offered) were sold in RGGI's 15th quarterly auction. Bids for the current control period (2012-2014) ranged from $1.93 to $5.36 per allowance, with a clearing price of $1.93 (the minimum reserve price). The auction generated $41.6 million in proceeds, which will continue to be invested in a variety of consumer-benefit initiatives. Since 2008, electricity generators and their corporate affiliates have won 87 percent of CO_2 allowances sold in RGGI auctions, according the independent market monitor's report. The states participating in RGGI are currently conducting a comprehensive review of RGGI's first three years of implementation; the review will gather stakeholder comments on all aspects of the program and will consider, among other things, the reduction in

emissions that has occurred since the regional emissions cap was put into place. The next RGGI auction is scheduled for June 6, 2012. March 16, 2012, http://www.rggi.org/docs/PR031612_Auction15Results.pdf.

"A robust optimization method for planning regional-scale electric power systems and managing carbon dioxide." The following is the Abstract of this article: "The uncertainties that are inherent in the energy systems planning process and complexities interaction among various uncertain parameters are challenging managers and decision makers. In this study, a robust interval-stochastic optimization (RISO) method is developed for planning energy systems and trading CO_2, through incorporating interval-parameter programming (IPP) within a robust optimization (RO) framework. In the RISO modeling formulation, penalties are exercised with the recourse against any infeasibility, and robustness measures are introduced to examine the variability of the second stage costs that are above that the expected levels. The RISO is generally suitable for risk-aversive planners under high-variability conditions. The RISO method is applied to a case of planning regional-scale electric power systems under consideration of CO_2 trading scheme. A number of solutions under different robustness levels have been generated. They are helpful for supporting (a) adjustment or justification of allocation patterns of regional energy resources and services, (b) formulation of local policies regarding energy consumption, economic development, and energy structure, (c) analysis of the effect of CO_2 trading scheme, and (d) in-depth analysis of tradeoffs between system cost and CO_2-mitigation levels under total emission permissions. The modeling results from the RISO can help generate desired decision alternatives that will be able to not only enhance energy-supply safety with a low system-failure risk level but also mitigate total CO_2-emissions under an effective trading scheme." **C. Chen, Y.P. Li, G.H. Huang, and Y.F. Li**, *International Journal of Electrical Power & Energy Systems*, Available online March 14, 2012, doi:10.1016/j.ijepes.2012.02.007, http://www.sciencedirect.com/science/article/pii/S0142061512000348. (Subscription may be required.)

May 2012

***Bloomberg Businessweek*, "South Korea Parliament Approves Carbon Trading System."** The National Assembly of South Korea approved a cap-and-trade system to cut GHGs. The bill will establish a market-based program requiring companies that exceed their emission quotas to purchase permits from companies that emit below their respective quotas. Under the bill, which calls for emissions trading to begin in 2015, companies emitting more than 125,000 metric tons of CO_2 annually will be subject to Korea's cap-and-trade system, as will factories, buildings, and livestock farms that annually produce more than 25,000 metric tons. Rules governing compliance are expected to be released within the next six months. May 3, 2012, http://www.businessweek.com/news/2012-05-02/south-korean-parliament-approves-carbon-trading-system#p2.

***RGGI News Release*, "2011 Annual Market Monitor Report: RGGI CO_2 Allowance Market Remains Competitive."** Potomac Economics, the independent market monitor, released the 2011 "Annual Report on the Market for RGGI CO_2 Allowances." In evaluating the activity in the market for Regional Greenhouse Gas Initiative (RGGI) CO_2 allowances in 2011, the report focused on allowance prices, trading and acquisition of allowances in the auctions and secondary market, participation in the market by individual firms, and market monitoring. According to the report, the majority of CO_2 allowances offered in each auction in 2011 was acquired by compliance entities; they purchased 91 percent of the allowances sold for the first control period, and 69 percent of the allowances sold for the second control period. For more information on the report, go to: http://www.rggi.org/docs/MM_2011_Annual_Report.pdf. May 4, 2012, http://www.rggi.org/docs/PR050412_2011-Annual-Market-Monitor-Report.pdf.

"The impact of the EU ETS on the corporate value of European electricity corporations." The following is the Abstract of this article: "In this research, the impact of the European Emission Trading Scheme (EU ETS) on the corporate value of European electricity corporations has been measured, and

a comparison study of the impact between phase I and phase II of the EU ETS has been performed. To achieve this, a modified multifactor market model has been used to investigate how the development of EU emission allowance (EUA) prices has influenced corporate value. The results indicate that the impact of these has changed much from phase I to phase II. EUA price developments have affected corporate value in opposite directions: in phase I, the increase in EUA prices tended to cause corporate value appreciation, while during phase II, it was more likely to induce depreciation. Second, the corporate value development has been much more sensitive to changes in EUA prices in phase II than in phase I. The causes of the impact change have also been analyzed. The conclusion reached has been that the changes have resulted mainly from the adjustment of the EUA allocation policy between phases I and II. Moreover, the effects of corporate efforts to reduce CO_2 emissions on corporate value did not emerge until phase II, when the EUA allocation became more rigorous." **Jian-Lei Mo, Lei Zhu, and Ying Fan**, *Energy*, Available online March 22, 2012, doi:10.1016/j.energy.2012.02.037, http://www.sciencedirect.com/science/article/pii/S0360544212001326. (Subscription may be required.)

June 2012

***RGGI News Release*, "97 [Percent] of RGGI Units Meet First Compliance Period Obligations."** According to the Regional Greenhouse Gas Initiative's (RGGI) first three-year Compliance Summary Report, 206 of the 211 power plants subject to the requirements met program compliance obligations. The program's first three-year control period began on January 1, 2009, and concluded on December 31, 2011. The average annual CO_2 emissions for the three-year period were 126 million short tons, a 23 percent reduction when compared to the preceding three-year period from 2006 to 2008. Three-year average electricity consumption across the participating states declined 2.4 percent during the same periods, according to the U.S. Energy Information Administration (EIA). Carbon dioxide emissions were collectively reduced to 33 percent below the annual cap of 188 million short tons. The number of allowances held in each compliance entity's RGGI CO_2 Allowance Tracking System (RGGI COATS) account is matched with actual emissions and submitted to the respective state to evaluate compliance. The Compliance Summary Report is available in RGGI COATS at: https://rggi-coats.org/eats/rggi/index.cfm?fuseaction=reportsv2.compliance_summary_rpt&clearfuseattribs=true. More information about the RGGI states' electricity generation and emissions trends is available as part of the comprehensive 2012 program review report, available at: http://www.rggi.org/docs/Retrospective_Analysis_Draft_White_Paper.pdf. June 6, 2012, http://www.rggi.org/docs/PR060412_Compliance.pdf.

***California Air Resources Board News Release*, "Air Resources Board Announces Release of Draft Regulations for Cap-and-Trade Linkage with Québec."** The California Air Resources Board (CARB) released proposed regulations linking its cap-and-trade program to Québec's, forming a joint carbon market to reduce GHG emissions. The proposed regulations provide guidelines to ensure that carbon allowances from Québec and California are interchangeable at auction and can be used in one another's programs for compliance purposes; provide joint, enforceable standards for development and use of CO_2 offsets; and establish a framework for investment in clean energy technology, businesses, and jobs. California adopted its cap-and-trade program in October 2010 with plans to link to other programs, and over the past five years has been working with several states and Canadian provinces within the Western Climate Initiative (WCI) on approaches to linking their emission trading. Québec is the first to be proposed for linkage as its program has similar reduction and reporting rules as California's. The first linked auction between California and Québec is scheduled for November 14, 2012. To view the proposed regulation, visit: http://www.arb.ca.gov/regact/2012/capandtrade12/capandtrade12.htm. May 9, 2012, http://www.arb.ca.gov/newsrel/newsrelease.php?id=300.

"An assessment of greenhouse gas emissions-weighted clean energy standards." The following is the Abstract of this article: "This paper quantifies the relative cost-savings of utilizing a [GHG] emissions-weighted Clean Energy Standard (CES) in comparison to a Renewable Portfolio Standard (RPS). Using a bottom-up electricity sector model for Hawaii, this paper demonstrates that a policy that gives 'clean

energy' credit to electricity technologies based on their cardinal ranking of lifecycle GHG emissions, normalizing the highest-emitting unit to zero credit, can reduce the costs of emissions abatement by up to 90 [percent] in comparison to a typical RPS. A GHG emissions-weighted CES provides incentive to not only pursue renewable sources of electricity, but also promotes fuel-switching among fossil fuels and improved generation efficiencies at fossil-fired units. CES is found to be particularly cost-effective when projected fossil fuel prices are relatively low." **Makena Coffman, James P. Griffin, and Paul Bernstein**, *Energy Policy*, Available online March 3, 2012, doi:10.1016/j.enpol.2012.01.068, http://www.sciencedirect.com/science/article/pii/S0301421512000961. (Subscription may be required.)

July 2012

***RGGI News Release*, "RGGI Auction Sells 20.9 Million CO_2 Allowances."** The Northeastern and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative's (RGGI) 16th quarterly auction announced that 20,941,000 CO_2 allowances (57 percent of 34,426,008 allowances offered) were sold in the second RGGI control period. Bids for the CO_2 allowances ranged from $1.93 (the clearing price) to $6.14 per allowance. The $40.4 million in funds generated by the auction will be reinvested in energy efficiency, clean and renewable energy, direct bill assistance, and other consumer-benefit programs. Electricity generators and their corporate affiliates have won 87 percent of the CO_2 allowances sold in RGGI auctions since 2008, according to Potomac Economics, the independent market monitor. As part of the 2012 program review, the RGGI states continue to analyze electricity generation and emissions trends; CO_2 emissions in the RGGI region were 33 percent below the annual of 188 million short tons during the first control period. For more information, the "Market Monitor Report for Auction 16" is available at: http://www.rggi.org/docs/Auctions/16/Auction_16_Market_Monitor_Report.pdf. June 8, 2012, http://www.rggi.org/docs/PR060812_Auction16.pdf.

***RGGI News Release*, "Auction Notice for CO_2 Allowance Auction 17."** The states participating in the RGGI 2012 auctions released the Auction Notice and application materials for their 17th quarterly CO_2 allowance auction scheduled for September 5, 2012. The Auction Notice for CO_2 Allowance Auction 17 provides potential auction participants with the information needed to submit a Qualification Application and indicate their intent to bid in Auction 17. The states will offer 37,949,558 CO_2 allowances for sale and use a reserve price of $1.93 for the September auction. July 9, 2012, http://www.rggi.org/docs/Auctions/17/Auction_Notice_Jul_9_2012.pdf.

August 2012

"Pricing emission permits in the absence of abatement." The following is the Abstract of this article: "If emissions are stochastic and firms are unable to control them through abatement, the cap in a permit market may be exceeded, or not be reached. [The author derived] a binary options pricing formula that expresses the permit price as a function of the penalty for noncompliance and the probability of an exceeded cap under the assumption of no abatement. [The author applied a] model to the EU ETS, where the rapid introduction of the market made it difficult for firms to adjust their production technology in time for the first phase. The model fits the data well, implying that the permit price may have been driven by firms hedging against stochastic emissions." **Beat Hintermann**, *Energy Economics*, Available online June 7, 2012, doi:10.1016/j.eneco.2012.06.005, http://www.sciencedirect.com/science/article/pii/S0140988312001119. (Subscription may be required.)

"Tradable credits system design and cost savings for a national low carbon fuel standard for road transport." The following is the Abstract of this article: "This research examines the economic implications of different designs for a national low carbon fuel standard (NLCFS) for the road transportation sector. A NLCFS based on the average Carbon Intensity (CI) of all fuels sold generates an incentive for fuel suppliers to reduce the measured CI of their fuels. The economic impacts are determined by the availability of low carbon fuels, estimates of which can vary widely. Also important are

the compliance path, reference level CI, and the design of the credit system, particularly the opportunities for trading and banking. To quantitatively examine the implications of a NLCFS, [the authors] created the Transportation Regulation and Credit Trading (TRACT) Model. With TRACT, [the authors] model a NLCFS credit trading system among profit maximizing fuel suppliers for light- and heavy-duty vehicle fuel use for the United States from 2012 to 2030. [The authors] find that credit trading across gasoline and diesel fuel markets can lower the average costs of carbon reductions by an insignificant amount to 98 [percent] depending on forecasts of biofuel supplies and carbon intensities. Adding banking of credits on top of trading can further lower the average cost of carbon reductions by [five to nine percent] and greatly reduce year-to-year fluctuations in credit prices." **Jonathan Rubin and Paul N. Leiby**, *Energy Policy*, Available online June 11, 2012, doi:10.1016/j.enpol.2012.05.031, http://www.sciencedirect.com/science/article/pii/S0301421512004430. (Subscription may be required.)

"Evaluating the application of different pricing regimes and low carbon investments in the European electricity market." The following is the Abstract of this article: "The EU-ETS is the first measure initiated by the EU to contribute to the decarbonization of the European energy sector. It is a cap and trade system that requires industries participating to the program to procure allowances to cover their emissions. Electricity Intensive Industries (EIIs) have complained that the system put their European plants at disadvantage compared to facilities located outside the EU. They have asked for actions to mitigate this effect; one of them is to have access to long term contracts with electricity suppliers, ideally with those operating carbon free plants. This paper presents and illustrates a method for assessing the impact of this measure on EIIs participating to the EU cap and trade system. [The authors] model a power market segmented in two consumer groups EIIs and the rest of the market (N-EIIs)." **Giorgia Oggioni and Yves Smeers**, *Energy Economics*, Available online June 7, 2012, doi.org/10.1016/j.eneco.2012.06.012, http://www.sciencedirect.com/science/article/pii/S0140988312001181. (Subscription may be required.)

Recent Publications

September 2011

"**A Strategy for CCS in the UK and Beyond."** The following is from the Executive Summary of this document: "[CCS] is a technology that can capture 90 [percent] or more of the CO_2 emissions produced from the use of fossil fuels in electricity generation. The captured CO_2 is then transported for permanent storage in depleted oil and gas fields or deep saline formations. CCS can also be applied to industrial processes such as chemical processing and steel and cement manufacture, preventing CO_2 from entering the atmosphere and contributing to climate change. The value of CCS as an important CO_2 abatement tool is already recognized by multiple authoritative organizations, including the UK Committee on Climate Change (CCC), the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA). The IEA asserts that CCS could deliver 19 [percent] of global emissions reductions, and account for over 30 [percent] of reductions from the power sector by 2050 and that reducing emissions without CCS is likely to be 70 [percent] more expensive. For many industrial applications, CCS remains the only credible abatement option." The complete CCSA publication is available at: http://www.ccsassociation.org.uk/index.php/download_file/view/251/76/.

"Overview of Carbon Capture and Storage in Europe." The following is a description of this brief: "This brief analyzes the [CCS] industry in the UK and Europe from various angles, examining the key drivers, issues, trends, players, and costs. Using a range of sources supplemented with unique insight from industry experts, it joins the dots to provide an informative and compelling overview of the CCS industry, and is imperative reading for strategic decision makers. [Feature and benefits include:] segments the large-scale integrated projects by various angles, such as by application type, capture type, and country; highlights the key players and projects; provides an overview of the different funding sources and the legal/risk landscape, highlighting their respective problems; provides detailed insight into

the economics of CCS, with cost breakdowns sourced from highly reputable organizations; and gives an estimate of the market size and future outlook." This document is available for purchase at: http://www.researchandmarkets.com/reportinfo.asp?report_id=1878356&t=d&cat_id.

"CO_2 Emissions from Electricity Generation and Imports in the 10-State Regional Greenhouse Gas Initiative: 2009 Monitoring Report." The following is from the Executive Summary of this document: "This report, the first report in a series of annual monitoring reports, summarizes data for electricity generation, electricity imports, and related CO_2 emissions in the [10]-state RGGI region for the period from 2005 through 2009. These monitoring reports were called for in the 2005 RGGI Memorandum of Understanding (MOU) in response to expressed concerns about the potential for the RGGI CO_2 Budget Trading Program to result in 'emissions leakage.' In the Northeast and Mid-Atlantic, CO_2 emissions from the regional electric power sector are a function of a highly dynamic wholesale electricity markets. The cost of compliance with the RGGI CO_2 Budget Trading Program is only one of several factors that influence the dispatch of electric generation, and resulting CO_2 emissions, through the operation of these markets. As a result, this report presents data without assigning causality to any one of the factors influencing observed trends. The observed trends in electricity demand, net electricity imports, electricity generation from multiple categories of generation sources (including electricity imports), show there has been no increase in CO_2 emissions or the CO_2 emission rate (pounds of CO_2 per megawatt hour or lb CO_2/MWh) from non-RGGI electric generation serving load in the [10]-state RGGI region in the first year of the RGGI program operation, 2009." This RGGI report is available at: http://www.rggi.org/docs/Elec_monitoring_report_11_09_14.pdf.

October 2011

"The Global Status of CCS: 2011." The following is from the Executive Summary of this document: "In 2011 the CCS industry exhibited measured progress, with an increase in the number of large-scale integrated projects (LSIPs) in operation or under construction and a clustering of projects around the advanced stages of development planning. There are eight large-scale projects in operation around the world and a further six under construction. Three of these projects have recently commenced construction. Importantly, these include a second power project, Boundary Dam in Canada, and the first project in the United States that will store CO_2 in a deep saline formation, the Illinois Industrial Carbon Capture and Sequestration (ICCS) project. The total CO_2 storage capacity of all 14 projects in operation or under construction is over 33 million tonnes a year. This is broadly equivalent to preventing the emissions from more than six million cars from entering the atmosphere each year. In the Institute's annual project survey for 2010, ten projects reported that they could be in a position in the next 12 months to decide on whether to take a final investment decision (FID) and move into construction. Power generation projects are prominent in this group and include Project Pioneer in Canada, the Texas Clean Energy project in the United States and the ROAD project in Europe. While the prospect of a number of power projects moving to [an] FID in the next year is a positive development, this is contrasted with other high-emitting industries such as iron and steel and cement, where there is a paucity of projects being planned at large-scale. In total there are 74 LSIPs recorded in this report, compared with 77 reported in the *Global Status of CCS: 2010* report. These CCS projects continue to be concentrated in North America, Europe, Australia and China with few large-scale projects planned in developing countries. It is vital that the lessons learned from demonstration projects in developed countries are conveyed to developing countries, and that capacity development activities and customized project support are undertaken so that these countries can eventually deploy CCS." To download the entire Global CCS Institute publication, go to: http://www.globalccsinstitute.com/publications/global-status-ccs-2011.

"World Energy Outlook 2011." The following is a summary of this document: "*World Energy Outlook 2011* brings together the latest data, policy developments, and the experience of another year to provide robust analysis and insight into global energy markets, today and for the next 25 years. This edition of the IEA's flagship *WEO* publication gives the latest energy demand and supply projection for different future scenarios, broken down by country, fuel and sector. It also gives special focus to such topical

energy sector issues as: Russia's energy prospects and their implications for global markets; The role of coal in driving economic growth in an emissions-constrained world; The implications of a possible delay in oil and gas sector investment in the Middle East and North Africa; How high-carbon infrastructure 'lock-in' is making the 2°C climate change goal more challenging and expensive to meet; The scale of fossil fuel subsidies and support for renewable energy and their impact on energy, economic and environmental trends; A 'Low Nuclear Case' to investigate what a rapid slowdown in the use of nuclear power would mean for the global energy landscape; [and] The scale and type of investment needed to provide modern energy to the billions of the world's poor that do not have it." For more information on the IEA document, scheduled for release on November 9, 2011, visit the World Energy Outlook 2011 website at: http://www.worldenergyoutlook.org/.

"Technology Roadmap: Carbon Capture and Storage in Industrial Applications." The following is from the Introduction of this document: "The IEA projects that cutting CO_2 emissions to 50 [percent] of their 2005 levels – the target necessary to limit the global warming between 2°C and 3°C – would require a reduction of 43 Gigatonnes of CO_2 ($GtCO_2$). Total CCS in power generation and industrial applications is expected to contribute 19 [percent] to this reduction target in 2050. Much of the most promising short-term potential for CCS – and half of the global economic potential by 2050 – lie in industrial applications, particularly in the developing world. In many industry sectors CCS is often the only technology, with the exception of energy-efficiency measures, that allows for deep reductions in CO_2 emissions. CCS in industrial applications has so far received little attention. Most studies on the potential application of CCS have focused on the power sector, even though all existing operational large-scale demonstrations of CCS are in industrial applications. If CCS is to achieve its full potential to reduce overall emissions, this imbalance needs to be corrected. The need to recognize the potential of CCS for industrial emission sources and to review demonstration opportunities was one of the conclusions of the April 2011 Clean Energy Ministerial meeting held in Abu Dhabi. In their report to the 2010 Muskoka G8 Summit, the IEA and the CSLF, in partnership with the Global CCS Institute, called for the identification of a larger number of CCS projects in industrial sectors globally, as well as support for CCS in developing countries. If developing countries are to implement CCS in the short- to medium-term, each country needs to address its own specific requirements and take steps to increase awareness of the possibilities for CCS in industrial applications." To read the entire Technology Roadmap, go to: http://cdn.globalccsinstitute.com/sites/default/files/ccs_industry_roadmap_web_2.pdf.

November 2011

"Communicating the Risks of CCS." The following is from the Introduction of this document: "CCS is a technology that can be used to reduce [GHG] emissions into the Earth's atmosphere. The technology has applications across multiple industries including the oil and gas industry where it is applied in the enhanced oil and gas recovery (EOR/EGR) process. CCS involves three primary steps: (1) capturing CO_2 at large point sources; (2) transporting the CO_2 to a suitable location; and, (3) injecting the CO_2 into deep geologic formations for permanent storage. Each of these steps is based on technologies that are used in other industrial applications. Although there are not many instances where CCS has been integrated for large scale use, there are numerous pilot projects and a growing number of larger-scale projects that are being used to develop and demonstrate CCS. As these projects increase in scale, and CCS becomes a commercially viable CO_2 reduction strategy, concerted effort has gone into systematic risk assessment and mitigation for CCS projects. The International Energy Agency Greenhouse Gas program (IEAGHG) sponsored the development of a database of more than 200 generic features, events, and processes (FEPs) potentially associated with CCS projects. The FEPs' focus on the behavior of CO_2 is with respect to the long-term performance and safety of CCS projects. The database is organized around eight categories of risk based on 'technical and scientific considerations.'" This Global CCS Institute (GCCSI) document is available for download at: http://cdn.globalccsinstitute.com/sites/default/files/communicating_the_risks_of_ccs.pdf.

"Evaluating Global CCS Communications." The following is a summary of this University of Cambridge report: "CCS communications are likely to play a crucial part in determining what kind of role CCS eventually ends up playing in the energy and climate infrastructures currently being planned and built around the world. With CCS not yet operating on a commercial scale, CCS communications via media coverage, visits to science museums, and especially websites, make up a significant part of the 'CCS' that most people will experience. As Hammond and Shackley (2010) point out, the images and presentation of CCS, more than actual CCS infrastructure or experiences with CCS, make up what CCS means to most people at the present time. The importance therefore of questions about how CCS is being communicated becomes imperative, specifically, how such communication is, and may be, developing and where it might be enhanced and improved in the future. This report reviews the scope and key characteristics of CCS communications and primarily builds upon a comprehensive Global CCS Communications Database that was compiled for this project. The report also draws upon investigations of non-web sources, including books, articles, media reporting of CCS, educational materials and museum exhibits, to provide as varied and comprehensive an overview as possible of CCS communication practices to date." The report is available through GCCSI's publication database at: http://www.globalccsinstitute.com/publications/evaluating-global-ccs-communications.

"Carbon Capture and Storage in Developing Countries: a Perspective on Barriers to Deployment." The following is a summary of this World Bank report: "CCS could have significant impact as a carbon mitigation technology in [GHG] emitting industries. Given the nascence of CCS technology, with only eight large-scale integrated projects in the world (Global CCS Institute 2010), significant challenges still must be overcome for large-scale deployment, such as addressing technical issues of integration and scale-up, legal and regulatory requirements to reduce investor risk, policies to create market drivers and mitigate economic impacts, including increases in electricity prices, and financing mechanisms to facilitate investment in the technology. This report does not provide prescriptive solutions to overcome these barriers, since action must be taken on a country-by-country basis, taking account of different circumstances and national policies. Individual governments should decide their priorities on climate change mitigation and adopt appropriate measures accordingly. The analyses presented in this report may take on added relevance, depending on the future direction of international climate negotiations and domestic legal and policy measures, and how they serve to encourage carbon sequestration. Both international and domestic actions can further incentivize the deployment of CCS and its inclusion in project development. Incentives to promote CCS include adopting climate change policies that could provide revenues for CCS projects, but it is likely that a combination of domestic and international mechanisms will be required, alongside carbon revenues, to kick-start CCS project development and reduce investor risk in developing countries in particular." The report is available through GCCSI's publication database at: http://www.globalccsinstitute.com/publications/carbon-capture-and-storage-developing-countries-perspective-barriers-deployment.

"The Costs of CCS and Other Low-Carbon Technologies." The following is a summary of this GCCSI report: "Managing the risks of climate change requires the development and adoption of a wide range of low-carbon technologies across many industrial sectors. It is likely that the stringent targets of 450 ppm can only be achieved efficiently with a portfolio of technologies that include options that have the potential for removing CO_2 from the atmosphere as well as negating CO_2 emissions from industrial sources, such as CCS technologies. This paper focuses on the electric power generation industry, and examines the costs of different technologies that are expected to play a part in reducing [CO_2] emissions to the atmosphere." The report is available through GCCSI's publication database at: http://www.globalccsinstitute.com/publications/costs-ccs-and-other-low-carbon-technologies.

December 2011

"The Carbon Capture and Storage/Sequestration (CCS) Technologies Market 2012-2020." The following is a summary of this document: "CCS is an alternative and convenient technology to eliminate [CO_2] before it is released in the atmosphere. It is one of the most innovative clean energy markets

which will experience stable growth rates in the next [10] years. Reduction in [CO_2] emission has received increasingly global attention in the past few years because of accelerating climate change issues. Visiongain calculates that global expenditure on CCS technologies in 2012 will total $13.70bn. Though the CCS industry will be faced with the restraints of proving the effectiveness of CCS technologies on the large-scale, the negative public perception of the technology and the unsupportive legislative framework, the CCS market is likely to provide substantial opportunities for potential investors. This report offers an examination of the CCS market over the next decade, providing detailed market forecasts for each of the leading national markets and offering in-depth analysis of the opportunities and challenges facing companies in the CCS market throughout the world. The report also describes the most important technological changes within the CCS industry and assesses their importance for the growth of the market over the long-term. The various drivers and restraints of the market are evaluated in order to provide readers with specific insights into the future direction of the CCS market. How much is going to be spent in the leading national CCS markets for new and upgraded CCS infrastructure between 2012 and 2022? Who are the leading companies in the CCS industry? Where are the growth opportunities over the next decade - in which countries and with which type of technology? These critical questions and many more are definitively answered in this comprehensive report." The report is available for purchase at: http://www.visiongain.com/Report/720/The-Carbon-Capture-Storage-Sequestration-(CCS)-Technologies-Market-2012-2022.

"Bridging the Emissions Gap." The following is from the Executive Summary of this document: "Global climate policy has advanced on several fronts over the past few years and this report deals with two developments of particular importance – The readiness of countries to pledge to new emission reductions, and the agreement among countries to an important global climate target…In their 'Emissions Gap Report' released in December 2010, the scientists reported that a gap was expected in 2020 between expected emissions and the global emissions consistent with the 2°C target, even if pledges were implemented fully. After receiving the report, policymakers requested UNEP to prepare a follow-up document which not only updates emission gap estimates, but more importantly, provided ideas on how to bridge the gap. This present report is a response to this request. To do the work UNEP has convened 55 scientists and experts from 28 scientific groups across 15 countries. This report first reviews and summarizes the latest scientific studies of the gap. It then tackles the question – How can the gap be bridged? – by examining the question from different vantage points: From that of global integrated assessment models, from bottom-up studies of individual economic sectors, and from published work on the mitigation potential in international aviation and shipping emissions. These different perspectives provide a rich body of information on how to plausibly bridge the emissions gap in 2020 and beyond." To view the entire UNEP report, visit: http://www.unep.org/pdf/UNEP_bridging_gap.pdf.

"Developing CCS Projects Under the CDM." The following is a summary of this document: "Taking into account this backdrop, this report sets out some of the key considerations for implementing CCS projects under the [Clean Development Mechanism (CDM)] and potentially other forms of climate finance in the future. The aim is to provide the reader with the necessary basic information to begin identifying and [conceptualizing] CCS projects under the CDM, begin building the business case, evaluating methodological aspects, and identifying regulatory issues and risks for establishing such a project in a developing country." To download this Global CCS Institute report, go to: http://www.globalccsinstitute.com/publications/developing-ccs-projects-under-clean-development-mechanism.

"ROAD CCS Project: Non-confidential FEED study report." The following is a summary of this document: "ROAD (Rotterdam Capture and Storage Demonstration Project) is one of the largest integrated demonstration projects in the world for the capture and storage of CO_2, based on a new coal-fired power station located outside of Rotterdam, the Netherlands. ROAD recently completed its front end engineering and design (FEED) studies and cost estimations for the project and has prepared a special report for the Global CCS Institute [summarizing] the main results of the FEED study for the capture plant

as performed by Fluor. This report includes topics such as technology selection, process flow diagrams, heat and mass balances, layout designs, cooling studies, capital and [operation and maintenance (O&M)] cost estimates and project schedules. The report aims to help other CCS projects, particularly those using post-combustion capture technology, to design and cost their own capture plant. The report is also likely to be useful to regulatory, permitting and other stakeholders who want to gain an understanding of what considerations project proponents give to the range of decision factors, including environmental performance of technologies." To download this Maasvlakte CCS Project CV report, go to: http://www.globalccsinstitute.com/publications/road-ccs-project-non-confidential-feed-study-report.

"Proceedings from CCS Cost Workshop." The following is a summary of this document: "More than 50 studies have been released in the past five years that provide estimates of the costs for operating a CCS equipped power plant in a variety of regions around the world. There are also many other studies that examine only variants or elements of CCS technologies such as different chemical choices, heat integration issues, retrofits, storage or transport issues or technologies still in the [research and development (R&D)] stage…At the 10th International Conference on Greenhouse Gas Control Technologies in 2010, the need to establish an Expert Group on CCS costs was identified in response to the growing number of reports regarding the costs of CCS…An initial Steering Group was formed to [organize] the first meeting of the group. The inaugural meeting was held on March 22-23, 2011, hosted by [IEA]. The current understanding of the costs of CCS presented at that meeting and the agreed outcomes for the Group to take forward are included in this document. This work program consists of efforts to improve both the transparency of CCS cost calculations and the broader challenges associated with conveying messages around costs to the broader community." To download the proceedings, go to: http://www.globalccsinstitute.com/publications/proceedings-ccs-cost-workshop.

"Legal and regulatory developments related to carbon capture and storage between November 2010 – June 2011." The following is a summary of this document: "As a part of the Policy, Legal and Regulatory (PLR) team's research and preparatory activity for the drafting of the Global Status of CCS Report 2011, a legal and regulatory scan of the CCS legal and regulatory environment was commissioned from Baker & McKenzie. The study is aimed at providing a comprehensive overview of international, regional, national and sub-national legal and regulatory developments; including details of negotiations currently in progress, the signaled intent of future CCS legal and regulatory decisions and the status of implementation of regulation in a number of countries. Fifty-one jurisdictions were surveyed in total, including the [European Union's (EU)] Member States, Federal, and state level jurisdictions in Australia and the [United States] and those developing nations which are the focus of the Institute's capacity development activities. The Institute's PLR team worked closely with Baker & McKenzie to develop the scope and format of the research; ensuring a detailed final report and accompanying legislation tables, as well as a process which is potentially replicable in the future." To download the Baker & McKenzie report, go to: http://www.globalccsinstitute.com/publications/legal-and-regulatory-developments-related-carbon-capture-and-storage-between-november-2.

January 2012

"CO_2 Storage Atlas: Norwegian North Sea." The following is from the Introduction of this document: "Production of power and other use of fossil energy is the largest source of [GHG] emissions globally. Capture and storage of CO_2 in geological formations emerges as an important potential measure to reduce global emissions. The Norwegian government places great emphasis on CCS as a measure to reduce CO_2 emissions. The government has set ambitious goals for achieving CO_2 capture at gas fired power plants and for establishing a chain for transport and injection of CO_2. In its Special Report on Carbon Dioxide Capture and Storage (2005), the United Nations IPCC concludes that capture and storage of CO_2 may account for as much as one half of emission reductions in this century. However, major challenges must be solved before this potential can be [realized]. The IPCC report points out that there is as yet no experience from capture of CO_2 from large coal and gas power plants. Norway has extensive experience in storage of CO_2 in geological structures. Since 1996, approximately one million

tonnes of CO_2 per year have been separated from gas production on the Sleipner Vest field in the North Sea for storage in Utsira, a geological formation 1,000 meters below the seabed. In connection with treatment of the well stream from the Snøhvit field and the liquefied natural gas (LNG) production on Melkøya, there is capacity for separation and storage of 700,000 tonnes of CO_2 in a reservoir 2,600 meters below the seabed. There is significant technical potential for storing CO_2 in geological formations around the world. Producing oil and gas fields, abandoned oil and gas fields and other formations such as saline aquifers are all candidates for such storage. Storage in reservoirs that are no longer in operation is a good solution in terms of geology because these structures are likely to be impermeable after having held oil and gas for millions of years. Other formations are also considered to be secure storage alternatives for CO_2. Environmentally sound storage of CO_2 is a precondition for a successful CCS chain. Consequently, the mapping, qualification and verification of storage sites is indispensable for CCS as a climate change mitigation measure. Geological formations offshore Norway are expected to be well-suited for storing large quantities of CO_2. It is important to have the best possible understanding of what can be the CO_2 storage potential. These factors necessitate an enhanced effort within the mapping and investigation of CO_2 storage sites. The production of this CO_2 storage atlas is at the very centre of this effort, and the atlas will be a key component in the development of aquifers at the Norwegian Continental Shelf as storage sites for CO_2. Various Norwegian research institutions and commercial enterprises have extensive experience and competence within CO_2 storage." To view the complete CO_2 Storage Atlas, visit: http://www.npd.no/Global/Norsk/3-Publikasjoner/Rapporter/PDF/CO2-ATLAS-lav.pdf.

"Mountaineer Commercial Scale Carbon Capture and Storage (CCS) Project CO_2 Storage Report." The following is from the Executive Summary of this document: "American Electric Power (AEP) has been actively involved in the development of CCS technology over the past eight years. AEP's early work with CCS began in 2003 in the Ohio River Valley CO_2 Storage Project. Additionally, AEP's Mountaineer power plant in New Haven, West Virginia hosted two CCS projects which include the Product Validation Facility (PVF) and the Mountaineer Commercial Scale Project (MT CCS II), facility. The PVF project was a 20 [megawatt (MW)] equivalent ammonia-based post combustion CO_2 capture and [storage] facility and the CSP is a planned scale-up of the same technologies for a 235 MW equivalent coal fired unit. There is substantial overlap with respect to the storage aspect between these two projects, however this report is primarily focused on the storage aspects of MT CCS II. Some of the broad findings and technical details captured from the previous projects are being shared in this report but further details are out of the scope of this project and cannot be shared. The MT CCS II project has been divided into four phases, Phase I – Front-end Engineering and Design, Phase II – Detailed Design, Phase III – Construction, and Phase IV – Operations; the MT CCS II project has recently completed Phase I. As a part of Phase I of MT CCS II, a geologic characterization well was drilled at Borrow Area which is approximately [two] miles southwest from the Mountaineer plant. Also, two 2D seismic lines were purchased, processed and analyzed. The characterization well at the Borrow Area and the two additional 2D seismic lines were essential in the characterization of the local geology. Prior to completing the Borrow Area characterization well, a geologic model for MT CCS II was generated based on the geologic knowledge gained from the PVF project and data from five deep wells of the PVF project (two injection wells and three deep monitoring wells). This geologic model was used as an input for a reservoir simulation model and multiple simulations were generated for a CO_2 injection rate of 1.5-million metric tonnes/year (the target capture rate of MT CCS II). The target reservoir for injection is the lower copper ridge formation at a depth of approximately 8,100 ft. The simulation results provided an estimate of CO_2 footprint, the extent of the pressure perturbation field, the expected injection pressures, and the CO_2 saturation in the reservoir (along with other parameters). Based on these reservoir simulations, it was decided that two injection wells (two sites with one well at each location with an approximately [seven] miles distance between the two sites) will be adequate to safely inject 1.5 million metric tonnes of CO_2 each year for a period of five years." The entire AEP CO_2 Storage Report is available at: http://www.globalccsinstitute.com/sites/default/files/publications/27436/mt-ccs-ii-co2-storage-report-final_0.pdf.

"Canadian and Albertan perceptions of carbon capture and storage." The following is from the Introduction of this document: "Project Pioneer represents a major step toward advancing the reduction of a key GHG emission – [CO_2]. TransAlta and its project partners believe that maintaining the long-term viability of fossil-fired generation is a global necessity. Through economic CCS [the authors] can keep coal and natural gas as fuel options while addressing climate change concerns. Much of the world, including Canada, is fortunate to have huge, reliable reserves of low-cost coal – more coal than oil, in fact. Within the global electricity generation mix, coal is vital and often the only practical fuel for some regions. With billions of dollars of energy infrastructure already built (and billions more to come) CCS may be the only way to minimize the long-term impact these facilities will have on the environment over the course of their lifespan. Project Pioneer will demonstrate a post-combustion, retrofit [CCS] process that can be attached to existing energy infrastructure. A solution to the CO_2 emissions challenge exists through CCS technology. CCS is a safe, tested and effective technology for reducing the amount of CO_2 entering the atmosphere. A number of projects have already demonstrated that with proper site selection, design and management, CO_2 can be successfully stored for many years… In partnership with Shell Canada, TransAlta commissioned a polling firm in the summer of 2010, to conduct research amongst Canadians and Albertans regarding their perceptions of CCS. Both corporate entities, with two separate CCS projects (Shell's Quest, and TransAlta's Pioneer), felt that with the shortage of established data on the subject of public perceptions on CCS, this initial research would serve to create baselines of perceptions not only at the local level, where the coal-fired plant Keephills 3 and the future carbon capture facility (CCF) of Pioneer would be located, but also to gauge the broader public acceptance for CCS, and to better understand where people would have questions regarding the technology, so that [the authors] could work to address those. What people would tell [the authors] through public polling, would form one of a number of pillars that would help determine a public engagement strategy, so [the authors] could ensure [they] were addressing the right issues that people had questions about. This initial polling activity in 2010 was designed to establish both an *Alberta* and a *Canada* baseline for the purposes of Project Pioneer." The full TransAlta Project Pioneer report is available at: http://www.globalccsinstitute.com/sites/default/files/publications/27611/public-perceptions-report-2010-polling-results.pdf.

"Policy Recommendations for Selection & Development of Offshore Geologic Carbon Sequestration Projects Within Texas State Waters." The following is the Abstract of this document: "This report evaluates the potential environmental impact of geologic carbon [storage] projects in the state waters of Texas and makes recommendations for decisions that can be followed during the site selection phase to alleviate risk and mitigate potential harm. This report also makes related recommendations for consideration during the project development and operations phase related to site-specific monitoring, verification, accounting and reports, and response planning." The full Environmental Defense Fund (EDF) report is available at: http://blogs.edf.org/energyexchange/files/2011/12/EDF-Policy-Recommendations-Offshore-CCS-Dec-2011.pdf.

February 2012

"Basin Resource Management for Carbon Storage." The following is from the Executive Summary of this document: "The Collie Hub in the Southern Perth Basin in Western Australia, CarbonNet in the Gippsland Basin in Victoria, and Wandoan in the Surat Basin in Queensland are being investigated as potential sites for CO_2 storage under an Australian Government flagship program. Each of the three CCS projects is located in resource-rich sedimentary basins, which contain high quality groundwater, oil and gas, unconventional gas, coal and geothermal resources. The Collie Hub CCS site is situated in the Southern Perth Basin in the south west of Western Australia. It is planned to eventually inject up to 10 Mt/yr of CO_2 into the lower Lesueur Sandstone from CO_2 sources in Collie and Kwinana. The CarbonNet CCS site is located in the nearshore and offshore areas of the Gippsland Basin in southeastern Victoria. Initial CO_2 storage of about 1-5 Mt/yr is planned in the Gippsland Basin, with a potential of scaling up to 20 Mt/yr. The Surat Basin in Queensland has been identified for geologic storage of [CO_2] for the Wandoan CCS Project which plans to eventually capture and store up to 2.5 Mt/yr of CO_2. The location

of injection wells is yet to be selected at these sites. CSIRO and its [Western Australia Energy Research Alliance (WA:ERA)] research partner, Curtin University, are jointly conducting an assessment of the site specific resources that are geographically co-located with proposed carbon storage. The project also aims to understand the structural, stratigraphic and geomechanical aspects at these sites to assess the potential impacts of CO_2 injection on adjacent resources." The full report is available for download at: http://www.globalccsinstitute.com/publications/basin-resource-management-carbon-storage.

"The Carbon Plan: Delivering our low carbon future." The following is from the Executive Summary of this document: "This plan sets out how the UK will achieve decarbonization within the framework of [their] energy policy: to make the transition to a low carbon economy while maintaining energy security, and [minimizing] costs to consumers, particularly those in poorer households. Emissions are down by a quarter since 1990. Current policies put the UK on track to cut emissions by over a third, on 1990 levels, by 2020. In the next [10] years, [the UK] will develop and deploy the technologies that will be needed to halve emissions in the 2020s. This will put the UK on a path towards an 80 [percent] reduction by 2050. By moving to a more efficient, low carbon and sustainable economy, the UK will become less reliant on imported fossil fuels and less exposed to higher and more volatile energy prices in the future." To view the entire UK Department of Energy and Climate Change (DECC) document, visit: http://www.decc.gov.uk/assets/decc/11/tackling-climate-change/carbon-plan/3702-the-carbon-plan-delivering-our-low-carbon-future.pdf.

"Clean Coal Technologies Markets and Trends Worldwide, 2nd Edition." The following is from the Summary of this document: "Global Clean Coal Technologies and Markets provides a detailed discussion of the key technologies, deployed or in development, to address the environmental impact of coal. The various clean coal technologies that hold the most promise for commercial deployment are discussed in the report. CCS and other clean coal technologies are reviewed from the point of view of their current status, likely future performance and [research and development (R&D)] needs, and potential for commercial adoption. The report also includes a broad review of the market for clean coal technologies for coal-fired electricity generation. The global market demand for coal, electricity, and clean coal-fired electricity is quantified and projections for growth in demand are provided, along with the key factors influencing this growth in leading coal consuming nation around the world. Global Clean Coal Technologies and Markets details the current and projected percentage of electricity generated by clean coal technologies. The historical and projected market value of the clean coal technologies is also covered. The report includes profiles of 15 companies actively engaged in the clean coal market, and also details current and potential U.S. employment in the sector. The ongoing research, development, commercialization and deployment of clean coal technologies is expected to generate a significant number of direct, indirect and induced jobs over the next 10 to 15 years. The construction and operation of coal-fired power plants that incorporate clean coal technologies will also result in the creation of tens of thousands of jobs across a variety of sectors. The report provides an overview of coal- and electricity-related employment and details projections for expected growth." The full report is available at: http://www.reportlinker.com/p0750344-summary/Clean-Coal-Technologies-Markets-and-Trends-Worldwide-Edition.html. (Subscription required.)

"CCS in New Zealand." The following is the Executive Summary of this document: "CCS has global significance as it is one of a range of options available for reducing [CO_2] emissions. This report considers whether CCS has the potential to deliver value to New Zealand as [it] moves to a low carbon future. CCS involves the capture of [CO_2] emissions from large emitters such as power stations and processing plants. That [CO_2] is then transported (usually through a pipeline) to a reservoir, very deep underground, where it is injected into porous rock. Although integrated CCS is in its infancy internationally, the individual components (capturing [CO_2], transporting it in pipelines, and injecting gas into reservoirs) have all been used internationally and in the New Zealand oil and gas industry for decades. The NZCCS Partnership [recognized] the need to investigate the implications of CCS should it be deployed in New Zealand. This study, led by Transfield Worley Ltd, considered the technical, commercial, legal/legislative, environmental, and social aspects of CCS fits into the international and

New Zealand responses to climate change. It includes two case studies considering the viability of CCS for existing and new plants, along with analysis of legislative, environmental, social and economic barriers to the adoption of CCS." To download the full document, visit: http://www.straterra.co.nz/uploads/files/ccs_in_new_zealand_summary_report_2011.pdf.

March 2012

"Global Opportunity in Carbon Capturing & Storage Technology Market (2011 – 2016)" The following is a description of this document: "The report contains an elaborative description of the Global [CCS] technology market. The report casts various developments and plans in respective field across the geographies along with the influential factors for this market. It provides the current market scenario and future market forecasts for major markets. The report provides a deep insight to the initiatives taken by governments across the globe which is one of the major driving forces for this market. The major players in this global technology market have been covered as company profiles." To view the full report, go to: http://www.researchandmarkets.com/research/2e260c/global_opportunity. (Subscription required.)

"A Greenhouse Gas Accounting Framework for Carbon Capture and Storage Projects." The following is from the Executive Summary of this document: "The Greenhouse Gas Accounting Framework for Carbon Capture and Storage (CCS) Projects—CCS Accounting Framework—provides methods to calculate emissions reductions associated with capturing, transporting, and safely and permanently storing anthropogenic CO_2 in geologic formations. It aims for consistency with the principles and procedures from ISO 14064-2:2006. *Greenhouse gases—Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements*, which represents best practice guidance for the quantification of project-based GHG emission reductions. Ultimately, the objective of the CCS Accounting Framework is to inform and facilitate the development of a common platform to account for GHG emissions reductions due to capturing and geologically storing CO_2. It also contributes to the public discussion about the viability of CCS to serve as a feasible CO_2 mitigation solution… The emissions accounting procedures in the CCS Accounting Framework apply to multiple CO_2 source types, including electric power plants—equipped with pre-combustion, [post-combustion], or oxy-fired technologies—and industrial facilities (for example, natural gas production, fertilizer manufacturing, and ethanol production). For CO_2 transport, the calculation methodology in this document applies only to pipelines because while other methods of transport, (e.g., truck transport) are possible, they are typically not considered viable options for large-scale CCS endeavors. With respect to the geological storage of CO_2, the CCS Accounting Framework applies to saline aquifers, depleted oil and gas fields, and enhanced oil and gas recovery sites. The CCS Accounting Framework provides a comprehensive set of GHG accounting procedures within a single methodology. The quantification approach includes equations to calculate emissions reductions by comparing baseline emissions to project emissions—the difference between the two represents the GHG reductions due to capturing and [storing] CO_2, which would have otherwise entered the atmosphere." To view the entire Center for Climate and Energy Solutions (C2ES) document, click: http://www.c2es.org/docUploads/CCS-framework.pdf.

"Geomechanical [modeling] as part of the site investigation for CO_2 injection in the onshore part of the Gippsland Basin, SE Australia." The following is the Abstract of this document: "The storage of [CO_2] into geological formations is responsible for a number of coupled chemical and mechanical processes. Injection of CO_2 results in pore-pressure gradients that give rise to a change of the *in-situ* stress state. These alterations cause expansion due to poro-elasticity and possible irreversible deformation of the reservoir (e.g. tensile fracture). In this work, as part of the site assessment, a first 2D numerical geomechanical model of the Seaspray Depression, located in the onshore part of the Gippsland Basin, SE Australia, is presented. The study aims to investigate short-term (10 [years]) local changes of the effective stress and the associated basin uplift for various total storage scenarios (7.81, 22.1 and 72.4Mt CO_2). In the approach, using the Hashin-Shtrikman bounds theory for multiphase materials, the model accounts for flow of supercritical CO_2, coupled with rock deformation, through a

system with site specific mechanical and hydrological properties of a rock plus water mixture. The simulations show under the assumptions made that the ground vertical displacement for a total injection volume of 7.81Mt CO_2 results in 7.25cm uplift. This is in good agreement with recently published InSAR field data from the In Salah storage project, which show that an average injection rate of 0.5-1Mt/yr gives rise to 5-7mm/yr surface uplift. [The authors] also conclude that a larger total volume of 72.4Mt would result in an uplift of 23cm. Although this current work does not yet take into account rock plasticity and multiphase flow, the analyses demonstrate that our model approach is appropriate to conduct more simulation studies associated with CO_2 injection in the future." The complete Global CCS Institute document is available at: http://www.globalccsinstitute.com/publications/geomechanical-modelling-part-site-investigation-co2-injection-onshore-part-gippsland.

April 2012

"CCS Roadmap: Supporting Deployment of Carbon Capture and Storage in the UK." The following is from the Executive Summary of this document: "CCS has the potential to be one of the most cost effective technologies for [decarbonization] of the UK's power and industrial sectors, as well as those of economies worldwide. CCS can remove CO_2 emissions created by the combustion of fossil fuels in power stations and in a variety of industrial processes and transport it for safe permanent storage deep underground, for example deep under the North and Irish Seas. [Modeling] for the Carbon Plan shows that CCS can play a significant role in achieving [decarbonization] of the UK economy at least cost. In the power sector CCS will contribute to diversity and security of electricity supply, and also has a unique role in providing a continuing role for flexible fossil fuel capacity that is able to respond to demand in the way that other low carbon technologies are not able to. CCS also represents a major green growth opportunity for the UK. Worldwide up to $40 billion has been committed by Governments to support CCS projects and, if CCS opportunities develop as anticipated, benefits for UK-based firms have been estimated to be between [approximately $4.8 to $10.4 billion] a year by the late 2020s. The deployment of CCS is at an early stage, so to the extent that UK based business can take advantage of these local opportunities it should help to establish them as leaders in a developing worldwide market. The Government is committed to helping make CCS a viable option for reducing emissions in the UK and in doing so to accelerate the potential for CCS to be deployed in other countries. [The UK's] vision is for widespread deployment of cost-competitive CCS. [The UK is] seeking to support the development of a sustainable CCS industry that will capture emissions from clusters of power and industrial plants linked together by a pipeline network transporting CO_2 to suitable storage sites offshore. That CO_2 might also be used to recover additional amounts of the UK's hydrocarbon reserves, thereby improving the economics of CCS and accelerating deployment. [The UK] will support the development of a strong and robust supply chain in the UK, creating jobs and markets locally and nationally to serve the early CCS plant and later clusters of CCS activity. Playing to the UK's business strengths and encouraging projects clustering in regions reflects the Government's ambition to capture opportunities for 'green jobs' that will arise from an emerging market for CCS. To make this vision a reality [the UK] must invest now. This Roadmap sets out how [the UK] will achieve [their] goal of seeing commercial deployment of CCS in the UK in the 2020s." The full DECC document is available at: http://www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-capture-storage/4899-the-ccs-roadmap.pdf.

"Independent assessment of high-capacity offshore CO_2 storage options." The following is from the Executive Summary of this document: "In early 2010, the Rotterdam Climate Initiative (RCI) contracted TNO Built Environment and Geosciences (TNO) to conduct an Independent CO_2 Storage Assessment (ISA) of offshore CO_2 storage sites under the Dutch North Sea, so as to support the early deployment of CCS in the Netherlands. The ISA was conducted in three phases, with this report summarizing Phase 3. Phases 1 and 2 are covered in two previous reports, one detailing the methodology employed and one presenting the results. As a whole, the ISA studies are intended to provide a comprehensive view of potential offshore CO_2 storage, with the specific goals of: ensuring that planning for CO_2 storage does not lag planning of other portions of the CCS value chain; identifying and

progressing work on several potential CO_2 storage sites, to provide sufficient alternatives should individual sites prove to be unavailable on desired timelines or prove less attractive during later stage work; providing greater certainty among emitters regarding storage availability and capacity, enhancing their confidence in planning CO_2 capture projects; and providing good, harmonized data for emitters to use in their planning and in applying for funding for CCS projects. ISA Phases 1 and 2 sought to support first-mover CCS projects by providing detailed assessment of the most promising prospective CO_2 storage sites available from 2015 to 2020. In doing so, Phase 1 screened the P and Q blocks close to Rotterdam to identify the most attractive options and to ensure that no good short-term prospects had been overlooked. Phase 2 then characterized the four most attractive prospects in greater detail, including feasibility-level analysis of their technical viability, capacity, availability and cost, as well as key actions and risks to bring each site operation. ISA Phase 3 broadens Phase 1 and 2 screening to underpin longer-term CCS deployment, seeking to identify high-capacity CO_2 storage sites throughout the entire Dutch Continental Shelf, irrespective of their location and of the timing of their availability. High-capacity sites were targeted because, while ISA Phases 1 and 2 successfully identified several near-term prospects, these sites do not represent sufficient CO_2 storage capacity for the volume of CO_2 capture anticipated with the commercialization of CCS, a concern that has grown in strategic importance for emitters throughout the Netherlands with the Dutch Government's prohibition of onshore CO_2 storage." The full document is available at: http://www.globalccsinstitute.com/publications/independent-assessment-high-capacity-offshore-co2-storage-options.

"CCS RETROFIT: Analysis of the Globally Installed Coal-Fired Power Plant Fleet." The following is from the Scope of this Study: "A large number of coal-fired power plants are currently in operation worldwide. No complete set of technical information of individual units of this globally installed fleet exists. However, available databases cover the bulk of these plants in a relatively comprehensive manner. These databases typically include key information related to the size, age, and performance level of the vast majority of the globally installed coal-fired power plants. The following analysis is based on IEA statistical information in combination with data from the UDI World Electric Power Plants Data Base, referred to henceforth as the WEPP database. Data from the IEA are used in this study for validation of WEPP results. IEA data are typically based on direct submissions by IEA member and non-member countries, as well as the agency's own analysis. Submitted data are often aggregated on a country-wide level. This study illustrates the size and regional distribution of the globally installed coal-fired power plant fleet that is potentially relevant for CCS retrofitting. The study draws upon existing research on CCS retrofitting: several studies have estimated the effective potential for retrofitting on a regional level, often based on generic assumptions. While significant progress has been made on understanding the importance of different aspects relevant for assessing CCS retrofitting, the realistic global potential is still unclear. No detailed economic analysis is performed under this study. Instead, a range of selected criteria for coal-fired power plants is extracted from global databases and combined with fundamental economic considerations in order to provide a realistic estimate of the potential for retrofitting plants with CCS. More specifically, the following analysis illustrates the global and regional distribution – broken down to a generation unit level (or power plant "block" size) – of power generation capacities, performance levels, and plant age." The document can be viewed from: http://www.iea.org/papers/2012/CCS_retrofit.pdf.

May 2012

"Tracking Progress in Carbon Capture and Storage." The following is a summary of this report: "At the second Clean Energy Ministerial in Abu Dhabi, April 2011 (CEM 2), the Carbon Capture, Use and Storage Action Group (CCUS AG) presented seven substantive recommendations to Energy Ministers on concrete, near-term actions to accelerate global CCS deployment. Twelve CCUS AG governments agreed to advance progress against the 2011 recommendations by the third Clean Energy Ministerial (London, 25-26 April 2012) (CEM 3). Following CEM 2, the CCUS AG requested the [International Energy Agency (IEA)] and the Global CCS Institute to report on progress made against the 2011

recommendations at CEM 3. “Tracking Progress in Carbon Capture and Storage: International Energy Agency/Global CCS Institute report to the third Clean Energy Ministerial” responds to that request. The report considers a number of key questions. Taken as a whole, what advancements have committed CCUS AG governments made against the 2011 recommendations since CEM 2? How can Energy Ministers continue to drive progress to enable CCS to fully contribute to climate change mitigation? While urgent further action is required in all areas, are there particular areas that are currently receiving less policy attention than others, where efforts could be redoubled? The report concludes that, despite developments in some areas, significant further work is required. CCS financing and industrial applications continue to represent a particularly serious challenge.” The full IEA publication is available for download at: http://iea.org/publications/freepublications/publication/name,26622,en.html.

“Carbon Capture and Storage: [Realizing] the potential?” The following is from the Executive Summary of this document: “The aim of the research is to assess the technical, economic, financial and social uncertainties facing CCS technologies, and to [analyze] the potential role they could play in the UK power sector between now and 2030. CCS technologies are often highlighted as a crucial component of future low carbon energy systems – in the UK and internationally. However, it is unclear when these technologies will be technically proven at full scale, and whether their costs will be competitive with other low carbon options. The important contribution that CCS technologies could make to reducing global carbon emissions has been [recognized] by the UK government for several years. There has been a plan to build at least one full scale demonstration project since 2006. But, at the time of writing, this has not yet resulted in a firm agreement to fund a specific project. Last autumn, the planned Scottish Power demonstration at the Longannet power plant became the latest CCS project to be cancelled. Despite continuing public commitments to CCS from Ministers, policy, economic and financial uncertainties remain a particular concern for investors in the UK – and in many other countries where CCS demonstrations are planned. The re-launch of the [~$1.5 billion] fund for CCS demonstration projects in April 2012, alongside a roadmap for the [commercialization] of CCS technologies, may signal a decisive turning point in UK policy. However, it remains to be seen whether the measures within the roadmap, and the generous package of financial support that is now available, will be sufficient to make CCS a commercial reality. Against this policy background, this report systematically examines the uncertainties facing CCS technologies in the UK. It uses historical evidence to explore these uncertainties, and the conditions under which they can be at least partly resolved. The historical evidence base comprises nine case studies, each of which focuses on a technology that is partly analogous to CCS. The report draws on this evidence to develop potential pathways for CCS in the UK to 2030, and uses this analysis to draw conclusions for current policies and strategies.” To view the entire UK Energy Research Center (UKERC) document, go to: http://www.ukerc.ac.uk/support/tiki-download_file.php?fileId=2386.

June 2012

“Carbon Storage Systems and Well Management Activities.” The following is from the Executive Summary of this document: “The purpose of the DOE Carbon Storage Program is to demonstrate that CO_2 can be economically, successfully, and securely stored permanently in a manner that is compliant with the best engineering and geological practices; Federal, state, and local regulations; and in the best interests of local and regional stakeholders. In a typical CCS project, CO_2 is captured at an anthropogenic source, transported to a suitable location, and injected into deep geologic formations for permanent storage in saline and hydrocarbon bearing formations. Wells are a critical component of any CCS project; they will be drilled and completed for multiple purposes, including: exploring the suitability of geologic formations; injecting CO_2; monitoring the behavior and location of injected CO_2; and, in the case of CO_2 utilization through enhanced oil recovery, producing hydrocarbons from the injection zone. The purpose of this report is to share lessons learned regarding site-specific management activities for carbon storage well systems. This manual builds on the experiences of the [RCSPs] and acquired knowledge from the petroleum industry and other private industries that have been actively drilling wells for more than 100 years. Specifically, this manual focuses on management activities related to the

planning, permitting, design, drilling, implementation, and decommissioning of wells for geologic storage projects. A key lesson and common theme reiterated throughout the seven DOE [BPMs] is that each project site is unique. This means that each CCS project needs to be designed to address specific site characteristics, and should involve an integrated team of experts from multiple technical (e.g., scientific and engineering) and nontechnical (e.g., legal, economic, communications) disciplines. Additionally, works during the characterization, siting, and implementation phases of projects are iterative; the results from previously completed tasks are analyzed and used to make decisions going forward. This means that as data comes in, the conceptual model of the site is revised and updated to allow better future decisions." The complete NETL BPM is available for download at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf.

"Induced Seismicity Potential in Energy Technologies (2012)." The following is a brief background on this National Academy of Sciences Report: "In the past several years, some energy technologies that inject or extract fluid from the Earth, such as oil and gas development and geothermal energy development, have been found or suspected to cause seismic events, drawing heightened public attention. Although only a very small fraction of injection and extraction activities among the hundreds of thousands of energy development sites in the United States have induced seismicity at levels noticeable to the public, understanding the potential for inducing felt seismic events and for limiting their occurrence and impacts is desirable for state and federal agencies, industry, and the public at large. To better understand, limit, and respond to induced seismic events, work is needed to build robust prediction models, to assess potential hazards, and to help relevant agencies coordinate to address them." The complete version is available for download at: http://dels.nas.edu/Report/Induced-Seismicity-Potential-Energy-Technologies/13355.

"North American Carbon Storage Atlas." The following is the Foreword of this document: "NRCan, the Mexican Ministry of Energy (SENER), and U.S. DOE are proud to release NACSA, which was produced under the leadership of NACAP. Production of this Atlas is the result of cooperation and coordination among carbon storage experts from local, state, provincial, and Federal government agencies, as well as industry and academia. This Atlas provides a coordinated overview of CCS potential across Canada, Mexico, and the United States. The primary purpose of the Atlas is to show the location of large stationary CO_2 emission sources and the locations and storage potential of various geological storage sites. This Atlas is a first attempt at providing a high-level overview of the potential for large-scale carbon storage in North America." The Atlas is available for download at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/NACSA2012.pdf.

"Carbon Dioxide Enhanced Oil Recovery: A Critical Domestic Energy, Economic, and Environmental Opportunity." The following is from the Introduction of this document: "…CO_2-EOR offers a safe and commercially proven method of domestic oil production that can help the United States simultaneously address three urgent national priorities: [1] Increasing [the Nation's] energy security by reducing dependence on foreign oil, often imported from unstable and hostile regimes; [2] Supporting job creation, increasing tax revenue, and reducing [the Nation's] trade deficit by keeping dollars now spent on oil imports [in the United States] and at work in the U.S. economy; and [3] Protecting the environment by capturing and storing CO_2 from industrial facilities and power plants, while getting more American crude from areas already developed for oil and gas production. A largely unheralded example of American ingenuity, CO_2-EOR was pioneered in West Texas in 1972 as a way to sustain oil production in otherwise declining oil fields. It works by injecting CO_2 obtained from natural or man-made sources into existing oil fields to free up additional crude oil trapped in rock formations. In this way, CO_2- EOR can significantly extend the lifespan and revitalize production of mature oil fields in the United States. Today, over 3,900 miles of pipelines in the United States annually transport approximately 65 million tons of CO_2 that the oil industry purchases for use in EOR, producing 281,000 barrels of domestic oil per day, or six percent of U.S. crude oil production." The report is available at: http://www.pewclimate.org/docUploads/EOR-Report.pdf.

July 2012

"Carbon Storage Systems and Well Management Activities." The following is from the Executive Summary of this document: "The purpose of this report is to share lessons learned regarding site-specific management activities for carbon storage well systems. This manual builds on the experiences of the [RCSPs] and acquired knowledge from the petroleum industry and other private industries that have been actively drilling wells for more than 100 years. Specifically, this manual focuses on management activities related to the planning, permitting, design, drilling, implementation, and decommissioning of wells for geologic storage projects. A key lesson and common theme reiterated throughout the seven DOE [BPMs] is that each project site is unique. This means that each CCS project needs to be designed to address specific site characteristics, and should involve an integrated team of experts from multiple technical (e.g., scientific and engineering) and nontechnical (e.g., legal, economic, communications) disciplines. Additionally, works during the characterization, siting, and implementation phases of projects are iterative; the results from previously completed tasks are analyzed and used to make decisions going forward. This means that as data comes in, the conceptual model of the site is revised and updated to allow better future decisions." The BPM is available for download at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf.

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"A Benefits Analysis of the Existing Plants Emissions and Capture (EPEC) Program." The following is from the Executive Summary of this document: "The overall goal of NETL's Existing Plants, Emissions, and Capture (EPEC) program is to develop carbon CCUS technologies that limit the increase in the cost of electricity generation to 35 percent of that generated by an equivalent greenfield plant without CCUS. If this goal is achieved and a climate change policy is enacted, this study estimates that the EPEC program could significantly benefit the [Nation's] economy, environmental quality, and energy security." The report is available at: http://www.netl.doe.gov/energy-analyses/pubs/EPECBenefitsAnalysisReport.pdf.

"U.S.-Canada Clean Energy Dialogue Action Plan II." The following is from the document: "Canada and the United States have a strong bilateral energy relationship. Energy fuels [Canadian and U.S.] prosperity, secures [Canadian and U.S.] future, and challenges [Canada and the United States] to reduce its effects on global climate change. The U.S.-Canada CED began in 2009 to strengthen bilateral collaboration on clean energy technologies and seek solutions for reducing GHG emissions to accelerate the transition to a low-carbon economy. Today, [Canadian and U.S.] responses to climate change are more coordinated. [Canadian and U.S.] emission reduction targets are aligned. [Canada and the United States] are pursuing North American standards for vehicles. [Canada and the United States] continue to share a common vision of a low-carbon North American economy powered by clean energy. Action Plan II describes initiatives that CED Working Groups plan to implement under Phase II of the CED to further progress toward a low-carbon economy that enhances energy security and revitalizes our economies

through the creation of clean energy jobs." The Action Plan is available at: http://energy.gov/sites/prod/files/CED%20Action%20Plan%20II_June%2012%202012.pdf.

"Biomass with CO_2 Capture and Storage (Bio-CCS)." The following is from the body of this document: "In short, there is now an urgent need for carbon-negative solutions, i.e. systems that *remove* CO_2 from the atmosphere. Indeed, Bio-CCS – the combination of CCS with sustainable biomass conversion – is the only large-scale technology that can achieve net negative emissions (in addition to any emissions reductions achieved by replacing fossil fuels with that biomass). This has already been [recognized] at an international level, e.g. in the [Intergovernmental Panel on Climate Change's (IPCC)] Special Report on Renewable Energy Sources and Climate Change Mitigation and in the Technology Roadmap Carbon Capture and Storage in Industrial Applications jointly published by the IEA and the United Nations Industrial Development Organization (UNIDO). Bio-CCS has already entered the European policy debate: the EU Energy Roadmap 205010 not only confirms that 'For all fossil fuels, [CCS] will have to be applied from around 2030 onwards in the power sector in order to reach [decarbonization] targets, it also [recognizes] that CCS "combined with biomass could deliver "carbon negative" values.'" The document is available at: http://bellona.org/ccs/uploads/tx_weccontentelements/filedownload/EBTP__ZEP_Report_Bio-CCS_The_Way_Forward.pdf.

August 2012

"Carbon Capture and Storage Legal and Regulatory Review – Edition 3." The following is from this document: "The International Energy Agency (IEA) considers CCS a crucial part of worldwide efforts to limit global warming by reducing GHG emissions. The IEA estimates that emissions can be reduced to a level consistent with a 2°C global temperature increase through the broad deployment of low-carbon energy technologies – and that CCS would contribute about one-fifth of emission reductions in this scenario. Reaching that goal, however, requires that approximately 100 CCS projects be implemented by 2020 and over 3,000 by 2050. Achieving such rapid expansion requires that regulatory frameworks, or a lack thereof, do not unnecessarily impede environmentally safe demonstration and deployment of CCS, so in 2008 the IEA established the IEA International CCS Regulatory Network (Network) as a forum for sharing knowledge amongst regulators and policy makers. This publication, the IEA *Carbon Capture and Storage Legal and Regulatory Review (CCS Review)*, was launched in October 2010 in response to a suggestion made at the Network's second meeting that the IEA produce a regular review of CCS regulatory progress worldwide. The *CCS Review* aims to help countries develop their own regulatory frameworks by documenting and analyzing recent CCS legal and regulatory developments. It also identifies steps taken towards the legal and regulatory goals in the 2009 IEA *Technology Roadmap: Carbon capture and storage*. The *CCS Review* is produced approximately every 12 months, to provide an up-to-date snapshot of CCS regulatory developments in contributing jurisdictions." The full IEA publication is available at: http://www.iea.org/publications/freepublications/publication/CCS_Review_3rd%20edition_FINAL.pdf.

"Carbon Storage Systems and Well Management Activities." The following is from the Executive Summary of this document: "The purpose of this report is to share lessons learned regarding site-specific management activities for carbon storage well systems. This manual builds on the experiences of the Regional Carbon Sequestration Partnerships and acquired knowledge from the petroleum industry and other private industries that have been actively drilling wells for more than 100 years. Specifically, this manual focuses on management activities related to the planning, permitting, design, drilling, implementation, and decommissioning of wells for geologic storage projects. A key lesson and common theme reiterated throughout the seven DOE [BPMs] is that each project site is unique. This means that each CCS project needs to be designed to address specific site characteristics, and should involve an integrated team of experts from multiple technical (e.g., scientific and engineering) and nontechnical (e.g., legal, economic, communications) disciplines. Additionally, works during the characterization,

siting, and implementation phases of projects are iterative; the results from previously completed tasks are analyzed and used to make decisions going forward. This means that as data comes in, the conceptual model of the site is revised and updated to allow better future decisions." The complete NETL BPM is available for download at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf.

"Global Status of Large-Scale Integrated CCS Projects: June 2012 Update." The following is the Introduction of this document: "The Global CCS Institute tracks the global status of large-scale integrated CCS projects (LSIPs), through a regular review of news reports and updates from Institute representatives around the world. The public data set on LSIPs, maintained by the Institute, is amended on a weekly basis to reflect changes to the status and details of projects. The Institute is currently [finalizing] its 2012 Annual Survey of LSIPs... The purpose of this paper is to [summarize] the present status of LSIPs and provide information on changes that have occurred since the publication of the Institute's *December 2011 Update.* Additional charts are provided in Appendix 1, and all changes made to the Institute's LSIP listing since the release of the *Global Status of CCS: 2011* report in October 2011 are listed in Appendix 2." The complete document is available for download at: http://cdn.globalccsinstitute.com/sites/default/files/publications/41146/globalstatusoflargescaleintegratedprojectsjune2012update.pdf.

"Our future is carbon negative: A CCS roadmap for Romania." The following is from the Executive Summary of this document: "Implementing a cost effective and reliable energy system has many challenges, including energy security, technology choice, utilization of indigenous resources and transnational cooperation. The added requirement of meeting the ever-tightening CO_2 emissions of the European Trading Scheme (ETS) adds to these challenges. Policy choices taken today will affect the development of the wider economy for at least a generation. This report assesses these interlinking factors, and provides stakeholders with an insight into future possible liabilities, opportunities, costs and risks. The document proposes specific recommendations on how to limit such risks and secure a cost-effective energy supply for the future. The report also assesses the impact of climate change legislation on major Romanian industries, cataloguing emissions, CCS applicability and actions necessary." The full report is available for download at: http://cdn.globalccsinstitute.com/sites/default/files/publications/41086/fil-romania-final2-opt.pdf.

"Valuation of Potential Risks Arising from a Model, Commercial-Scale CCS Project Site." The following is the Abstract of this document: "A diverse group of organizations from industry, government, and the environmental community jointly sponsored Industrial Economics (IEc), an expert in environmental economics and natural resource damage assessment, to develop and test a model approach for valuing the economic damages arising from a well-sited and well-managed CCS project. These damages included environmental and human health impacts arising from a range of potential events such as pipeline ruptures and subsurface [release]. They do not address potential impacts from facility construction or routine operation, nor do they address potential impacts to workers, business interruption, facility repair or similar 'private' costs internal to the operator. The model was successfully developed and applied to a 'realistic' project based on the publicly available risk assessment for a site from the FutureGen 1.0 site selection process. The project was planned to inject 50 million metric tons of CO_2 over 50 years and to have a 50 year post-injection period (for a 100-year analysis period). This site-specific application of the model showed that the 'most likely' (50^{th} percentile) estimated damages arising from CO_2 totaled approximately $7.3 million and 'upper end' (95th percentile) estimated damages totaled approximately $16.9 million. On a per metric ton basis, these results translate into 'most likely' (50^{th} percentile) estimated damages of $0.15 per metric ton and 'upper end' (95^{th} percentile) estimated damages of $0.34 per metric ton. When combined, the estimated damages for CO_2 and hydrogen sulfide (H_2S) were roughly 10-15 [percent] higher. It is important to note that the range of damage estimates is highly sensitive to site-specific data. The sponsor group concludes that the tools exist to estimate prospective financial damages. Further, the sponsor group has developed insight into the magnitude and timing of dollar amounts that are likely to be at risk and the conditions under which they may be at risk at

a well-selected and well-managed CCS project. This analytic approach is based on generally accepted practices within the financial and insurance industries, and can be applied, with adjustment for location, to CCS projects around the world." To download the full report, go to: http://cdn.globalccsinstitute.com/sites/default/files/publications/40831/iec2012valuationofpotentialrisks.pdf.

"Project Pioneer: Transporting CO_2: A non-confidential report." The following is from the Introduction to the project: "Project Pioneer would have been one of the first CCS projects to utilize an integrated approach for CCS, and was expected to serve as a prototype for the long-term, commercial-scale application and integration of CCS technologies to achieve reductions in [GHG] emissions. The partners in Project Pioneer were TransAlta Corporation (TransAlta), Capital Power L.P. (CPLP), Enbridge Inc. (Enbridge), the Alberta provincial and Canadian federal governments, and the Global CCS Institute as a Knowledge Sharing Partner. Project Pioneer was proposed to capture 1 million metric tons of CO_2 annually from a coal fired power plant and transport the CO_2 by pipeline to a [storage] site or to be utilized for EOR in a depleted oil/gas field. The key components of Project Pioneer were: carbon capture facility (CCF), pipeline from the CCF to the [storage] site, pipeline from the CCF to the EOR site, [and] saline formation [storage] site." The full document is available at: http://cdn.globalccsinstitute.com/sites/default/files/publications/40766/nonconfidentialreporttransportingco22012-opt.pdf.

Legislative

September 2011

***Platts*, "Illinois Governor Signs CO_2 Legislation to Aid Pipeline Projects."** Illinois has approved legislation that aids plans by Denbury Resources to construct a pipeline to transport CO_2 from several proposed clean coal plants across the state. Similar legislation enabling CO_2 pipeline developers to obtain property rights for their projects have already been approved by neighboring states Indiana and Kentucky. The provisions in the bills allow Denbury Resources to move forward with plans to build a 700-mile-long pipeline that would carry CO_2 from several plants in Illinois, Indiana, and possibly Kentucky to the Gulf Coast for enhanced oil recovery (EOR). To view S.B. 1821, "The Carbon Dioxide Transportation and Sequestration Act," go to: http://www.ilga.gov/legislation/fulltext.asp?DocName=&SessionId=84&GA=97&DocTypeId=SB&DocNum=1821&GAID=11&LegID=57876&SpecSess=&Session=. August 24, 2011, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Coal/6408491.

October 2011

***MarketWatch*, "Australia's Carbon Tax Gets Green Light,"** and ***Nasdaq*, "Australia's Lower House Passes Carbon Pricing Bill."** A plan to price carbon emissions passed through the lower house of the Australian parliament on Wednesday, October 12. The plan would allow the government to price CO_2 emissions by Australia's largest carbon emitters in an attempt to limit emissions. According to officials, the legislation is expected to encourage investment, estimated at $101.7 billion, in clean and renewable energy; provide assistance to several affected industries; and other areas. Under the legislation, the nation's 500 biggest carbon emitters will be subject to an initial fixed carbon price of $23.4 per tonne tax beginning in July 2012. The package will eventually transition to an emissions-trading scheme with a floating price in 2015. The package will now be debated in the upper house Senate. October 11, 2011, http://www.marketwatch.com/story/australias-carbon-tax-gets-green-light-2011-10-11, and October 12, 2011, http://www.nasdaq.com/aspx/stock-market-news-story.aspx?storyid=201110112209dowjonesdjonline000472&title=update-australias-lower-house-passes-carbon-pricing-bill.

November 2011

***BNA.com*, "Senate Passes Bill to Allocate $2 Billion for Carbon Storage, Fund Climate Service."** A fiscal 2012 spending bill that allots $2 billion for CCS projects and provides $161.5 million to the National Oceanic and Atmospheric Administration (NOAA) climate service has been approved by the Senate and will go back to the House for consideration. The spending bill (H.R. 2112) would provide funding for the Department of Agriculture (DOA), the Department of Commerce (DOC), and the Department of Transportation (DOT), as well as other Federal departments, through September 30, 2012. Up to $2 billion in CCS funding was added to the measure in October for the construction, acquisition, or improvement of coal-fired and other fossil fuel-fired, electricity-generating plants that capture and store their CO_2 emissions. To view H.R. 2112, visit: http://www.govtrack.us/congress/billtext.xpd?bill=h112-2112. November 2, 2011, http://www.bna.com/senate-passes-bill-n12884904101/.

December 2011

***The State Column*, "State Rep. Jerome Delvin Introduces Bill to Streamline Greenhouse Gas Reporting."** A bill to align Washington state's GHG reporting requirements with those of the Federal government has been introduced. Washington state currently requires all businesses that emit 10,000 MT CO_2 equivalent or more per year to report, while the Federal threshold is 25,000 MT CO_2 equivalent per year. In 2008 and 2010, the Washington Legislature passed two bills authorizing the state's GHG reporting program and directing the Department of Ecology to recover the costs of collecting, storing, and reporting certain information. The first set of fees would be collected after the series of reports have been submitted in 2013. However, the newly introduced S.B. 5999 would eliminate the need for the fee by allowing business to file a single Federal report and give a copy to the state, effectively removing state GHG reporting requirements and requiring anyone reporting GHGs to the U.S. Environmental Protection Agency (EPA) to also submit the report to the Department of Ecology. In addition, the bill would remove all language, as well as the fees, regarding state rules for reporting GHGs, and revise the requirement for the Department of Ecology to share state GHG reports to sharing the EPA GHG reports with the local air authority where the reporting entity operates. To view S.B. 5999, visit: http://apps.leg.wa.gov/billinfo/summary.aspx?bill=5999. December 14, 2011, http://www.thestatecolumn.com/washington/state-rep-jerome-delvin-introduces-bill-to-streamline-greenhouse-gas-reporting/.

January 2012

***University College London Carbon Capture Legal Programme*, "CCS Gains CDM Eligibility at COP17."** An executive board with the Kyoto Protocol has adopted draft modalities and procedures for CCS, allowing CCS projects to be eligible under the Clean Development Mechanism (CDM). Any outstanding issues associated with including CCS in the CDM will be addressed by the Subsidiary Body for Scientific and Technological Advice (SBSTA). The CDM allows emission reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one metric ton of CO_2. These CERs can be traded and sold and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. The final draft of the modalities and procedures adopted by the CMP is available at the Global CCS Institute website at: http://www.globalccsinstitute.com/sites/default/files/campaign/25936/files/111209-sbsta-recommendation-ccs-cdm.pdf. December 9, 2011, http://www.ucl.ac.uk/cclp/ccsnews.php?rn=1312.

February 2012

***Billings Gazette*, "Wyoming Lawmakers Want State Regulation of Gases,"** and ***The Republic*, "Wyoming Legislative Committee Moves Toward State Regulation of Greenhouse Gases."** The Wyoming Legislature's Joint Minerals, Business, and Economic Development Interim Committee has endorsed a bill authorizing the Wyoming Department of Environmental Quality to begin drafting regulations that would amend the Wyoming Clean Air Act to give the state primacy over GHGs that otherwise would be regulated by the U.S. Environmental Protection Agency (EPA). The Federal government has been regulating GHGs in Wyoming since 2000, when the Legislature adopted a policy that the state wouldn't regulate GHGs; currently, Wyoming only regulates non-GHGs. Wyoming cannot begin regulating GHGs until the Legislature gives its approval, or until a Federal court rules on Wyoming's claims in a pending lawsuit against EPA. February 11, 2012, http://billingsgazette.com/news/state-and-regional/wyoming/wyoming-lawmakers-want-state-regulation-of-gases/article_43b2f569-4f3d-5d07-ab1e-73e7b32a3231.html, and February 11, 2012, http://www.therepublic.com/view/story/cd2bafdb7113413b983249caf10b0642/WY--Greenhouse-Gases/.

March 2012

***National Enhanced Oil Recovery Initiative Press Release*, "Enhanced Oil Recovery Plan Draws Bipartisan Welcome in Congress."** Recommendations have been released by the National Enhanced Oil Recovery Initiative (NEORI) calling for Federal and state incentives to stimulate the expansion of EOR using CO_2 from power plants and industrial facilities. In the practice of CO_2-EOR, which represents six percent of current U.S. domestic oil production, oil producers inject CO_2 into wells to draw more oil to the surface. However, limited supplies of CO_2 constrain the expansion of EOR – an issue that NEORI's recommendations attempt to address. The centerpiece of the recommendations is a Federal tax incentive focused on companies that capture and transport CO_2. According to NEORI estimates, the tax credit, which would be administered by the U.S. Treasury Department, would quadruple U.S. oil production from EOR to 400 million barrels per year, while reducing CO_2 emissions by 4 million tons over the next 40 years. In addition, NEORI calculates that the program would produce a net return of $100 billion of 40 years, and reduce the trade deficit by saving the United States approximately $610 billion on imported oil over the same time period. February 28, 2012, http://neori.org/press-release-feb28/.

April 2012

***Senator Bingaman Press Release*, "Bingaman Bill Drives Cleaner Electricity Generation in America's Power Sector."** On March 1, 2012, U.S. Senator Jeff Bingaman introduced the Clean Energy Standard Act of 2012 (CES). The legislation emphasizes a market-based approach for a wide variety of electricity-generating technologies. The CES sets a national grid for clean energy and establishes a transparent framework for resources to compete. Under the plan, all generators of clean energy are given credits based upon their carbon emissions; to be considered "clean," a generator must be either a zero-carbon energy source or have lower carbon intensity than a modern, efficient coal plant. Allowing a wide variety of sources to be used to meet the standard enables market forces to determine the optimal mix of technologies and fuels, making it easier for new technologies to be incorporated. In addition, the CES also rewards industrial efficiency, as combined heat and power units are treated as clean generators, helping deploy this kind of efficiency and provide another source of inexpensive, clean energy. To view the CES, go to: http://www.energy.senate.gov/public/index.cfm/files/serve?File_id=b3580f37-ec8c-4698-a635-3e19f9815b9a. March 1, 2012, http://bingaman.senate.gov/news/20120301-02.cfm.

May 2012

***Lexology*, "Carbon Sequestration Bill Advances in California Legislature,"** and ***California Current*, "Senate Panel Keep Carbon Capture and Sequestration Bill Alive."** The California Senate's

Committee on Environmental Quality unanimously approved SB 1139 (Carbon Capture and Storage Act of 2012) aimed at establishing a regulatory system for CCS plants in California by closing gaps in current state law. As drafted, the measure assigned three different agencies to develop regulations for various aspects of CCS: (1) the Fire Marshal would be in charge of pipelines carrying captured CO_2 from power plants to geological storage sites; (2) the Division of Oil, Gas, and Geothermal Resources would be in charge of regulating the underground injection of CO_2 when in conjunction with EOR; and (3) the California Air Resources Board would be responsible for developing methodology for determining how much emissions reduction credit should be granted for CCS operations. Under an Environmental Quality Committee amendment, the methodology would be due by January 1, 2015. To view SB 1139, go to: http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_1101-1150/sb_1139_cfa_20120413_121218_sen_comm.html. April 18, 2012, http://www.lexology.com/library/detail.aspx?g=aef932c3-a1c5-48fc-9dd7-6643446a3dd6, and April 20, 2012, http://www.cacurrent.com/storyDisplay.php?sid=6063.

June 2012

***Officer of Governor Matt Mead News Release*, "Governor Looks to Support CO_2 Pipeline Network."** Wyoming governor Matt Mead has opened discussions about a proposed statewide network of CO_2 pipeline corridors within Federal land boundaries that would protect open spaces and minimize environmental impacts. As a result of pre-approved corridors, permitting time would be shortened, allowing for EOR. Under current plans, pipeline corridors on Federal land are determined separately by the nine individual Wyoming BLM offices. Any proposal between Governor Mead and BLM would be reviewed and open to public comment, possibly becoming a Record of Decision to update each Resource Management Plan of the various Wyoming BLM offices. May 1, 2012, http://governor.wy.gov/media/pressReleases/Pages/GovernorLookstoSupportCO2.aspx.

***Oroville Mercury-Register*, "Oroville City Council Approves Plan to Reduce Greenhouse Gas Emissions."** Using a grant from the Strategic Growth Council, Oroville City Council (California) will develop a Climate Control Plan to comply with California legislation to reduce GHG emissions. The goal of Sustainable Community Planning Grants is to develop plans to reduce GHG emissions in compliance with Assembly Bill 32 and Senate Bill 375 for Sustainable Communities and Climate Protection. To view AB 32, go to: http://www.arb.ca.gov/cc/ab32/ab32.htm. To view SB 375, visit: http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080930_chaptered.pdf. May 16, 2012, http://www.orovillemr.com/news/ci_20634563/oroville-city-council-approves-plan-reduce-greenhouse-gas.

July 2012

***Department of Environmental Conservation Press Release*, "DEC Adopts Ground-Breaking Power Sector Regulations to Analyze Possible Environmental Impacts and Limit CO_2 Emissions from Power Plants."** New or expanding electric-generating facilities in New York will be required to evaluate the potential impacts on nearby environmental justice communities under new regulations adopted by the New York State Department of Environmental Conservation (DEC). The regulations require an environmental justice analysis in the siting of major electric-generating facilities. In addition, DEC also adopted regulations to limit CO_2 emissions from new electric-generating facilities and expansions at existing electric-generating facilities. The environmental justice regulations require applicants to evaluate the cumulative impact on air quality; evaluate the demographic, economic, and physical description of the community where the facility will be located, and compare and contrast to the county and adjacent communities; evaluate the environmental impacts of a proposed major electric-generating facility; and avoid, minimize, or offset any environmental impacts to the maximum extent. The CO_2 emission regulations set a CO_2 emission limit of 925 lbs/megawatt-hour (output-based limit) or 120 lbs/mmBtu (input-based limit) for most new or expanded baseload fossil fuel-fired plants; set a CO_2 emission limit of

1,450 lbs/megawatt-hour (output-based limit) or 160 lbs/mmBtu (input-based limit) for simple cycle combustion turbines; allow each facility's owner/operator to choose whether to comply with the relevant output- or input-based emission limits; provide for DEC to set case-specific CO_2 emission limits for certain power plants that fire non-fossil fuels; and require recordkeeping, monitoring, and reporting consistent with existing Federal and state regulations. The regulations were adopted by DEC as required by the Power NY Act of 2011, which was signed into law in August 2011. June 28, 2012, http://www.dec.ny.gov/press/83269.html.

August 2012

***Congressman Jim McDermott News Release*, "McDermott Bill: Addresses Climate Change, Protects Consumers and Reduces Deficit."** Congressman Jim McDermott has introduced a bill proposing an approach to reduce carbon emissions, titled, "The Managed Carbon Price Act of 2012" (MCP). The bill is an updated version of legislation introduced in 2009 that incorporates suggestions from the energy industry, environmental advocates, policy experts, and economists. MCP would create a market incentive to reduce carbon emissions by placing a price on emissions that would increase over time. Proceeds from MCP would go into a newly created Energy and Economic Security Trust Fund, with 25 percent of the revenue going towards deficit reduction and 75 percent going back to the public to offset any price increases. According to a recent report from the Brookings Institution, if the starting price were set at $15 per ton, MCP would raise an estimated $80 billion, rising to $170 billion in 2030 and $310 billion by 2050. Within 42 years of enactment, MCP would reduce CO_2 emissions by 80 percent of 2005 levels. To view the MCP fact sheet, click: http://mcdermott.house.gov/images/pdf/MCP%20-%20Fact%20Sheet%20final.pdf. The bill is available at: http://mcdermott.house.gov/images/pdf/MPC%20-%20Section-by-Section%20Final.pdf. August 2, 2012, http://mcdermott.house.gov/index.php?option=com_content&view=article&id=624:mcdermott-bill-addresses-climate-change-protects-consumers-a-reduces-deficit&catid=25:press-releases&Itemid=20.

Announcements

September 2011

The Carbon Sequestration Newsletter Annual Index. The Carbon Sequestration Newsletter Annual Index, covering the September 2010 to August 2011 issues of NETL's Carbon Sequestration Newsletter, is now available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/subscribe.html.

NATCARB Viewer Available. An updated and redesigned version of the National Carbon Sequestration Database and Geographic Information System (NATCARB) was launched on the NETL website. The interactive online tool integrates a wealth of information about worldwide efforts to deploy CCS technologies. The tabs within NATCARB open different maps for query and analysis capabilities, including an (1) RCSP tab; (2) ATLAS tab; (3) FIELD PROJECTS tab; and (4) Worldwide CCS (WCCS) projects tab. The NATCARB Viewer is accessible from: http://www.netl.doe.gov/technologies/carbon_seq/natcarb/index.html.

October 2011

New UK CCS Training Academy Announced. CCS TLM and The National Center for CCS (NCCCS) have launched an academy offering training courses in CCS. The academy will develop and run a series of short (2-3 days) training courses aimed at improving knowledge and understanding of the CCS business. The courses will be aimed at personnel in industry and other stakeholders who may be involved in CCS in the future, or those who need to have a technical overview about CCS but are unable

to undertake lengthy periods of training. The first academy is planned for early December 2011. For more information, visit: http://www.ccstlm.com/news.aspx?id=162.

New GHG Measurement Standards Released. On October 4, 2011, the *Greenhouse Gas Protocol (GHG Protocol)* launched two new standards that allow businesses to better measure, manage, and report their greenhouse gas emissions. Developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), the Corporate Value Chain (Scope 3) and Product Life Cycle Standards enable companies to save money, reduce risks, and gain competitive advantage. The standards are available at: http://www.wri.org/publication/greenhouse-gas-protocol-corporate-value-chain-accounting-and-reporting-standard and http://www.wri.org/publication/greenhouse-gas-protocol-product-life-cycle-accounting-and-reporting-standard, respectively.

November 2011

EPA Issues First GHG Permit in Texas. The Lower Colorado River Authority (LCRA) Thomas C. Ferguson Power Plant has been issued the U.S. Environmental Protection Agency's (EPA) first Texas GHG permit. The LCRA is replacing its old unit with a new natural gas powered unit. LCRA is the first company in Texas to complete the GHG permitting process, which began in January 2011 after EPA finalized national GHG regulations specifying that projects increasing their GHG emissions would require a permit. To learn more, click: http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/074af11b53976c6c85257944005ad79c!OpenDocument.

RGGI Secondary Market Report Now Available. According to the Regional Greenhouse Gas Initiative's (RGGI) "Report on the Secondary Market for RGGI CO_2 Allowances: Third Quarter 2011," which is now available, 99 percent of RGGI CO_2 allowances are currently held by electricity generators and their corporate affiliates. The report, covering the period from July to September 2011, also states that secondary market CO_2 allowance prices remained stable through the third quarter, ranging from $1.85 to $1.89 (the auction reserve price). The complete report is available at: http://www.rggi.org/docs/Market/MM_Secondary_Market_Report_2011_Q3.pdf.

December 2011

Carbon Capture Trial Begins in Western Australia. The Government of Western Australia's Department of Mines and Petroleum (DMP) announced that drilling will commence in early 2012 at Harvey 1 Well in southwest Australia as part of the government's first onshore CCS trial project. The $8.5 million research project will also investigate underground heat for geothermal energy and assess water and other resources. To learn more about the 40-day drilling program, click: http://www.dmp.wa.gov.au/7105_14234.aspx.

CCS Network Announced. Nine environmental non-governmental organizations (NGOs) have formed the Environmental NGO Network on Carbon Capture and Sequestration (ENGO Network) with a mission of pursuing domestic and international policies, regulations, and initiatives that safely and efficiently enable CCS. For more information, visit: http://www.engonetwork.org/.

February 2012

"Valuation of Human Health and Ecological Risks Arising from Carbon Capture and Storage (CCS)."The following is from the Executive Summary of this document: "The public debate as it relates to carbon capture and storage [hereinafter, CCS] has been clouded by subjective perceptions of what is at risk, and whether the consequences of such risks are material from a financial perspective. In [the authors'] view, analytic evaluation of the range of potential impacts and calculation of the financial

consequences arising from CCS can illuminate the risks requiring mitigation, the dollar amounts that need to be managed, the set of circumstances under which amounts will present, and the time frame over which these dollars will be needed. Although the probability of a release at a well-sited, well-operated CCS project may be small, prudent risk management requires estimates of the dollars necessary to remediate or compensate for harm, should a release occur. Damages are a function of location, plant design, fuel source, and technology, and therefore must be estimated on a site-specific basis. With the availability of site-specific data, the analytic tools exist to estimate dollar values of potential damages at individual CCS sites." The complete Industrial Economics, Incorporated, report is available at: http://www.indecon.com/iecweb/documents/Valuation%20of%20CCS%20Risks.pdf.

FE Releases Newsletter. DOE's Office of Fossil Energy (FE) has released the latest edition of "Fossil Energy Today," a free quarterly digital newsletter that provides up-to-date information on important activities, progress, and other developments within FE. To download the latest edition, click: http://www.fossil.energy.gov/news/energytoday.html.

March 2012

Netherlands Storage Site Suitable for Carbon Capture. The EU announced that an approximately 1.9-mile deep storage site off the coast of the Netherlands is suitable for a carbon capture project. Under the European Energy Program for Recovery, the EU awarded the project $242 million in funding. To read the European Commission's statement, visit: http://ec.europa.eu/clima/news/articles/news_2012022901_en.htm. For more information, go to: http://www.bloomberg.com/news/2012-02-29/eu-says-netherlands-storage-site-is-suitable-for-carbon-capture.html.

Carbon Permits to Be Auctioned for Germany. The European Energy Exchange (EEX) won a tender to auction up to 85 million EUAs on behalf of Germany in the third phase (2013-2020) of the EU Emissions Trading Scheme (EU ETS). In the second phase (2008-2012), the majority of the carbon permits are free; beginning in 2013, approximately half of the EUAs will be sold via auctions. For more information, visit: http://www.reuters.com/article/2012/02/29/eex-carbon-idUSL5E8DT2J220120229.

April 2012

North American Partnership Launched. North America 2050: A Partnership for Progress (NA2050) was launched, facilitating state and provincial efforts to design, promote, and implement cost-effective policies that move their jurisdictions toward a low-carbon economy while simultaneously creating jobs, enhancing energy independence and security, protecting public health and the environment, and demonstrating climate leadership. To access NA2050, visit: http://na2050.org/.

CCS Research Center Launched. The Engineering and Physical Sciences Research Council (EPSRC) and DECC have established a CCS Research Center to support innovative research to maximize the contribution of CCS to a low-carbon energy system. Based at the University of Edinburgh, the new capture research facilities will include pilot-scale advanced testing facilities in Yorkshire, with a 1-tonne of CO_2 per day amine capture facility; a mobile testing unit to allow a range of tests to be conducted on real power station flue gases; and advanced oxy-fuel fluidized bed and chemical looping pilot facilities. For more information, visit: http://www.carboncapturejournal.com/displaynews.php?NewsID=923&PHPSESSID=sl01kmagthng0kc0qif34s9lb6.

May 2012

WRI Launches New CCS Regulatory Matrix. The World Resources Institute (WRI) launched a new online tool that compares CCS regulations, standards, and best practice guidelines. The CCS Regulatory Matrix is designed to enable decision-makers to quickly see how different frameworks deal with key issues, such as site selection/characterization requirements and long-term liability. To acces CCS Regulatory Comparison Matrix 2.0, click: http://www.wri.org/project/carbon-dioxide-capture-storage/proposal-matrix.

Global CCS Institute to Facilitate CCS Knowledge Sharing in Europe. The Global CCS Institute won a tender to provide secretariat and knowledge dissemination services for the European Commission's CCS Demonstration Project Network. The services, which began in March 2012 and will last four years, include coordination of network secretariat, communications activities, aggregation and dissemination of data, and meeting facilitation. For more information, visit: http://www.carboncapturejournal.com/displaynews.php?NewsID=937.

June 2012

NETL Paper Released: *NEMS-CCUS: A Model and Framework for Comprehensive Assessment of CCUS and Infrastructure*. This paper presents a recent application of the NETL-funded NEMS-CCUS (National Energy Modeling System) Model that enables the simulation of CO_2 pipelines and pipeline networks across the 48 contiguous states. The model was used to assess the role of CO_2 capture, utilization, and storage in both carbon tax and clean energy standard (CES) cases. The paper is available at: http://www.netl.doe.gov/energy-analyses/pubs/CMTC150377.pdf.

DOE's Assistant Secretary for Fossil Energy Discusses CCUS. Charles McConnell, DOE's Assistant Secretary for Fossil Energy, discussed CCUS in an online interview with Platts TV. To view a video of the interview, visit: http://www.plattsenergyweektv.com/video/default.aspx?bctid=1648563473001.

July 2012

North American Carbon Storage Atlas Released. DOE, with partners from Canada and Mexico, released NACSA, the first-ever atlas mapping the potential CO_2 storage resource in North America. According to NACSA, North America contains at least 500 years of geologic storage resource for CO_2 emissions that result from either industrial sources or power plants. To view the atlas, go to: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/NACSA2012.pdf. For more information on the North American Carbon Atlas Partnership (NACAP), visit: http://www.nacsap.org/. The NACSA Interactive Viewer is available at: http://gis.netl.doe.gov/NACAP/.

August 2012

DOE Advances Innovative CCS Polygeneration Plant. DOE and the California Energy Commission (CEC) are working together to advance an innovative CCS plant simultaneously through both the Federal National Environmental Policy Act (NEPA) review and a complementary California Energy Quality Act process. Part of DOE's Clean Coal Power Initiative (CCPI), the new polygeneration plant will incorporate CCS and utilize CO_2 for EOR. For more information on DOE's CCPI, visit: http://www.fossil.energy.gov/programs/powersystems/cleancoal/index.html.

DOE-Funded Project to Capture CO_2 Launched in Ohio. A novel method to capture CO_2 from flue gas and produce biofuels has been formally launched in the second phase of a DOE project at a nursery in Ohio. The successful application of the process could eventually help reduce GHG emissions and provide a source of liquid biofuels and biogas. More information is available at: http://www.fossil.energy.gov/news/techlines/2012/12035-Bioconversion_Pilot_Plant_Launched.html.

Latest Fossil Energy Today Newsletter Now Available. DOE's FE has released the latest edition of "Fossil Energy Today," a free quarterly digital newsletter that provides up-to-date information on important activities, progress, and other developments within FE. For subscription information and to download the latest issue, click: http://www.fossil.energy.gov/news/energytoday.html.

NETL Publication Earns National Communications Award. NETL received a National Association of Government Communicators (NAGC) 2012 first-place award for superior government communications for the *Carbon Sequestration Atlas of the United States and Canada (Atlas III).* The annual Blue Pencil & Gold Screen awards recognize communications pieces produced by government agencies that are particularly high quality and effective. Atlas III received top honors in the Technical or Statistical Report category. Atlas III can be viewed at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIII/2010atlasIII.pdf.

DOE Manual Features Strategies for Carbon Storage Wells. NETL released its latest best practices manual (BPM), titled, "Carbon Storage Systems and Well Management Activities." The BPM covers the planning, permitting, design, drilling, implementation, and decommissioning of CO_2 storage wells. The BPM is available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf.

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For more information on the Carbon Storage Program please visit:
http://www.netl.doe.gov/technologies/carbon_seq/index.html.