THE NETL CARBON SEQUESTRATION NEWSLETTER: ANNUAL INDEX

SEPTEMBER 2010 – AUGUST 2011

This is a compilation of the past year's monthly National Energy Technology Laboratory Carbon Sequestration Newsletter. The newsletter is produced by the NETL to provide information on activities and publications related to carbon sequestration. It covers domestic, international, public sector, and private sector news. This compilation covers newsletters issued from September 2010 to August 2011. It highlights the primary news and events that have taken place in the carbon sequestration arena over the past year. Information that has become outdated (e.g. conference dates, paper submittals, etc.) was removed.

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U.S. DEPARTMENT OF ENERGY

HIGHLIGHTS

September 2010

***Fossil Energy Techline*, "Federal Task Force Sends Recommendations to President on Fostering Clean Coal Technology."** The Interagency Task Force on Carbon Capture and Storage (CCS) delivered a series of recommendations for achieving the widespread, cost-effective deployment of CCS within 10 years to President Barack Obama on August 12, 2010. The report concludes that CCS technologies can be vital in reducing domestic greenhouse gas (GHG) emissions while preserving the option of using coal and other domestic fossil energy resources. The main findings of the report include: CCS is viable, a carbon price is critical, Federal coordination should be strengthened, and long-term liability could be a barrier to CCS deployment. The report contains input from 14 Federal agencies and departments, stakeholders, and CCS experts. In addition, the report addresses incentives for CCS adoption and a number of financial, economic, technological, legal, and institutional barriers to deployment; how best to coordinate existing Federal authorities and programs; and areas where additional Federal authority may be necessary. The task force was charged in February 2010 with proposing a plan to overcome the barriers to the widespread, cost-effective deployment of CCS within 10 years, and with a goal of bringing five to 10 commercial demonstration projects online by 2016. The Interagency Task Force on CCS is co-chaired by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA). (**See Recent Publications section for a portion of the Executive Summary and a link to the "Report of the Interagency Task Force on Carbon Capture and Storage."**) August 12, 2010, http://www.fossil.energy.gov/news/techlines/2010/10035-CCS_Task_Force_Issues_Report.html.

***Fossil Energy Techline*, "Department of Energy Announces 15 Projects Aimed at Secure Underground Storage of CO_2."** U.S. Energy Secretary Steven Chu announced the selection of 15 projects to develop technologies aimed at safely and economically storing carbon dioxide (CO_2) in geologic formations. The selections will receive $21.3 million over three years and will help reduce U.S. GHG emissions and develop and deploy near-zero-emission coal technologies. In addition, the projects will: (1) complement existing DOE initiatives to help develop the technology and infrastructure to implement large-scale CO_2 storage in different geologic formations across the Nation; and (2) complement ongoing efforts by developing and testing technologies that address critical challenges for geologic storage, including CO_2 injection, storage capacity, plume migration, and containment by caprock and other trapping mechanisms. August 11, 2010, http://www.fossil.energy.gov/news/techlines/2010/10034-DOE_Selects_CO2_Storage_Projects.html.

October 2010

***Fossil Energy Techline*, "DOE Regional Partnership Successfully Demonstrates Terrestrial CO_2 Storage Practices in Great Plains Region of U.S. and Canada."** The Plains CO_2 Reduction (PCOR) Partnership, one of seven U.S. Department of Energy (DOE) Regional Carbon Sequestration Partnerships (RCSPs), successfully completed a field test demonstrating approaches for terrestrial carbon dioxide (CO_2) storage in North America. The field test was conducted in the Prairie Pothole Region – an area that stretches from central Iowa into Northern Alberta, Canada, and contains thousands of shallow wetlands formed by retreating glaciers approximately 10,000 years ago. Terrestrial carbon capture and storage (CCS) involves plant removal of CO_2 from the atmosphere using photosynthesis and storing the greenhouse gas (GHG) in biomass and soils. Soil and gas samples from restored grasslands, native prairie, croplands, and wetlands throughout Montana, North and South Dakota, Minnesota, and Iowa were collected by participating organizations; carbon uptake and storage measurements were also measured to estimate the net change in GHG levels. The results will help to develop protocols for terrestrial carbon credit development and trading, as well as serve as a model for promoting and implementing terrestrial sequestration across the Prairie Pothole Region and other areas

of North America. The Prairie Pothole Region project is one of four small-scale validation tests (one terrestrial and three geologic) completed by the PCOR Partnership, which is currently conducting two large-scale geologic storage development tests. To learn more about the PCOR Partnership, click: http://www.undeerc.org/pcor/. August 19, 2010, http://www.netl.doe.gov/publications/press/2010/10037-DOE_Partner_Successfully_Demonstra.html.

***Fossil Energy Techline*, "Secretary Chu Announces Carbon Capture Storage Simulation Initiative,"** and ***Fossil Energy Techline*, "Secretary Chu Announces Simulation-Based Engineering User Center."** On September 8, 2010, U.S. Secretary of Energy Steven Chu announced the creation of the Carbon Capture and Storage Simulation Initiative with an investment of up to $40 million from the American Recovery and Reinvestment Act of 2009 (Recovery Act) to fund simulation and modeling activities at national laboratories and universities across the United States. The initiative will examine the following areas: (1) the development of validation data for simulations that predict processes and components associated with CO_2 capture at industrial facilities and long-term CO_2 storage in geologic reservoirs; (2) development of advanced simulation tools to speed the path from concept to deployment of new methods for capturing CO_2 at a variety of industrial facilities; and (3) development of simulation tools for quantitative assessment of potential risks associated with long-term storage. These efforts will build upon the efforts of DOE's National Risk Assessment Partnership (NRAP) and the Administration's goal to overcome the barriers to widespread, cost-effective deployment of CCS within 10 years. In addition, on September 16, 2010, Energy Secretary Chu announced the creation of the Simulation-Based Engineering User Center (SBEUC) to facilitate computational research for energy applications with $20 million in Recovery Act funding. The SBEUC will (1) develop a high performance computing user center as a platform for utilization of the advanced simulation tools, and (2) accelerate the deployment of industrial carbon capture technology through enhanced ability to predict industrial-scale performance. For more information on DOE's Carbon Sequestration Research Program, click: http://www.fossil.energy.gov/programs/sequestration/index.html. September 8, 2010, http://www.fossil.energy.gov/news/techlines/2010/10043-DOE_Announces_CCS_Simulation_Initi.html, and September 16, 2010, http://www.fossil.energy.gov/news/techlines/2010/10045-DOE_Creates_SBEUC.html.

***Fossil Energy Techline*, "New Recovery Act Funding Boosts Industrial Carbon Capture and Storage Research and Development."** Twenty-two projects have been selected to receive funding from the Recovery Act to accelerate CCS research and development (R&D) for industrial sources. The 22 projects, located in 15 states, will receive more than $575 million in Recovery Act funds to support President Barack Obama's goal of cost-effective CCS deployment within 10 years. The funding for the selected projects covers four areas of CCS R&D: (1) large-scale testing of advanced gasification technologies ($312 million); (2) advanced turbo-machinery to lower emissions from industrial sources ($123 million); (3) post-combustion CO_2 capture with increased efficiencies and decreased costs ($90 million); and (4) geologic storage site characterization ($50 million). To view the full list of selected projects, click: http://www.fossil.energy.gov/recovery/projects/iccs_projects_0907101.pdf. September 7, 2010,http://www.fossil.energy.gov/news/techlines/2010/10042-DOE_Announces_Industrial_CCS_Proje.html.

November 2010

***Fossil Energy Techline*, "'Sour' Gas Streams Safe for Carbon Sequestration, DOE-Sponsored Study Shows."** A field test completed by the Plains CO_2 Reduction (PCOR) Partnership, one of seven U.S. Department of Energy (DOE) Regional Carbon Sequestration Partnerships (RCSPs), produced results that show gas streams containing both carbon dioxide (CO_2) and hydrogen sulfide (H_2S) can be safely used for carbon capture and storage (CCS). The findings of PCOR's test, which also demonstrated that carbon storage using "sour" gas streams can be successfully combined with enhanced oil recovery (EOR) and H_2S disposal, will help support national and global efforts to develop and deploy CCS use as an option for mitigating potential climate change. During the four-year field test,

a gas stream (70 percent CO_2, 30 percent H_2S) was injected at a depth of 4,900 feet into the Zama oilfield in northwestern Alberta, Canada. Approximately 33,500 tons of sour gas was injected, simultaneously storing CO_2, disposing of H_2S, and increasing oil recovery. All of the project goals were achieved, including: demonstrating the safe and feasible (within existing industry and regulatory standards) capture and injection of a sour gas stream into properly characterized and selected underground reservoirs; designing, implementing, and demonstrating monitoring, verification, and accounting (MVA) strategies; and confirming that sour gas could be successfully used for EOR operations in a previously untested geologic feature. To learn more about DOE's RCSP Program, visit: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html. September 23, 2010, http://www.fossil.energy.gov/news/techlines/2010/10046-PCOR_Project_Demonstrates_Importan.html.

***Fossil Energy Techline*, "DOE Manual Studies 11 Major CO_2 Geologic Storage Formations."** DOE issued a new manual containing a comprehensive study of 11 geologic formations suitable for permanent underground CO_2 storage. The National Energy Technology Laboratory (NETL)-developed manual used data from DOE's RCSPs and other research activities to better understand the characteristics of geologic formations that could potentially be used for CCS. One of DOE's program goals is to identify geologic formations that can store large volumes of CO_2, receive CO_2 at an efficient and economic rate of injection, and safely retain it over long periods of time. These three criteria are investigated in the manual for 11 major geologic reservoirs. In addition, the manual builds on lessons learned from CO_2 behavior in geologic reservoirs during earlier investigations. To date, DOE's Carbon Sequestration Program has implemented 28 CO_2 injection field projects in conjunction with the RCSP Initiative, as well as an additional 10 site characterization projects funded through the Recovery Act. The information provided by the manual is expected to allow government agencies and their project partners and/or private investors to optimize their storage efforts. (**See Recent Publications section for a portion of the Executive Summary and a link to the "Geologic Storage Formation Classification: Understanding Its Importance and Impacts on CCS Opportunities in the United States."**)To learn more about DOE's Carbon Sequestration Research Program, click: http://www.fossil.energy.gov/programs/sequestration/index.html. October 5, 2010, http://www.fossil.energy.gov/news/techlines/2010/10050-Geologic_Storage_Manual_Issued.html.

***Fossil Energy Techline*, "FutureGen Industrial Alliance Announces Carbon Storage Site Selection Process for FutureGen 2.0,"** and ***NETL News Release*, "Department of Energy Formally Commits $1 Billion in Recovery Act Funding to FutureGen 2.0."** On October 6, 2010, the FutureGen Industrial Alliance announced details of a site selection process for an Illinois site to store CO_2 collected at FutureGen 2.0. The storage site will be designed to accept and store the 1.3 million metric tons per year of CO_2 captured at Ameren Energy Resources' Meredosia Plant for at least 30 years. The FutureGen Industrial Alliance has released its ~~"G~~uidance for Prospective Site Offerors" to provide a description of the site selection process and schedule, selection criteria, and type of site-related data and documentation to be provided by applicants. The Alliance plans to issue a Request for Proposals (RFP) in late 2010; the site selection decision will also consider factors ranging from protecting environmental resources and human health and safety; minimizing project costs; and supporting a design, construction, and operation schedule for the project. Following the site selection – expected in early 2011 – the FutureGen Alliance will prepare detailed environmental and technical information for the selected site to comply with the National Environmental Policy Act (NEPA) and its preparation of the Environmental Impact Statement (EIS). The siting guidance follows an announcement in September 2010 that DOE signed final cooperative agreements with the FutureGen Industrial Alliance and Ameren Energy Resources to commit $1 billion in American Recovery and Reinvestment Act of 2009 (Recovery Act) funding to construct FutureGen 2.0. The project partners estimate that FutureGen 2.0 will bring 900 jobs to downstate Illinois and another 1,000 jobs for suppliers across the state. For more information on FutureGen 2.0 Siting Guidance, go to: http://www.futuregenalliance.org/media/FGA_Guidance_100510_Final.pdf. October 6, 2010, http://www.fossil.energy.gov/news/techlines/2010/10051-FutureGen_Site_Selection_Process_A.html,

and September 28, 2010,
http://www.netl.doe.gov/publications/press/2010/10048-DOE_Formally_Commits_1_Billion_to.html.

December 2010

***Fossil Energy Techline*, "Third Carbon Sequestration Atlas Estimates Up to 5,700 Years of CO_2 Storage Potential in U.S. and Portions of Canada."** On December 1, the U.S. Department of Energy (DOE) released the ―Carbon Sequestration Atlas of the United States and Canada – Third Edition (Atlas III)," which documents 1,800 billion to more than 20,000 billion metric tons of carbon dioxide (CO_2) storage resource potential in saline formations, oil and gas reservoirs, and unmineable coal areas in the United States and portions of Canada. This suggests a potential 500 to 5,700 years of CO_2 storage resource in assessed geologic formations. In addition, Atlas III provides updates on Regional Carbon Sequestration Partnerships (RCSPs) activities, DOE's Carbon Sequestration Program, international carbon capture and storage (CCS) collaborations, worldwide CCS projects, CCS regulatory issues, and CO_2 stationary source emissions. The CO_2 storage resource calculation methodology of *Atlas III* was refined to better reflect uncertainties in geologic formation properties. Two versions of Atlas III are available: (1) an interactive version located at the National Carbon Sequestration Database and Geographic Information System (NATCARB) website (http://www.natcarb.org), and (2) a print version available for download at the NETL website (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIII/). (**See Recent Publications section for a portion of the Atlas III Foreword and a link to Atlas III)**. December 1, 2010, http://www.netl.doe.gov/publications/press/2010/10058-Third_Edition_of_Carbon_Sequestrat.html.

***Fossil Energy Techline*, "DOE-Sponsored Field Test Finds Potential for Permanent Storage of CO_2 in Lignite Seams."** The Plains CO_2 Reduction (PCOR) Partnership injected approximately 90 tons of CO_2 over two weeks into a 10- to 12-foot deep coal seam at an approximate depth of 1,100 feet in Burke County, North Dakota, in a DOE-sponsored field test, demonstrating that opportunities to address climate change by permanently storing CO_2 in unmineable coal seams of lignite may be more widespread than previously documented. The field test showed that the CO_2 did not significantly move from the wellbore and was contained within the coal seam for the duration of a three-month monitoring period. In addition, the PCOR Partnership evaluated a variety of carbon storage operation conditions to determine their applicability to similar coal seams, and investigated the feasibility of combining CO_2 storage with enhanced methane production. The results indicate that suitable lignite seams are potential targets for CCS, and that the combination of CO_2 storage and enhanced methane production has the potential to offer both a near-term economic return and a long-term environmental benefit. The successful injection and storage of CO_2 in this field test provides for similar CO_2 injection tests at a larger scale and longer duration. To learn more about DOE's RCSP Initiative, visit: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html, or click: http://www.undeerc.org/pcor/, for more information on the PCOR Partnership. November 4, 2010, http://www.fossil.energy.gov/news/techlines/2010/10054-Field_Test_Demonstrates_CO2_Storag.html.

***Fossil Energy Techline*, "New DOE-Sponsored Study Helps Advance Scientific Understanding of Potential CO_2 Storage Impacts."** A Duke University study, sponsored by DOE, has confirmed earlier research showing that proper site selection and monitoring is essential for helping anticipate and mitigate possible risks. The report, titled ―Potential Impacts of Leakage from Deep CO_2 Geosequestration on Overlying Freshwater Aquifers," presented the results of a year-long study in which researchers incubated core samples from a variety of freshwater formations with CO_2 for more than 300 days. The Duke research project, which also provides information that can be used for advanced detection of CO_2, is one of many DOE-sponsored projects that investigate the impact of CO_2 injection into geologic formations. To learn more about DOE's Carbon Sequestration Research Program, visit: http://www.fossil.energy.gov/programs/sequestration/index.html. November 30, 2010, http://www.fossil.energy.gov/news/techlines/2010/10057-Study_Helps_CCS_Understanding.html.

January 2011

***Carbon Sequestration Leadership Forum Press Release*, "Advancement of Carbon Capture and Storage Contingent on Addressing Key Issues."** According to a report released by the Carbon Sequestration Leadership Form (CSLF), significant international progress on advancing carbon capture and storage (CCS) has been made in the past year. The report, titled, "CSLF's 2010 Technology Roadmap," also states that a number of important challenges must be addressed in order for widespread commercial deployment to be achieved. In addition, the report notes that globally significant national investments are occurring to advance the deployment of CCS technologies. There are 32 active or completed CSLF-recognized projects that demonstrate worldwide collaboration on CCS and contribute to the CCS knowledge base. The CSLF is a 25-member, ministerial-level international climate change initiative focused on developing and deploying cost-effective CCS technologies worldwide. (**See Recent Publications section for a portion of the Introduction and a link to "CSLF's 2010 Technology Roadmap."**) To learn more about the 32 projects that demonstrate worldwide CCS collaboration, click: http://www.cslforum.org/projects/. December 2, 2010, http://www.cslforum.org/pressroom/publications/CSLF_Roadmap_Press_Release2.pdf.

February 2011

***Fossil Energy Techline*, "DOE 'Best Practices' Manual Focuses on Site Selection for CO_2 Storage."** The U.S. Department of Energy (DOE) released its latest carbon capture and storage (CCS) best practices manual (BPM), which focuses on the most promising methods for assessing potential carbon dioxide (CO_2) geologic storage sites. Developed by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL), the manual, titled, "Site Screening, Site Selection, and Initial Characterization for Storage of CO_2 in Deep Geologic Formations," will be used as a resource by future project developers and CO_2 producers and transporters. In addition, the BPM will be used to inform government agencies of the best practices for exploring potential CO_2 geologic storage sites and educate the public about the analyses being conducted. This is the fourth BPM released by DOE, and it provides a framework for reporting resources calculated using methods developed by DOE, the Carbon Sequestration Leadership Forum (CSLF), and others. This BPM focuses on the exploration phase of the site characterization process and communicates analyses and guidelines for narrowing potential sub-regions into qualified sites for CO_2 geologic storage. Development of the geologic storage system proposed in this BPM will be instrumental in establishing consistent, industry-standard terminology and guidelines for communicating storage resources and storage capacity estimates, as well as project risks, to stakeholders. (**See Recent Publications section for the Executive Summary and a link to the "Site Screening, Site Selection, and Initial Characterization for Storage of CO_2 in Deep Geologic Formations" BPM.**) January 5, 2011, http://www.fossil.energy.gov/news/techlines/2011/11002-Best_Practices_Manual_Released.html.

***Fossil Energy Techline*, "New Roadmap Updates Status of DOE Carbon Capture and Storage RD&D Efforts."** DOE published a new roadmap that provides an overview of research, development, and demonstration (RD&D) efforts to supply cost-effective, advanced CCS technologies for coal-based power systems. The "DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap" outlines the efforts to develop advanced CCS technology, as well as several technologies being pursued to mitigate risks inherent to RD&D efforts. DOE anticipates that an array of advanced CCS technologies will be ready for large-scale demonstration by 2020, providing safe, cost-effective carbon management to meet national goals for reducing greenhouse gas (GHG) emissions. Research success will enable CCS technologies to overcome a wide range of challenges, such as successful integration of CO_2 capture, compression, transport, and storage technologies with power generation systems; effective CO_2 monitoring, verification, and accounting (MVA); permanence of underground CO_2 storage; and public acceptance. (**See Recent Publications section for a portion of the Overview and a link to the "DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap."**) For more information on

DOE's Carbon Sequestration Research Program, visit: http://www.fossil.energy.gov/programs/sequestration/index.html. January 11, 2011, http://www.fossil.energy.gov/news/techlines/2011/11003-New_CCS_Roadmap_Released.html.

***Fossil Energy Techline*, "DOE Manual Studies Terrestrial Carbon Sequestration."** According to a BPM released by DOE, entitled, "Best Practices for Terrestrial Sequestration of Carbon Dioxide," there is considerable opportunity and growing technical sophistication to make terrestrial carbon storage both practical and effective. The BPM details the most suitable operational approaches and techniques for terrestrial CO_2 storage, which uses photosynthesis to create organic matter that is stored in vegetation and soils; this is different from CO_2 mitigation technologies that focus on capturing and permanently storing anthropogenic CO_2 emissions. NETL used data from the seven Regional Carbon Sequestration Partnerships (RCSPs) to prepare the BPM, which also discusses the analytical techniques necessary to monitor, verify, and account for terrestrially stored carbon. In addition, results from the RCSPs' terrestrial field projects are presented. The best practices outlined in this BPM will help those interested in pursuing terrestrial storage projects, as well as those interested in regulating them, to optimize their efforts. (**See Recent Publications section for the Introduction and a link to the "Best Practices for Terrestrial Carbon Sequestration" BPM.**) January 18, 2011, http://www.fossil.energy.gov/news/techlines/2011/11005-DOE_Publishes_Best_Practices_Manua.html.

March 2011

***Fossil Energy Techline*, "State Regulatory Framework Will Most Likely Result in Robust CO_2 Pipeline System, New Study Says."** According to a new report funded by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL), the approach most likely to result in a strong carbon dioxide (CO_2) pipeline system in the United States will be a private sector model with a state-based regulatory framework. However, the study also notes that a Federal role, which would encourage private construction of CO_2 pipelines through incentives, would also be important in the future. The report, titled, "A Policy, Legal, and Regulatory Evaluation of the Feasibility of a National Pipeline Infrastructure for the Transport and Storage of Carbon Dioxide," analyzes a potential pipeline network that would transport CO_2 from large CO_2 stationary sources to underground storage locations. A pipeline network is believed to be an important component to commercialize and deploy carbon capture and storage (CCS) technology to reduce the buildup of CO_2 in the atmosphere. The report, which was undertaken by the DOE-funded Pipeline Transportation Task Force (PTTF), was developed by the Southeast Regional Carbon Sequestration Partnership (SECARB), one of seven DOE Regional Carbon Sequestration Partnerships (RCSPs), and the Interstate Oil and Gas Compact Commission (IOGCC). The data collected for the report is expected to improve commercialization efforts by analyzing current CO_2 storage situations and identifying what is needed for viable transport to storage areas. (**See Recent Publications section for the Abstract and a link to "A Policy, Legal, and Regulatory Evaluation of the Feasibility of a National Pipeline Infrastructure for the Transport and Storage of Carbon Dioxide."**) February 1, 2011, http://www.fossil.energy.gov/news/techlines/2011/11007-New_Report_Analyzes_CO2_Pipeline_S.html.

April 2011

***Fossil Energy Techline*, "Carbon Capture and Storage Initiative Aims to Bring Technologies to Market Faster."** The Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL) is beginning research with numerous national laboratories, universities, and industry under the Carbon Capture and Simulation Initiative (CCSI) to develop state-of-the-art computational modeling and simulation tools to accelerate the commercialization of carbon capture and storage (CCS) technologies. CCSI will utilize a software infrastructure to accelerate the development and deployment of new, cost-effective CCS technologies. This will be achieved by identifying promising concepts through rapid computational screening of devices and processes; reducing the time and expense to design and

troubleshoot new devices and processes through science-based optimal designs; quantifying the technical risk in taking technology from laboratory- to commercial-scale; and quantifying deployment costs more quickly by replacing some of the tests with power plant simulations. Led by NETL, CCSI leverages the core strengths of the U.S. Department of Energy's (DOE) national laboratories in modeling and simulation and unites the best capabilities at NETL, Los Alamos National Laboratory (LANL), Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL), and Pacific Northwest National Laboratory (PNNL). For more information on DOE's Carbon Sequestration Research Program, visit: http://www.fossil.energy.gov/programs/sequestration/index.html. March 16, 2011, http://www.fossil.energy.gov/news/techlines/2011/11018-CCS_Initiative_Begins_Research.html.

***Fossil Energy Techline*, "Licensing Agreement Moves Two NETL-Patented Carbon Capture Sorbents Closer to Commercialization."** A licensing agreement between NETL and ADA Environmental Solutions (ADA-ES) has moved two new patented sorbents used for CO_2 capture from coal-fired power plants closer to commercialization. The first patent involves treating a solid substrate with an acid or a base and a substituted amine salt, eliminating the need for organic solvents and polymeric materials for the preparation of CO_2 capture systems. The second patent involves treating an amine to increase the number of secondary amine groups and impregnating the amine in a porous solid support. The method increases the CO_2 capture capacity and decreases the cost of utilizing an amine-enriched solid sorbent in CO_2 capture systems. The commercial license for these sorbents allows NETL to control the right to make, use, and sell the products and services claimed in the patent, ensuring strategic commercialization throughout the coal-fired power plant industry. March 23, 2011, http://www.fossil.energy.gov/news/techlines/2011/11019-CO2_Capture_Sorbents_Move_Closer_t.html.

May 2011

NETL Releases Updated Version of the Carbon Sequestration Website. The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) released a new, user-friendly version of the Carbon Sequestration Program website in early May. The Carbon Sequestration Program website contains both introductory and in-depth information about sequestration fundamentals, supporting technologies, sequestration applications, environmental benefits, and the status of the latest research and development (R&D) activities. In addition, the website, which is accessible from the NETL homepage, contains updated material on the program's Core R&D, Infrastructure, and Global Collaborations elements; a modified Frequently Asked Questions (FAQ) section; a section highlighting the National Carbon Sequestration Database and Geographic Information System (NATCARB); and an updated Reference Shelf. NETL's Carbon Sequestration Program is developing a technology portfolio of safe, cost-effective, commercial-scale carbon dioxide (CO_2) capture, storage, and mitigation technologies that will be available for commercial deployment beginning in 2020. The updated website can be viewed at: http://www.netl.doe.gov/technologies/carbon_seq/index.html.

June 2011

***Fossil Energy Techline*, "National Carbon Capture Center Launches Post-Combustion Test Center."** According to the U.S. Department of Energy (DOE), the recent successful commissioning of the Post-Combustion Carbon Capture Center (PC4) at the National Carbon Capture Center (NCCC) in Alabama will speed deployment of post-combustion carbon dioxide (CO_2) capture technologies for coal-based power plants. Initial testing began at the PC4 facility, which is located at the Alabama Power Gaston Power Plant Unit 5 (an 880-megawatt [MW] supercritical pulverized coal unit), when researchers used a monoethanolamine (MEA) solvent to capture CO_2 from a slipstream of flue gas from the plant. To date, the MEA solvent has exceeded the expected 90 percent CO_2 capture; the unit is now in steady operation, capturing approximately 10 tons of CO_2 per day. NCCC, a testing and evaluation center established by DOE in 2009, is operated and managed by Southern Company and works collaboratively with technology developers worldwide to test and evaluate both pre- and post-combustion CO_2 capture

technologies under realistic conditions. NCCC's goal is to accelerate development of these technologies and ensure continued use of coal for power generation. To learn more about NCCC, visit: http://www.nationalcarboncapturecenter.com/index.html. June 7, 2011, http://www.fossil.energy.gov/news/techlines/2011/11024-NCCC_Launches_Post-Combustion_Test.html.

July 2011

***Fossil Energy Techline*, "Redesigned CCS Website Offers Wealth of Information on Worldwide Technology, Projects."** An updated and redesigned version of the National Carbon Sequestration Database and Geographic Information System (NATCARB) was launched on the U.S. Department of Energy's National Energy Technology Laboratory (DOE/NETL) website. The interactive online tool integrates a wealth of information about worldwide efforts to deploy carbon capture and storage (CCS) technologies. The tabs within NATCARB open different maps for query and analysis capabilities: (1) the RCSP tab shows the seven Regional Carbon Sequestration Partnership (RCSP) regions and provides links to CCS projects undertaken by DOE's RCSP Initiative; (2) the ATLAS tab is the interactive version of data (carbon dioxide [CO_2] stationary sources, saline formations, oil and gas reservoirs, unmineable coal areas, and sedimentary basins) contained in the 2010 Carbon Sequestration Atlas of the United States and Canada - Third Edition (Atlas III); (3) the FIELD PROJECTS tab shows the locations of CCS field projects and provides links for more information on these small- and large-scale projects, including the 10 American Recovery and Reinvestment Act of 2009 (ARRA) site characterization projects; and (4) the WCCS tab shows a user-friendly world map with locations for all active, postponed, canceled, and terminated CCS projects. NATCARB is a geographic information system (GIS)-based tool developed to provide a view of CCS potential in the United States and portions of Canada. The updated NATCARB Viewer includes projects and information on the Carbon Sequestration Program's research and development (R&D) initiatives to advance geologic CO_2 storage toward commercialization. The information contained in NATCARB is current as of July 1, 2011, and will be updated quarterly. The NATCARB Viewer is accessible from: http://www.netl.doe.gov/technologies/carbon_seq/natcarb/index.html. June 28, 2011, http://www.fossil.energy.gov/news/techlines/2011/11029-Redesigned_NATCARB_Website_Launche.html.

***Fossil Energy Techline*, "Confirming CCS Security and Environmental Safety Aim of Newly Selected Field Projects."** On July 6, 2011, DOE announced the selection of three small-scale CO_2 injection field projects to collectively receive $34.5 million over four years. The total award value of the new projects, which aim to confirm that long-term geologic CO_2 storage is safe and environmentally secure, is more than $45 million, with approximately $10.5 million provided by the recipients. The three projects include: (1) Blackhorse Energy, LLC, plans to inject approximately 53,000 tons of CO_2 into a geologic formation located in Livingston Parish, Louisiana, to assess the suitability of strandplain geologic formations for future large-scale geologic CO_2 storage in association with enhanced oil recovery (EOR); (2) the University of Kansas Center for Research, Inc. will inject at least 70,000 metric tons of CO_2 into multiple formations to demonstrate the application of state-of-the-art monitoring, verification, and accounting (MVA) tools and techniques to monitor and visualize the injected CO_2 plume and establish best practice methodologies for MVA and closure in shelf clastic and shelf carbonate geologic formations; and (3) the Virginia Polytechnic Institute and State University will attempt to reduce uncertainty, test the properties of coal seams, and evaluate the potential for enhanced coalbed methane (ECBM) recovery by injecting approximately 20,000 tons of CO_2 into unmineable coalbeds. The data from these projects will be incorporated into NATCARB. July 6, 2011, http://www.fossil.energy.gov/news/techlines/2011/11032-DOE_Selects_CCS_Field_Projects.html.

August 2011

***NETL News Release*, "Projects Aimed at Advancing State-of-the-Art Carbon Capture from Coal Power Plants Selected for Further Development."**On August 15, 2011, the U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) selected four projects aimed at reducing the energy and cost penalties of advanced carbon capture systems applied to power plants for further development. The projects are valued at approximately $67 million (including $15 million in non-Federal cost sharing) over four years. The overall goal of the research is to develop carbon dioxide (CO_2) capture and separation technologies that can achieve at least 90 percent CO_2 removal at no more than a 35 percent increase in the cost of electricity. The projects, managed by FE's National Energy Technology Laboratory (NETL), include: (1) Linde, LLC, which will use a post-combustion capture technology incorporating BASF's novel amine-based process at a 1-megawatt electric (MWe) equivalent slipstream pilot plant at the National Carbon Capture Center (NCCC) (DOE contribution: $15 million); (2) Neumann Systems Group, Inc., which will design, construct, and test a patented NeuStreamTM absorber at the Colorado Springs Drake #7 power plant (DOE contribution: $7,165,423); (3) Southern Company, which will develop viable heat integration methods for the capture of CO_2 produced from pulverized coal (PC) combustion using a waste heat recovery technology (DOE contribution: $15 million); and (4) the University of Kentucky Research Foundation, which plans to use an innovative heat integration method that uses waste heat from a Hitachi H3-1 advanced solvent carbon capture system while improving steam turbine efficiency. (DOE contribution: $14,502,144). August 15, 2011, http://www.netl.doe.gov/publications/press/2011/110815_projects_aimed_at_advancing%20.html.

Sequestration in the News

September 2010

***Fossil Energy Techline*, "Secretary Chu Announces Six Projects to Convert Captured CO_2 Emissions from Industrial Sources into Useful Products."** DOE selected six projects that aim to find methods of converting CO_2 emissions captured from industrial sources into useful products, such as fuel, plastics, cement, or fertilizers. The projects, which will be funded with $106 million from the American Recovery and Reinvestment Act of 2009 (Recovery Act) and $156 million in private cost-share, were initially selected for first phase funding in October 2009 as part of a $1.4 billion effort to capture CO_2 from industrial sources for storage or beneficial use. After performing experiments on innovative concepts and producing preliminary designs, the projects now enter a second phase involving the design, construction, and operation of their innovations at pilot scale, as well as the evaluation of the technical and economic feasibility of commercial application. For more information on DOE's Carbon Sequestration Research Program, click: http://www.fossil.energy.gov/programs/sequestration/index.html. July 22, 2010, http://www.fossil.energy.gov/news/techlines/2010/10027-DOE_Announces_Six_Projects_to_Conv.html.

***Texas Clean Energy Project News Release*, "Summit Power Begins FEED Study for Texas IGCC-CCS Project."** The Summit Power group launched a pre-construction Front-End Engineering and Design (FEED) study for its Texas Clean Energy Project (TCEP) located in Penwell, Texas. Construction will begin on the project in the second half of 2011 following completion of the FEED study, which was formally launched on June 30, 2010. TCEP, which will be an integrated gasification combined cycle (IGCC) 400-MW plant, received a $350 million award to demonstrate the commercial integration of large-scale IGCC with CCS and serve as a model for carbon capture projects throughout the world. TCEP will reportedly capture nearly 3 million tons of CO_2 annually. July 22, 2010, http://texascleanenergyproject.com/news/Summit+Power+begins+FEED+study+for+Texas+IGCC-CCS+project.

***The Chemical Engineer*, "Teesside Industry Investigates CCS."** A joint initiative has been formed by several process engineering companies in the Teesside region of the United Kingdom to investigate the

potential of a joint CCS system. The group will examine methods to implement and progress previous studies on setting up an industrial CCS network that would capture CO_2 emissions from the local process companies and transport them for storage in depleted North Sea oil fields. The plan for the joint initiative is to determine how a CCS system would benefit those involved, while linking with one of the four CCS projects under consideration by the region's power plants. August 6, 2010, http://www.tcetoday.com/tcetoday/NewsDetail.aspx?nid=13019.

October 2010

***DOE Press Release*, "Secretary Chu Announces U.S. Centers for U.S.-China Clean Energy Research,"** and ***The Charleston Gazette*, "WVU to Lead New Carbon Capture Project."** West Virginia University (WVU) will lead a new effort to aid in the development of technology to capture GHG emissions from coal-fired power plants as part of U.S.-China Clean Energy Research Center (CERC) funding announced by U.S. Energy Secretary Steven Chu. DOE is providing a total of $25 million in funding, with $12.5 million going toward the WVU-led consortium (the remaining $12.5 million will fund a separate project). Partners in WVU's consortium will contribute funds, bringing their consortium's funding total to $50 million. September 2, 2010, http://www.energy.gov/news/9443.htm, and September 2, 2010, http://sundaygazettemail.com/News/201009021095.

***ScottishPower Press Release*, "ScottishPower Sponsors UK's First Academic Alliance to Focus on Carbon Capture and Storage."** ScottishPower announced it will invest $7.9 million over the next five years to fund the ScottishPower Academic Alliance (SPAA), the first alliance between industry and academia in the United Kingdom (UK) that specifically focuses on CCS. ScottishPower's investment will fund up to 12 full-time researchers from the Imperial College London and the University of Edinburgh to help develop the UK's CCS industry. SPAA will focus on technical innovation with regards to the capture and offshore storage of CO_2; the policy and regulatory aspects of CCS; and determining commercial opportunities. ScottishPower will seek additional contributions from government and international sponsors. September 9, 2010, http://www.scottishpower.com/PressReleases_2073.htm.

***EUROPA Press Release*, "Commission Sets up World's First Project Network for CO_2 Capture and Storage."** On September 17, 2010, the European Commission launched the "CCS Project Network" to foster knowledge sharing and raise public awareness in the role of CCS in reducing emissions. Officials hope the network will accelerate learning and ensure that CCS safely fulfills its potential as a commercial-scale viable technology. To date, a number of members already conducting CCS projects have signed a joint agreement to share CCS knowledge. These projects are supported by the European Commission's European Energy Programme for Recovery (EEPR); as a condition for receiving European Union (EU) funding, each beneficiary is required to distribute a project's results, thus enhancing the network. The European Commission's goal is to create a community of projects united in their goal of achieving commercially viable CCS by 2020. In addition, an annual Advisory Forum was established to review progress and specify the network's current and future activities. In 2008, the EU committed to reducing CO_2 emissions by 50 percent by 2050. To learn more about the CCS Project Network, visit: http://www.ccsnetwork.eu/. September 17, 2010, http://europa.eu/rapid/pressReleasesAction.do?reference=IP/10/1140&format=HTML&aged=0&language=EN&guiLanguage=en.

November 2010

***Fossil Energy Techline*, "Projects Selected to Boost Unconventional Oil and Gas Resources."** DOE has selected 10 projects that focus on increasing the Nation's supply of "unconventional" fossil energy, reducing potential environmental impacts, and expanding CO_2 storage options. Four of the projects would develop advanced computer simulation and visualization capabilities to enhance understanding of ways to improve production and minimize environmental impacts associated with

unconventional energy development. Production from unconventional fossil energy resources, which are extracted by techniques other than those used for traditional oil or natural gas wells, often has more environmental challenges than traditional methods. Advancements in simulation and visualization technologies can provide improved assessments and understanding of the cumulative environmental and model-improved impacts for advancing unconventional fossil energy recovery. The other six projects would seek to advance next generation CO_2-EOR for small-scale testing. The average recovery factor of oil recovered from U.S. oil fields is estimated at 35 percent. EOR and techniques that use advanced CO_2 injection offers the potential for additional recovery and to produce up to 60 percent more of the reservoir's original oil in place (OOIP). Managed by NETL, the total value of the projects is approximately $12.2 million ($9 million of DOE funding; $3.2 million of non-Federal cost sharing). September 27, 2010, http://www.fossil.energy.gov/news/techlines/2010/10047-Projects_Selected_to_Boost_Unconve.html.

***Platts*, "Petrofac Agrees UK Carbon Storage Plan with Shell,"** and ***BBC News*, "Shell Carbon Capture and Storage Offshore Bid Signed."** CO2DeepStore, a subsidiary of Petrofac, and Shell UK signed an agreement to redevelop Goldeneye oil and gas field in the North Sea as a potential CO_2 storage facility for a ScottishPower CCS project. As part of the project, CO_2 from the plant will be piped to St. Fergus in Scotland and then transported offshore to the Goldeneye platform. The storage project will be operated by Shell, while Petrofac will provide offshore engineering, modification, and operations services at Goldeneye through its offshore engineering and operations business. October 4, 2010, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/HeadlineNews/ElectricPower/8021351, and October 4, 2010, http://www.bbc.co.uk/news/uk-scotland-north-east-orkney-shetland-11465633.

December 2010

***Europa Press Release*, "State Aid: Commission Approves [$200] Million Aid for Carbon Capture and Storage."** The European Commission authorized The Netherlands to provide a [$200] million grant for a CCS demonstration project in the Rotterdam port area. E.ON and GDF Suez will construct a 250-megawatt (MW) equivalent plant that will capture part of the CO_2 emitted by E.ON's coal-fired Maasvlakte Power Plant 3 and transport it via pipeline to a gas field in the North Sea for geologic storage. The CO_2 capture plant is expected to capture 1.1 million tons of CO_2 annually. The CCS project has also been allocated funding under the European Energy Programme for Recovery (EEPR). October 27, 2010, http://europa.eu/rapid/pressReleasesAction.do?reference=IP/10/1392&format=HTML.

***Business Standard*, "Norway Offers ONGC a [Stake] of $1-[Billion] Carbon Project."** The Oil and Natural Gas Corporation (ONGC) has been invited to participate in a $1 billion CCS project by the Norwegian government, which holds approximately 75 percent in the project. Located at Statoil's Mongstad oil refinery in Norway, the CO_2 Technology Centre would have access to flue gas from the gas-fired power plant. The partners have already invested approximately $450 million in the project, which is designed to capture around 100,000 tonnes of CO_2 annually. Full commissioning is expected in 2012. October 30, 2010, http://www.business-standard.com/india/news/norway-offers-ongcbite1-bn-carbon-project/413205/.

***Industrial Fuels and Power*, "Siemens Completes First Phase of CO_2 Pilot Project, Demonstrated Capture Efficiency of 90 [Percent]."** Siemens Energy successfully completed the first test phase of its CO_2 capture facility at the E.ON-operated Staudinger power plant. Following more than 3,000 operating hours since the facility was commissioned in September 2009, a CO_2 capture efficiency of more than 90 percent was achieved. The project investigated process efficiency and long-term stability of the scrubbing agent. Sponsored by E.ON and the German Federal Ministry of Economics and Technology, the pilot project promotes research and development of low emissions power plant technologies. November 19, 2010, http://www.ifandp.com/article/008247.html.

January 2011

***ExxonMobil News Release*, "ExxonMobil Expands World's Largest Carbon Capture Plant in Wyoming."** ExxonMobil completed an $86 million expansion of the world's largest carbon dioxide (CO_2) capture plant, in LaBarge, Wyoming, including the installation of compressors to capture 50 percent more CO_2 for potential use in enhanced oil recovery (EOR) and other industrial uses. The expansion provides the plant with the capacity to capture approximately 365 million cubic feet of CO_2 per day from the natural gas streams produced from fields in Wyoming. According to ExxonMobil, the captured CO_2 is sold to companies for EOR. December 10, 2010, http://www.businesswire.com/portal/site/exxonmobil/index.jsp?ndmViewId=news_view&ndmConfigId=1001106&newsId=20101210005689&newsLang=en.

***Reuters*, "China's Shenhua Says CTL Plant to Begin Storing Carbon in '11."** A pilot CCS facility built by China's Shenhua Group at their coal-to-liquid (CTL) plant in Inner Mongolia will begin injecting CO_2 in underground storage facilities in early 2011, according to the firm. The CTL plant is the first of its kind to go into operation in China, which has two small pilot CCS plants in Beijing and Shanghai. Shenhua plans to produce 3 millions tonnes of oil products from coal in 2015, up from 500,000 tonnes in 2010; in addition, the company plans to produce 11 million tonnes of oil products and 18.3 billion cubic meters of gas from coal by 2020. November 29, 2010, http://www.reuters.com/article/idUSTRE6AT0L320101130.

***CSIRO Media Release*, "CO_2 Capture from Coal Power Begins in [Queensland]."** Tarong Power Station has begun capturing CO_2 using post-combustion capture technology, becoming the first power station in Queensland to demonstrate such technology. The $5 million post-combustion capture demonstration project, a partnership between CSIRO and Tarong Energy Corporation Limited, uses a liquid solvent to capture CO_2 from flue gases, which experts believe has the potential to reduce CO_2 emissions from coal-fired power stations by more than 80 percent. The pilot plant, designed to capture approximately 1,000 tonnes of CO_2 per year, will evaluate the effectiveness of CO_2 capture using amine-based solvents and inform the development of efficient and economical post-combustion capture technology at commercial scale. The project received funding from the Australian Government as part of the Asia-Pacific Partnership on Clean Development and Climate program, which includes two other post-combustion capture pilot plants operating in Victoria and China. December 2, 2010, http://www.csiro.au/news/CO2-capture-from-coal-power-begins-in-Qld.html.

February 2011

***Kansas Geological Survey News Release*, "Kansas Geological Survey Receives Grant to Test Tool for Predicting CO_2 Storage Potential."** The Kansas Geological Survey will use a $1.5 million DOE grant to test a tool that can predict the CO_2 storage potential in the deep subsurface of parts of Kansas. The new tool, called volumetric curvature, will be used by researchers to analyze data from seismic reflection – a technique that creates images of underground rocks without having to drill. The target for the test (a deep saline formation located in the south-central and southwestern parts of Kansas) is a porous rock formation more than 3,500 feet deep, up to 1,000 feet thick, and covered by caprocks. The tool will be operated from the surface to analyze seismic data collected at the study area. If successful, the seismic data analysis tool would provide a cost-effective way to assess geologic CO_2 storage capacity and lead to a better understanding of the underground movement of CO_2 in saline formations. December 30, 2010, http://www.kgs.ku.edu/General/News/2010/arbuckle.html.

***Providence Resources News Release*, "Ulysses Gas Storage Project Update,"** and ***Carbon Capture Journal*, "Ulysses Storage Project Completes First Phase."** A new study carried out by Providence Resources, on behalf of AMEC, has confirmed that the construction of an offshore natural gas salt cavern storage facility at the Undersea Large-Scale Saline Sequestration and Enhanced

Storage (ULYSSES) location is economically and technically feasible. The ULYSSES Project will store CO_2 in the Kish Bank Basin in offshore Dublin, Ireland. The initial development phase of the study includes planning, capacity modeling, infrastructural integration, and gas sourcing. The ULYSSES Project, which began in 2008, will also be advanced by the detailed technical data relating to the subsurface geology. January 10, 2011, http://www.providenceresources.com/uploads/ulyssesgasstorageprojectupdate-january2011-10-1-11.pdf, and January 10, 2011, http://www.carboncapturejournal.com/displaynews.php?NewsID=710&PHPSESSID=4ndsvm4kbkuviahlsrbe72q844.

March 2011

***Reuters*, "Petrobras to Begin Offshore CO_2 Sequestration."** Petrobras, a Brazilian state oil company, will begin storing CO_2 in the offshore Lula oil field. Brazil's offshore oil fields are located in the subsalt region, which contains large quantities of CO_2. Petrobras will re-inject CO_2 back into the oil reservoirs to boost production through enhanced oil recovery (EOR) or into sub-sea salt caverns to prevent it from being released into the atmosphere. When the platform moored at the Lula field, which is approximately 186.4 miles from the coast of Rio de Janeiro, reaches full production, Petrobras could re-inject as much as 1 million cubic meters of CO_2 per day. February 3, 2011, http://www.reuters.com/article/2011/02/03/us-petrobras-co-idUSTRE7124PJ20110203.

***American Electric Power News Release*, "AEP to Receive Funds from Global CCS Institute for Commercial-Scale Carbon Dioxide Capture and Storage Project."** The Global CCS Institute will provide $4.01 million in funding to support American Electric Power's (AEP) installation of a commercial-scale CCS system on AEP's Mountaineer coal-fired power plant in New Haven, West Virginia. The funding will support the initial engineering and characterization phase of the CCS system, which uses Alstom's chilled ammonia process to capture at least 90 percent of the CO_2 released from 235 MW of the 1,300-MW Mountaineer power plant. The 1.5 million metric tons of CO_2 captured per year will be treated, compressed, and injected into suitable geologic formations for safe, permanent storage approximately 1.5 miles below the surface. Commercial operation of the system is expected to begin in 2015. February 16, 2011, http://www.aep.com/newsroom/newsreleases/?id=1673.

***Bloomberg*, "Abu Dhabi Studying Proposal to Expand Carbon Capture and Storage."** After a pilot project injected 60 tons of CO_2 per day into the Rumaitha field, Abu Dhabi National Oil Company (Adnoc) is studying a proposal to inject 1,750 tons of CO_2 per day into larger areas for EOR. Abu Dhabi Company (Adco) is looking for ways to reduce its use of the 5 billion cubic feet of natural gas produced daily in the United Arab Emirates (UAE) by as much as 40 percent. According to officials, potential CO_2 sources include Emirates Steel Industries PJSC and the Habshan field. January 18, 2011, http://www.bloomberg.com/news/2011-01-18/abu-dhabi-studying-proposal-to-expand-carbon-capture-and-storage.html.

***The Engineer*, "SSE, Shell, Petrofac Plan Peterhead Carbon Capture and Storage Project."** A proposal has been submitted by Scottish and Southern Energy plc (SSE) to develop a CCS project at its gas-fired power station in Peterhead, Aberdeenshire. The offshore transport and storage elements of the proposal will be provided by Shell UK Ltd and Petrofac subsidiary CO_2 DeepStore. The proposed project will 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 Peterhead power station. The CO_2 will then be transported via an existing underground pipeline to St. Fergus for further compression, and then via an undersea pipeline to an existing gas reservoir in the North Sea. February 11, 2011, http://www.theengineer.co.uk/sse-shell-petrofac-plan-peterhead-carbon-capture-and-storage-project/1007394.article#ixzz1Dwtd20Vs.

***Carbon Capture Journal*, "Alberta Government Concludes CCS Agreement with Enhance Energy."** Enhance Energy and the Alberta Government reached an agreement on the Alberta Carbon Trunk Line (ACTL), a pipeline that will deliver CO_2 captured from a refinery to be used for EOR. The ACTL project will receive $495 million under the Government of Alberta's Carbon Capture and Storage Funding Act and construction is expected to begin in 2012; engineering and procurement are currently underway. A contract with North West Upgrading/Canadian Natural Resources Limited (CNRL) Partnership will lead to construction of a new bitumen refinery in Alberta's Industrial Heartland as part of the Government of Alberta's bitumen royalty-in-kind (BRIK) initiative. Construction of Phase One of the bitumen refinery is expected to be completed in mid-2014. February 18, 2011, http://www.carboncapturejournal.com/displaynews.php?NewsID=741.

April 2011

***Chaparral Energy News Release*, "Chaparral Energy Agrees to a CO_2 Purchase and Sale Agreement with CVR Energy for Capture of CO_2 for Enhanced Oil Recovery."** Subsidiaries of Chaparral Energy and CVR Energy reached a CO_2 purchase and sale agreement to capture CO_2 from CVR's nitrogen fertilizer plant in Coffeyville, Kansas. The agreement provides for the purchase of CO_2 for Chaparral's initiation of enhanced oil recovery (EOR) operations in its North Burbank Unit in northeastern Oklahoma. Coffeyville Resources Nitrogen Fertilizers, LLC (CVR Energy's subsidiary) owns and operates a nitrogen fertilizer facility that produces approximately 850,000 tons of CO_2 per year. As part of the new agreement, most of the fertilizer plant's CO_2 will be captured by Chaparral, who will construct a CO_2 compression facility at the plant site and install approximately 70 miles of pipeline to deliver it to its North Burbank Unit in Osage County. The injection is expected to begin no later than July 2013. March 23, 2011, http://www.chaparralenergy.com/index.php?page=chaparral-energy-agrees-to-a-co2-purchase-and-sale-agreement-with-cvr-energy-for-capture-of-co2-for-enhanced-oil-recovery.

***Denbury News Release*, "Denbury Enters Into Two Industrial CO_2 Purchase Contracts."** Denbury Resources announced it has entered into two contracts to purchase CO_2 from anthropogenic sources in the Gulf Coast and Rocky Mountain regions. In the first contract, Denbury will purchase CO_2 captured from the DKRW Advanced Fuels LLC's Medicine Bow Fuel and Power LLC (MBFP) coal-to-transport fuels project in Wyoming. MBFP will capture CO_2 produced from its project and clean, compress, and deliver the CO_2 to Denbury for EOR in their Rocky Mountain region oil fields; deliveries are expected to begin in late 2014 or early 2015. In the second contract, Denbury will purchase 70 percent of the CO_2 captured from Mississippi Power Company's Kemper County integrated gasification combined cycle (IGCC) project in Mississippi. Mississippi Power will capture, clean, compress, and deliver CO_2 from its recently initiated 582-megawatt (MW) IGCC power plant to Denbury's Heidelberg Field; deliveries are expected to begin in 2014. March 16, 2010, http://phx.corporate-ir.net/phoenix.zhtml?c=72374&p=irol-newsArticle&ID=1539782&highlight.

***Enel Press Release*, "Inauguration of Italy's First CCS Pilot Plant in Brindisi."** Enel inaugurated a pilot plant for capturing and storing CO_2 at its Federico II power plant in Brindisi, the first of its kind in Italy. The pilot plant will be capable of separating 2.5 metric tons of CO_2 per hour (up to a maximum of 8,000 metric tons per year) from the Federico II coal-fired power plant. The CO_2 will be transported to Cortemaggiore, where it will be injected and permanently stored underground. The design stage has been completed and existing CO_2 levels are being assessed. The plant, which is expected to be operational by 2012, will treat 810,000 m^3 of emissions per hour, separating up to 1 million metric tons of CO_2 per year for storage below the Adriatic Sea. The development of the project is part of a combined Enel and ENI project aimed at testing the first integrated Italian pilot plant. March 1, 2011, http://www.enel.com/en-GB/media/press_releases/release.aspx?iddoc=1641325.

May 2011

***University of Wyoming News Release*, "Drilling to Begin at Carbon Storage Project Site."** Phase I of the Wyoming Carbon Underground Storage Project (WY-CUSP) was scheduled to begin on the Rock Springs Uplift in Sweetwater County, Wyoming, in late April. The $16.9 million Phase I project, co-sponsored by DOE's Office of Fossil Energy (FE), is expected to lay the groundwork for Wyoming's first successful carbon capture and storage (CCS) project and produce a detailed characterization of two saline formations for potential pilot- and commercial-scale CO_2 storage. Drilling the 2,000-foot top hole, the first stage of the 14,000-foot stratigraphic test well, is expected to take in the range of 30 to 60 hours to complete. Once a large rig is onsite, the remainder of the drilling will take approximately 100 days. According to preliminary data from prior research, the Rock Springs Uplift has the potential to store 26 billion tons of CO_2 over 50 years. The project's initial phase began in December 2009; project completion is scheduled for December 2012. April 22, 2011, http://www.uwyo.edu/uw/news/2011/04/drilling-to-begin-sunday-at-carbon-storage-project-site.html.

***Energy Central*, "Government Approves $1.24 Billion Carbon Capture Project."** The Government of Saskatchewan has approved a $1.24 billion Integrated Carbon Capture and Storage (CCS) Demonstration Project at SaskPower's Boundary Dam Power Station. The project will transform a generating unit at Boundary Dam into a producer of reliable, clean electricity while reducing greenhouse gas (GHG) emissions by approximately 1 million tonnes per year and capturing CO_2 for enhanced oil recovery (EOR). The project received $240 million in Federal funding. SNC Lavin, an engineering and construction company, will oversee the engineering, procurement, and construction activities, while Cansolv, subsidiary of Shell Global Solutions, will supply the carbon capture process. The new generating unit is expected to begin operations in 2014 and have the capacity to generate 110 megawatts (MW) of electricity. April 26, 2011, http://www.energycentral.com/functional/news/news_detail.cfm?did=19778297.

***Carbon Capture Journal*, "Oil Refinery CO_2 Capture Pilot in Brazil."** An oxy-combustion capture test has been initiated by the CO_2 Capture Project (CCP) on a pilot-scale Fluid Catalytic Cracking (FCC) unit at a Petrobras research complex in Parana state, Brazil. The test is expected to progress a technology capable of capturing up to 95 percent of FCC CO_2 emissions (potentially equivalent to 20 to 30 percent of emissions from a typical refinery). The demonstration will test start-up and shut-down procedures and different operational conditions and process configurations. The testing is expected to confirm the technical and economic viability of retrofitting an FCC unit to enable CO_2 capture through oxy-combustion. The testing is scheduled for completion at the end of May 2011. To view the project fact sheet, click: http://www.co2captureproject.com/media/CCP_Project_Factsheet_FCC_March2011_Final.pdf. April 8, 2011, http://www.carboncapturejournal.com/displaynews.php?NewsID=776.

June 2011

***Southern Company Press Release*, "World's Largest Power Plant CCS Project Is Capturing Carbon."** Southern Company's 25-MW carbon capture and storage (CCS) facility located at Plant Barry near Mobile, Alabama, is now operating and capturing CO_2. The facility will capture approximately 150,000 tons of CO_2 annually for storage in a saline formation. The CO_2, which is being captured at the Barry facility by using Mitsubishi Heavy Industries Ltd. technology KM-CDR™, will be supplied to the Southeast Regional Carbon Sequestration Partnership (SECARB) for pipeline transport and injection 9,500 feet underground at a site within the Citronelle Oil Field, which is approximately 11 miles from the plant. The site was revealed to have excellent characteristics for safe geologic storage from a characterization well previously drilled within the field by SECARB, one of DOE's Regional Carbon Sequestration Partnerships (RCSPs). June 13, 2011, http://www.southerncompany.com/news/dyn_pressroom.aspx?s=43&item=2337.

***Transmission and Distribution World*, "Mountaineer Carbon Capture and Sequestration Project Results Announced."** Alstom Power announced the successful operation of a chilled ammonia CCS validation project at American Electric Power's (AEP) Mountaineer Plant in New Haven, West Virginia. The project achieved capture rates ranging from 75 percent to as high as 90 percent; CO_2 purity of greater than 99 percent; and CO_2 injection levels of approximately 7,000 tons/month. In addition, the project achieved energy penalties within a few percent of predictions from Alstom's process simulation model, and robust steady-state operation during all modes of power plant operations. These results suggest a large-scale demonstration project planned for Mountaineer would have the ability to capture up to 1.5 million metric tons of CO_2 per year. In 2009, a 20-megawatt electric (MWe) portion of AEP's 1,300-MWe coal-fired Mountaineer Plant was retrofitted with Alstom's chilled ammonia CO_2 capture technology. May 9, 2011, http://tdworld.com/business/alstom-ccs-project-results-0511/.

***Air Products News Release*, "Air Products Signs Two Agreements to Move Texas Carbon Capture and Sequestration Project Forward."** Air Products announced the signing of two agreements to proceed with a planned CCS project in Port Arthur, Texas, where CO_2 will be captured and delivered for enhanced oil recovery (EOR) operations. As part of the agreements, Air Products will design, construct, and operate a state-of-the-art system to capture CO_2 from two steam methane reformers (SMRs) located within the Valero Refinery in Port Arthur. The CO_2 will then be delivered via a pipeline owned by Denbury Green Pipeline-Texas to Denbury Onshore, LLC, beginning in late 2012, where it will be used for EOR operations. Approximately 1 million tons of CO_2 will be recovered annually. May 26, 2011, http://www.airproducts.com/company/news-center/2011/0526-air-products-signs-two-agreements-for-texas-carbon-capture-and-sequestration-project.aspx.

July 2011

***Fossil Energy Techline*, "DOE-Sponsored IGCC Project in Texas Takes Important Step Forward."** A newly signed memorandum of understanding (MOU) for the purchase of electricity produced by a first-of-a-kind integrated gasification combined cycle (IGCC) power plant represents an important step forward for what is expected to be one of the world's most advanced and cleanest coal-based power plants, funded in part by DOE. Under the MOU, CPS Energy, a municipally owned utility serving San Antonio, Texas, will purchase the electricity generated by the Texas Clean Energy Project (TCEP), a 400-megawatt (MW) IGCC facility located 15 miles west of Odessa, beginning in mid-2014. TCEP will capture approximately 90 percent of its CO_2 emissions (3 million tons annually), which will be used for EOR in the West Texas Permian Basin. TCEP was a third round selection under the Office of Fossil Energy's (FE) 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 through successful commercial demonstrations. For more information on DOE's CCPI, visit: http://www.fossil.energy.gov/programs/powersystems/cleancoal/index.html. To learn more about TCEP, go to: http://www.texascleanenergyproject.com/. June 20, 2011, http://www.fossil.energy.gov/news/techlines/2011/11026-IGCC_Project_in_Texas_Moves_Forwar.html.

***Reuters*, "Toshiba to do Carbon Capture Study in Bulgaria."** Toshiba Corporation announced plans to conduct a feasibility study in Bulgaria for the possible construction of a coal-fired power plant with CCS facilities. The study, which will be conducted in the Maritsa East lignite coal mining complex in southern Bulgaria, will run from July 2011 through March 2012. The project is part of the European Union (EU) member state's efforts to boost energy efficiency and reduce greenhouse gas (GHG) emissions in line with the region's climate change policies. Schlumberger Carbon Services, Sofia University, and Taisei Corporation will also participate in the study. Currently, thermal power utilities account for approximately 50 percent of electricity generation in Bulgaria. July 5, 2011, http://www.reuters.com/article/2011/07/05/us-bulgaria-ccs-toshiba-idUSTRE76420V20110705.

***The Press*, "CO_2 Pipeline Across Yorkshire is Proposed."** The National Grid revealed proposals for an underground pipeline to transport CO_2 across Yorkshire into the North Sea to be stored underground. The proposed route would begin by capturing CO_2 emissions from the 2Co Energy Don Valley Power project in Stainforth, near Doncaster, and then run between Goole and Selby, south of Market Weighton and north of Beverley, and finally south of Driffield towards the coast, where it will then go under the sea to a suitable geologic storage site. The infrastructure is expected to be used by other power generators in Yorkshire. June 28, 2011, http://www.yorkpress.co.uk/news/9108967.Co2_pipeline_across_Yorkshire_is_proposed/.

***Conroenews.com*, "Denbury CO_2 Pipeline Scheduled for Late 2013 Start."** According to officials from Denbury Resources, Inc., enhanced extraction of crude oil from the Conroe field should begin in late 2013. The "Conroe Lateral," which will commence once Denbury completes the construction of a pipeline through Southeast Texas, is an 87-mile pipeline designed to transport up to 700 million standard cubic feet of CO_2 per day for injection into the Conroe field. The process is projected to recover an additional 125 million barrels of crude oil from the field over the next 25 to 30 years. Denbury's "Green Pipeline," a 320-mile pipeline from Donaldsonville, Louisiana, to Alvin, Texas, connects one of the largest reserves of CO_2 in Mississippi to the Hastings oil field, southwest of Houston. Denbury began extracting crude oil from the Hastings field in December 2010. July 8, 2011, http://www.yourhoustonnews.com/courier/news/article_6d52706f-373f-5c5d-991f-36540d3678a6.html.

August 2011

***Thunderbird Energy News Release*, "Carbon Storage Project at Thunderbird Energy's Gordon Creek Natural Gas Field Moving Forward with Operations."** Thunderbird Energy announced that the Southwest Regional Partnership on Carbon Sequestration's (SWP) Deployment Phase (Phase III) CO_2 storage project is moving forward with field operations on their natural gas field. SWP, one of DOE's seven Regional Carbon Sequestration Partnerships (RCSPs), will site the project at Thunderbird's Gordon Creek natural gas project located in Carbon County, Utah, which is a sub-recipient of the NETL financial award and will act as the project field operator. The project budget is approximately $90 million; up to $67 million will come from DOE funds, with the remaining balance provided by participating organizations. The initial phase of field operations will include an extensive 3-D seismic shoot and the drilling of up to two, 12,000-foot deep CO_2 source wells to establish the potential size of the known CO_2 resource at Gordon Creek, thereby securing a long-term supply of CO_2 and satisfying Phase II requirements. In addition, the field operations will include drilling and/or re-completing monitoring wells; upgrading Thunderbird's existing injection facility, constructing roads, pipeline, and surface facilities; and conducting ongoing supervisory and monitoring operations. RCSP Development Phase efforts are intended to demonstrate proof-of-concept technologies for the potential commercialization of CO_2 storage with a project objective of safely storing up to 1 million tons of CO_2 per year. August 11, 2011, http://www.marketwire.com/press-release/carbon-storage-project-thunderbird-energys-gordon-creek-natural-gas-field-moving-forward-tsx-venture-tbd-1548655.htm.

***Reuters*, "Montana Launches $85 Million Carbon Storage Project,"** and ***Montana State University News Release*, "MSU Moves Forward with U.S. Department of Energy Backed Carbon Dioxide Storage Project in Northern Montana."** DOE has approved a pilot project headed by Montana State University that will involve permitting, injecting, and monitoring 1 million tons of CO_2 into deep porous rock formation in northern Montana. The goal of the project, which will be carried out by DOE's Big Sky Carbon Sequestration Partnership (BSCSP), is to determine whether CO_2 emissions can be captured and safely stored in regional geologic formations. The project site will be located at Kevin Dome, a subterranean rock formation in the north-central part of Montana that stretches for 700 square miles and has been capturing naturally occurring CO_2 for millions of years. The CO_2 will be injected into a rock layer that has not been previously exposed to CO_2, allowing scientists to study the reaction between rocks that have been previously exposed to CO_2 and those that have not. Development of the site,

including the drilling of injection wells, is expected to begin immediately, with storage planned to begin in two years. According to scientists, the site has the potential to store as much as 1 billion tons of CO_2. For more information on the Kevin Dome Large-Scale Storage Project, visit the BSCSP website at: http://www.bigskyco2.org/research/geologic/kevinstorage. July 26, 2011, http://www.reuters.com/article/2011/07/27/us-carbon-montana-idUSTRE76Q0AI20110727, and July 26, 2011, http://www.montana.edu/cpa/news/nwview.php?article=10021.

***Battelle News Release*, "Battelle Successfully Completes Carbon Storage Project Benefiting Industry in Ohio Valley Energy Corridor."** Battelle and American Electric Power (AEP) have completed a small-scale carbon capture and storage (CCS) test at a coal-fired power plant at AEP's Mountaineer Power Plant in New Haven, West Virginia. The test aids understanding of how to reduce CO_2 emissions and represents an important milestone in the path toward commercialization. The project began in 2003 with funding from DOE, the state of Ohio, and other sources to study the region's geology and determine the merits of CO_2 storage in the area. In 2007, AEP deployed a 20-megawatt (MW) pilot-scale CCS system at Mountaineer Power Plant. The project became operational in 2009, marking one of the first instances that CO_2 capture, transport, injection, storage, and monitoring were all in operation at a coal-fired power plant. July 21, 2011, http://battelle.org/SPOTLIGHT/7-21-11_carbon.aspx.

***Government of Alberta News Release*, "Clean Energy Project Agreement in Place,"** and ***St. Albert Gazette*, "Province Invests $285 Million in Carbon Capture."** The Government of Alberta and Swan Hills Synfuels have signed a final funding agreement for a CCS project that will capture 1.3 million tonnes of CO_2 annually from a coal gasification process and store it underground for enhanced oil recovery (EOR). The coal gasification process will tap into an unmineable coal area near Swan Hills and turn the coal into a syngas. In total, the project is expected to cost $1.5 billion; the Government of Alberta has committed $285 million to the project, providing 40 percent initially, 20 percent after commercial start-up, and the remaining 40 percent over the next 15 years. Construction is expected to begin in 2013, with carbon capture beginning in late 2015. July 27, 2011, http://alberta.ca/home/NewsFrame.cfm?ReleaseID=/acn/201107/309936C704039-C791-2E11-450AA4194BD5C4C0.html, and July 30, 2011, http://www.stalbertgazette.com/article/20110730/SAG0801/307309978/province-invests-285-million-in-carbon-capture.

Science

September 2010

***Science Daily*, "'Dry Water' Could Make a Big Splash Commercially, Help Fight [Climate Change]."** At the 240th National Meeting of the American Chemical Society, scientists said that a substance known as "dry water" could potentially absorb and store CO_2. The scientists reported that the substance is known as dry water because it consists of 95 percent water and is a dry powder; each particle of powder contains a water droplet surrounded by modified silica, the material that makes up beach sand. The silica coating prevents the water droplets from combining and turning back into liquid form, resulting in a powder that can absorb gases to chemically form a hydrate. In laboratory-scale research, the scientists found that dry water, which resembles powdered sugar in appearance, absorbed more than three times as much CO_2 as ordinary, uncombined water and silica in the same amount of time. This ability to absorb large amounts of CO_2 as a hydrate could make it useful in addressing climate change, according to the scientists. In addition to CO_2 absorption, the scientists had previously demonstrated the ability to store methane (CH_4), which could be applied to collecting and transporting natural gas deposits. August 26, 2010, http://www.sciencedaily.com/releases/2010/08/100825174102.htm.

***The Independent*, "[Climate Change] Threatens Asian Rice Production: Study."** According to a study conducted by researchers from the United States, the Philippines, and the Rome-based Food and Agriculture Organization (FAO), small rises in global temperatures have the potential to reduce rice production in Asia. The study looked at the impacts of rising daily minimum and maximum temperatures on irrigated rice production from 1994 to 1999 in 227 fields in China, India, Indonesia, the Philippines, Thailand, and Vietnam. The data showed that the primary reason behind reduced rice yields was the rising daily minimum temperatures, which have cut the rice yields by 10 to 20 percent in several key locations over the past 25 years. As the temperatures continue to rise, researchers expect the loss in production increase. August 11, 2010, http://www.independent.co.uk/environment/global-warming-threatens-asian-rice-production-study-2049267.html.

October 2010

***University of Florida News Release*, "UF Study Shows Carnivore Species Shrank During Global Warming Event."** Extinct carnivorous mammals shrank in size during a climate change event that occurred 55 million years ago, according a recent University of Florida study. Scheduled to appear in the Journal of Mammalian Evolution, the study describes a new species, referred to as a "hyena-like animal," that began the size of a bear, but during a 200,000-year period in which the average temperature of the Earth saw an approximate 15 degree Fahrenheit increase, evolved to the size of a coyote. As the Earth's temperature cooled following this warming period, the animal, Palaeonictis wingi, began evolving back to a larger size. Researchers discovered a nearly complete jaw from the animal in Wyoming's Big Horn Basin during a fossil collecting expedition in 2006. Recent findings are expected to help scientists better understand the impact of potential climate change. August 24, 2010, http://news.ufl.edu/2010/08/24/global-warming-3/.

***Science Daily*, "Most Penguin Populations Continue to Decline, Biologists Warn."** According to penguin biologists, 10 of 18 penguin species have experienced population declines due to the effects of potential climate change. Many penguin species are dependent on small schooling fish for food, such as sardines and anchovies, which are seasonally brought to penguin habitats by cold water currents. The warming of sea surface temperatures prevents cold water currents along the western coast of South America. Galapagos penguins and Humboldt penguins, found on the coasts of Peru and Chile, have already been affected by reduced food availability as cold water currents have shifted and are now found further offshore. Research shows that, at the current rate, Galapagos penguins have a 30 percent probability of extinction this century; in addition, Humboldt penguins have been classified as endangered by the Peruvian government. September 9, 2010, http://www.sciencedaily.com/releases/2010/09/100906145115.htm.

November 2010

***Science Daily*, "Climate Change Affects Horseshoe Crab Numbers."** According to a recent study by researchers from the University of Gothenburg in the scientific journal "Molecular Ecology," potential climate change is affecting the horseshoe crab population. Having survived for more than 400 million years, the horseshoe crab's body design and lifestyle have remained consistent. Researchers studied the four species of horseshoe crabs (one in North America and three in South East Asia) to gather data, and noted a decline in the number of horseshoe crabs at the end of the Ice Age. The researchers believe that future changes in sea level and water temperature could lead to a similar result in horseshoe crabs' distribution and reproduction. October 6, 2010, http://www.sciencedaily.com/releases/2010/10/101004101330.htm.

***Science Daily*, "Turtle, Dugongs ,at Risk Under Climate Change.'"** The northern Great Barrier Reef (GBR) and Torres Strait region, referred to as the "turtle and dugong capital of the world," is facing increased pressure due to potential climate change. According to scientists, a potential shift in climate

could decrease the region's turtles' hatching success, cause them to lose nesting areas, overheat their beaches, and decrease reproduction. In addition, potential climate change could affect the gender balance of the turtle population, which is determined by the temperature of the beach sand. Potential climate change could indirectly affect dugongs through the negative impact it has on seagrass, their main food source. Seagrass diebacks are linked to lower reproduction, increased mortality, and emigration of dugongs. Scientists have been monitoring turtle numbers and the movement of dugongs to provide short- and long-term measures to protect them from potential climate change, as they believe the loss of these species would have an impact on the northern Australian marine environment. October 10, 2010, http://www.sciencedaily.com/releases/2010/10/101008082926.htm.

December 2010

***USA Today*, "Global Warming May Bring Giant, Voracious Crabs to Antarctica."** According to scientists from the National Oceanography Centre in Southampton in the United Kingdom, changing ocean temperatures may allow giant predatory crabs to enter the continental-shelf ecosystems of Antarctica. According to their research, published in the journal *Polar Biology*, a small increase in water temperature due to potential climate change could bring king crabs into the area, where they historically have not been able to survive – the cold-blooded crabs cannot mature in water temperate less than approximately 32.9°F. Data was gathered by studying the distribution of 17 species of king crabs in the Southern Ocean; it was found that the coldest waters the crabs have been found in range from 32.72°F to 32.9°F in the Ross Sea. Scientists believe the arrival of the predatory species could cause a major shift in the current populations living in the high-Antarctic continental shelves. November 2, 2010, http://content.usatoday.com/communities/sciencefair/post/2010/11/global-warming-may-bring-giant-voracious-crabs-to-antarctica/1?csp=34tech.

***NASA Press Release*, "NASA Study Finds Earth's Lakes are Warming."** In a comprehensive global survey of lake temperature trends, NASA researchers found that the Earth's largest lakes have warmed over the last 25 years, which they believe is due to climate change. Using satellite data to measure the surface temperatures of 167 large lakes worldwide, researchers reported an average warming rate of 0.81°F per decade. The greatest increases in temperature, which in some lakes was as much as 1.8°F per decade, were found in the mid- to high-latitudes of the Northern Hemisphere. Researchers focused on summer temperatures (July to September in the Northern Hemisphere; January to March in the Southern Hemisphere) due to the difficulty in collecting data in seasons when lakes are ice-covered and/or hidden by clouds. The lakes chosen were selected from a global database of lakes and wetlands based on size (at least 193 square miles) or other unique characteristics. The selected lakes had large surface areas and were located away from shorelines, preventing land influences from interfering with the measurements; data were collected from the point farthest from any shoreline. November 23, 2010, http://www.nasa.gov/topics/earth/features/earthb20101123.html.

January 2011

***Associated Press*, "Feds: Wolverines Need Protection But Have to Wait."** According to wildlife officials, the wolverine population is worthy of being classified as threatened or endangered due to potential climate change. The wolverine population has grown to an estimated 250 to 300 since being nearly wiped out in the West during the early 20th century. However, warmer winter temperatures are reducing the snow pack in the West, which wolverines need to reproduce. According to the Fish and Wildlife Service (FWS), wolverines likely exist as a network of semi-isolated populations that require gene flow between groups to prevent extinction. The reduced snow pack means the cover suitable for wolverines is shrinking, resulting in growing distances between the populations, making it more difficult for the species to exchange genes as a result. Environmental models project the wolverine's habitat will shrink by approximately 25 percent by 2045, and by nearly 66 percent by 2099. As a result, the species will be added to a list of species awaiting Federal protection; the length of time a species remains on the

list depends on funds available and the status of species ahead of them on the list. December 13, 2010, http://www.google.com/hostednews/ap/article/ALeqM5i6vCjeIHR61NSPm_Or0R8o8fp8kQ?docId=cd03eb6b7da94ad69de10fad648340c0.

***UPI*, "Bamboo Urged as Climate-Change Tool."** According to the International Network for Bamboo and Rattan (INBAR), bamboo could be considered as a way to mitigate GHG emissions because it can absorb CO_2, needs little water, grows quickly, and can withstand storms. There are more than 1,000 species of bamboo in the world, all of which have yet to be studied or utilized for mitigation. According to INBAR, 2.5 acres of bamboo in China can capture 30 tons more of CO_2 over a 10-year span than the same area of fir trees in China. December 8, 2010, http://www.upi.com/Science_News/2010/12/08/Bamboo-urged-as-climate-change-tool/UPI-35271291855205/.

February 2011

***The Guardian*, "Glacier Shrinkage will Hit European Alps Hardest, Study Claims."** According to a new study published in the journal *Nature: Geoscience*, glaciers in the European Alps could shrink by 75 percent by the end of the century due to potential climate change. In the study, researchers conclude that mountain glaciers and ice caps around the world are projected to lose 15 to 27 percent of their volume by 2100. Researchers also believe that this projected decrease in volume will lead to ~~"~~substantial impacts" on regional water availability, as well as a rise in sea levels (the study predicts melting glaciers and ice caps will result in increases in sea levels by as much as 16.1 cm by 2100). Data was gathered by simulating the response of 2,638 ice caps and 120,229 mountain glaciers worldwide to the 10 state-of-the-art projected climate change models developed for the last Intergovernmental Panel for Climate Change (IPCC) report. It was found that while melting mountain glaciers and ice caps have contributed less than one percent of all water on Earth, their retreat has caused half of the sea level rises over the past 50 years. January 9, 2011, http://www.guardian.co.uk/environment/2011/jan/09/global-warming-glaciers-sea-levels.

***ScienceDaily*, "Warming Climate Means Red Deer Rutting Season Arrives Early."** The annual rutting season of wild red deer on the Isle of Rum could be changing due to warming spring and summer temperatures, according to scientists. A new study shows that the rutting and calving seasons are occurring two weeks earlier, on average, compared to 30 years ago. Scientists came to this conclusion by using annual records of breeding success in more than 3,000 individually recognizable deer as part of a 38-year study of the ecology of red deer on the Isle of Rum. The long-term research was conducted by scientists at the Universities of Cambridge and Edinburgh, who believe the data provides evidence that warming temperatures are affecting the behavior of British mammals. January 16, 2011, http://www.sciencedaily.com/releases/2011/01/110114100948.htm.

March 2011

***The Telegraph*, "Polar Bears Having Fewer Cubs Due to Global Warming."** According to a new study conducted by researchers at the University of Alberta, potential climate change could result in less polar bears as females give birth to fewer cubs due to the loss of sea ice. Researchers studied the effect of melting sea ice on the breeding success of polar bears in the 1990s, finding that the early melting of the ice made it more difficult for the bears to hunt for food sources. As a result, there was less chance of a successful pregnancy; in the 1990s, 28 percent of energy-deprived, pregnant polar bears in the Hudson Bay region failed to give birth. Using mathematical equations, researchers found that, in future years, if the ice breaks up one month earlier than it did in the 1990s, 40 to 73 percent of pregnant female polar bears will not reproduce. According to researchers, Arctic sea ice reached its lowest level this January since records began in 1979. The current polar bear population in western Hudson Bay is estimated to be approximately 900, down from 1,200 a decade ago. February 8, 2011,

http://www.telegraph.co.uk/earth/environment/climatechange/8311137/Polar-bears-having-fewer-cubs-due-to-global-warming.html#.

***AFP*, "Global Warming Means Longer Allergy Seasons: Study."** According to a new study, warmer temperatures and later fall frosts have led to ragweed allergy season lasting two to four weeks longer than usual in North America. The study states that the most dramatic rise in allergy season length appeared in northern parts of the United States and Canada from 1995 to 2009. For example, the city of Saskatchewan, Canada, saw the longest pollen season, with 27 more days in 2009 compared to 1995; during the same time frame, Winnipeg, Manitoba, saw a 25-day increase. Pollen measurements from the U.S. National Allergy Bureau and Canada's Aerobiology Research Laboratories were used for the study, as was data from U.S. weather stations, Environment Canada, and the Canadian National Climate Data and Information Archive. According to researchers, the changes in the northern latitudes were consistent with the United Nation's (UN) Intergovernmental Panel on Climate Change (IPCC) projections of more intense warming in areas closer to the Arctic. February 22, 2011, http://www.google.com/hostednews/afp/article/ALeqM5h-sw1E5MXotK5BB3l3ovhlir8xQg?docId=CNG.f6bbc13595f98b74300029280925e216.5d1.

April 2011

***The Guardian*, "Moray Firth Rocks „Could Store 15 Years of Carbon Emissions,'"** and ***The Press and Journal*, "Study Reveals Rocks Under Firth can Store CO_2 Emissions."** According to a report sponsored by the Scottish Carbon Capture and Storage (SCCS) consortium, sandstone rocks under the North Sea have the potential to store at least 15 years worth of CO_2 emissions from power plants in Scotland with the help of CCS technologies. The study, titled, "Progressing Scotland's CO_2 storage opportunities," estimates that the rock formation, known as Captain sandstone and buried more than half a mile beneath the Moray Firth, could eventually store up to 100 years' worth of CO_2 emissions and, by 2020, create at least 13,000 jobs. Three Scottish power firms are competing for funding for CCS demonstration projects. According to the SCCS research, which was funded by the Scottish Government and businesses in the energy sector, the development of CCS technologies could generate more than $16.2 billion a year for the United Kingdom by 2025. (**See Recent Publications section for a portion of the Executive Summary and a link to "Progressing Scotland's CO_2 storage opportunities."**) For more information on SCCS, visit: http://www.geos.ed.ac.uk/research/sccs/. March 14, 2011, http://www.guardian.co.uk/environment/2011/mar/14/moray-firth-carbon-capture-storage and March 14, 2011, http://www.pressandjournal.co.uk/Article.aspx/2177573?UserKey=.

***Indiana University News Release*, "Rising CO_2 is Causing Plants to Release Less Water to the Atmosphere, Researchers Say."** Coinciding with rising CO_2 levels over the last 150 years, the density of pores that allow plants to breathe has shrunk by 34 percent, restricting the amount of water vapor released to the atmosphere, according to researchers. In reports published in the *Proceedings of the National Academy of Sciences*, scientists from Indiana University Bloomington and Utrecht University in the Netherlands analyzed data gathered from a diversity of plant species in Florida ranging from 100 to 150 years in age. According to their predictions, more than doubling today's CO_2 levels from 390 parts per million (ppm) to 800 ppm will further reduce the amount of water released by the plants. March 3, 2011, http://newsinfo.iu.edu/news/page/normal/17577.html.

May 2011

***International Union for Conservation of Nature*, "Degraded Coastal Wetlands Contribute to Climate Change."** According to a new report, drainage and degradation of coastal wetlands emit amounts of CO_2 into the atmosphere, leading to decreased carbon storage. The report highlights the current rates of degradation and loss of coastal wetlands, which are up to four times those of tropical forests. A total of 15 coastal deltas were studied, with seven found to have each released more than 500

million tons of CO_2 since the wetlands were drained – mostly within the past 100 years. Mangroves, tidal marshes, and sea-grass meadows remove CO_2 from the atmosphere and store it in soil. When they are degraded as a result of drainage or conversion for agriculture, they emit CO_2 into the atmosphere. The report also calls for coastal wetlands to be protected and for the improving of their restoration to be included in CO_2 reduction strategies. April 11, 2011, http://www.iucn.org/?7239/Degraded-Coastal-Wetlands-Contribute-to-Climate-Change.

***Oregon State University News Release*, "Carbon Sequestration Estimate in U.S. Increased – Barring a Drought."** According to a study published in the journal *Agricultural and Forest Meteorology*, forests and other terrestrial ecosystems in the lower 48 U.S. states have the potential to store up to 40 percent of the United States' fossil fuel carbon emissions, which is larger than the previously estimated amount. However, the scientists also note that major disturbances – such as droughts, wildfires, and hurricanes – can affect the amount of CO_2 stored in a given year. For example, large droughts that happened twice in the United States in the past decade reduced carbon storage approximately 20 percent (compared to a "normal" year). The research, which was compiled by scientists from 35 institutions, found that the temperate forests in the eastern United States absorbed carbon because of forest regrowth following the abandonment of agricultural lands, while some areas of the Pacific Northwest absorbed carbon during much of the year due to the region's mild climate. April 14, 2011, http://oregonstate.edu/ua/ncs/archives/2011/apr/carbon-sequestration-estimate-us-increased-%E2%80%93-barring-drought.

June 2011

***Science Daily*, "Antarctic Icebergs Help Ocean Take Up Carbon Dioxide."** According to a study published in the journal *Deep Sea Research Part II: Topical Studies in Oceanography*, icebergs in the Antarctic fertilize the Southern Ocean, which enhances the growth of carbon-storing algae. The biological effects of Antarctic icebergs were analyzed by tracking individual icebergs during three separate cruises to the Weddell Sea. The icebergs drifted to Weddell Sea as Antarctic ice shelves shrunk and split apart. According to the research, the drifting icebergs carry iron-rich sediment, which, as the icebergs melt, dissolves into the water and helps fertilize the growth of microscopic algae. Scientists measured the amount of organic carbon sinking into the deep sea beneath a free-floating iceberg and compared that with the amount of carbon sinking in the open ocean nearby. They found that approximately twice as much carbon sank into the deep sea within an 18.6-mile radius of the iceberg compared to an open-ocean area. May 12, 2011, http://www.sciencedaily.com/releases/2011/05/110511131140.htm.

***Science Daily*, "Global Warming May Increase the Capacity of Trees to Store Carbon."** According to a study by the Marine Biological Laboratory (MBL), potential climate change may affect the ability of trees to store CO_2 by altering forest nitrogen cycling. Published in the journal "Proceedings of the National Academy of Sciences," the paper summarizes the results of a seven-year study at Harvard Forest in central Massachusetts where about one-quarter of the forest was artificially warmed by approximately 9°F above ambient to simulate a warmer climate. The results indicated that a warmer climate leads to more rapid decomposition of the organic matter soil, which in turn leads to an increased amount of CO_2 released in the atmosphere. However, the study also showed that the warmer temperatures stimulate the gain of CO_2 stored in trees, partially offsetting the soil carbon loss in the atmosphere. According to the research, the CO_2 gain in trees is due to the availability of more nitrogen to the trees with warmer soil. May 31, 2011, http://www.sciencedaily.com/releases/2011/05/110525120050.htm.

July 2011

***The Telegraph*, "Duck-Billed Platypus at Risk from Climate Change."** According to researchers at Monash University, the cool rivers and ponds that platypus inhabit could become too warm for their

survival due to potential climate change. By using weather and platypus habitat data from the last 100 years, researchers were able to connect declines in populations with droughts and heat events. Currently, the platypus population is able to feed for up to 10 hours in near-freezing water due to its watertight fur. However, researchers have found that in 60 years, approximately one-third of the platypus' habitat could become too hot. Under a worst-case scenario, the animals could become extinct on the Australian mainland and confined to three of the coolest part of the country – the Tasmania, King, and Kangaroo islands. June 24, 2011, http://www.telegraph.co.uk/earth/wildlife/8596068/Duck-billed-platypus-at-risk-from-climate-change.html.

***Reuters*, "Climate Change Raising Tick Threat for Northern Moose: Officials."** Moose living in northern parts of the United States are being increasingly threatened from blood-feeding ticks and deer-borne parasites due to shorter winters caused by potential climate change, according to U.S. wildlife officials. A recently released study by New Hampshire's Fish and Game Department states that winter ticks account for 41 percent of all moose deaths in the state – the same percentage killed by hunting and vehicular collisions. The study, which began in 2001, also found that nearly all of the calf deaths were caused by winter ticks. On average, a moose can become infested with approximately 30,000 ticks in normal fall weather conditions. However, in years when the first snowfall is later than usual, one animal can be infested with as many as 160,000 ticks during winter, often leading to malnutrition and eventual death. When ticks are feeding, moose suffer from stresses such as reduced blood volume, a thinner coat due to scratching, and an inability to lie down and rest. According to a recent report by the Union of Concerned Scientists, New Hampshire's snow season may shrink by 50 percent by mid-century. June 18, 2011, http://www.reuters.com/article/2011/06/18/us-moose-ticks-idUSTRE75H1UJ20110618.

August 2011

***National Oceanic and Atmospheric Administration Press Release*, "NOAA Scientists Link Shifting Atlantic Mackerel Distribution to Environmental Factors, Climate Change."** Scientists from the National Oceanic and Atmospheric Administration (NOAA) have discovered that the distribution patterns of Atlantic mackerel have been altered due to environmental factors such as potential climate change. Atlantic mackerel, a marine species found in waters from Cape Hatteras to Newfoundland, migrate great distances on a seasonal basis to feed and spawn. However, the mackerel are sensitive to changing water temperatures and shifted northeastward into shallower waters, potentially impacting U.S. commercial and recreational fisheries. Using spatial data, researchers from NOAA's Northeast Fisheries Science Center (NEFSC) studied annual changes in the winter and early-spring distribution of the Atlantic mackerel stock on the northeast U.S. continental shelf. They found that the overwintering distribution of the Northwest Atlantic stock shifted approximately 155 miles north and 30 miles east between 1968 and 2008, also shifting from deep, off-shelf locations to more shallow, on-shelf areas that have more water within their preferred temperature range, which is above 5°C. The shift is likely to pose a challenge to U.S. commercial vessels looking to locate large school of the marine species during the winter months, when the majority of landings occur, because the fish are dispersed over a larger area of waters. August 11, 2011, http://www.nefsc.noaa.gov/press_release/2011/SciSpot/SS1104/.

***Science Daily*, "Climate Change Could Drive Native Fish out of Wisconsin Waters."** According to a report published in the online journal "Public Library of Science One," the cisco, a key forage fish found in Wisconsin's deepest and coldest bodies of water, could be driven out of local waters due to potential climate change. Researchers from the University of Wisconsin-Madison and the Wisconsin Department of Natural Resources ran several possible future climate scenarios that led to their prediction that the cisco, a cold water-dependant fish found in approximately 170 inland lakes in Wisconsin, could disappear from the majority of the state's lakes due to warmer waters. The cisco is an important food for many of Wisconsin's game species, and the report claims that the impoverishment of aquatic ecosystems could have potential socio-economic implications in settings where fishing is a reliable industry. August 16, 2011, http://www.sciencedaily.com/releases/2011/08/110816112115.htm.

Policy

September 2010

***U.S. Environmental Protection Agency News Release*, "EPA Proposes Rules on Clean Air Act Permitting for Greenhouse Gas Emissions."** EPA is proposing two rules to ensure that businesses planning to build new, large facilities, or expansions to existing facilities, will be able to obtain Clean Air Act (CAA) permits that address their GHG emissions. Beginning in 2011, projects that will significantly increase GHG emissions will require an air permit as a result of EPA's GHG Tailoring Rule; the two proposed rules will help ensure these sources will be able to get permits regardless of where they are located. In the first rule, EPA is proposing to require permitting programs in 13 states to make changes to their implementation plans to make certain that GHG emissions are covered. The second rule proposes a Federal implementation plan, which would allow EPA to issue permits for large GHG emitters located in states that may not be able to develop and submit revisions to their plans before the Tailoring Rule becomes effective. EPA is working to finalize these rules prior to January 2, 2011. August 12, 2010, http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/708bd315d348b5568525777d0060c5da!OpenDocument.

***U.S. Department of Commerce Press Release*, "U.S. Departments of Commerce and the Interior to Cooperate on Climate-Related Activities."** The U.S. Departments of Commerce and the Interior (DOC/DOI) formalized an agreement to cooperate on climate-related activities involving science, services, mitigation, adaption, education, and communication. A Memorandum of Understating (MOU) was signed, providing a framework to build upon existing partnerships that bring together their best available climate science and services to inform adaption strategies and response decisions to manage America's oceans, coasts, the Great Lakes, and public lands. In addition, the MOU will support broader interagency coordination efforts through the U.S. Global Change Research Program. The MOU is available at: http://www.noaa.gov/climateresources/resources/doidocclimatemoufinal.pdf. August 3, 2010, http://www.commerce.gov/news/press-releases/2010/08/03/us-departments-commerce-and-interior-cooperate-climate-related-activi.

"Personal carbon trading: A policy ahead of its time?" The following is from the Abstract of this article: "In 2008, the UK government undertook a review of personal carbon trading (PCT) and declared that it was 'an idea currently ahead of its time.' PCT is a radical policy proposal which would entail all adults receiving an equal, tradable carbon allowance to cover emissions from household energy and/or personal travel. The allowance would reduce over time, in line with national emissions reduction goals. The government's key concerns about PCT were its social unacceptability and high cost. This paper reviews the literature and identifies knowledge gaps, and then discusses whether these concerns are justified. Contrary to the government's conclusions, most research shows PCT to be at least as socially acceptable as an alternative taxation policy. People think it could be both fair and effective. Set-up and running costs for PCT will undoubtedly be higher than for alternative taxation policies. However, PCT could deliver benefits from individual and social change motivated by non-economic aspects of the policy. These potential benefits are outlined here. The conclusion is that PCT is a promising and timely policy idea." **Tina Fawcett**, *Energy Policy*, Available online July 18, 2010, doi:10.1016/j.enpol.2010.07.001, http://www.sciencedirect.com/science/article/B6V2W-50JPS6Y-4/2/642870d246f9a7d7344a993a687afdf2. (Subscription may be required.)

October 2010

***Global CCS Institute Press Release*, "China Joins Global CCS Institute as Legal Member."** China's lead governmental body responsible for industrial sector policy development and management has become a legal member of the Global CCS Institute. Members of the Institute can help shape the

organization's strategic direction through participation in meetings and working groups and by sharing knowledge, information, and expertise that can facilitate the commercial deployment of CCS. Funded by the Australian government, the Global CCS Institute works to accelerate the commercial deployment of CCS and ensure that the technology plays a role in responding to the need for a low-carbon energy future. The Global CCS Institute's interim goal is to accelerate the development of 20 commercial-scale integrated demonstration projects prior to 2020. August 14, 2010, http://www.globalccsinstitute.com/downloads/news/2010/PressRelease-China-Joins-Global-CCS-Institute-as-Legal-Member.pdf.

"Deployment Models for Commercialized Carbon Capture and Storage." The following is the Abstract of this article: "Even before technology matures and the regulatory framework for CCS has been developed, electrical utilities will need to consider the logistics of how widespread commercial-scale operations will be deployed. The framework of CCS will require utilities to adopt business models that ensure both safe and affordable CCS operations while maintaining reliable power generation. Physical models include an infrastructure with centralized CO_2 pipelines that focus geologic sequestration in pooled regional storage sites or supply CO_2 for beneficial use in enhanced oil recovery (EOR) and a dispersed plant model with sequestration operations which take place in close proximity to CO_2 capture. Several prototypical business models, including hybrids of these two poles, will be in play including a self-build option, a joint venture, and a pay at the gate model. In the self-build model operations are vertically integrated and utility owned and operated by an internal staff of engineers and geologists. A joint venture model stresses a partnership between the host site utility/owner's engineer and external operators and consultants. The pay to take model is turn-key external contracting to a third party owner/operator with cash positive fees paid out for sequestration and cash positive income for CO_2-EOR. The selection of a business model for CCS will be based in part on the desire of utilities to be vertically integrated, source-sink economics, and demand for CO_2-EOR. Another element in this decision will be how engaged a utility decides to be and the experience the utility has had with pre-commercial R&D activities. Through R&D, utilities would likely have already addressed or at least been exposed to the many technical, regulatory, and risk management issues related to successful CCS. This paper provides the framework for identifying the different physical and related prototypical business models that may play a role for electric utilities in commercial-scale CCS." **Richard A. Esposito, Larry S. Monroe, and Julio S. Friedman**, *Environ. Sci. Technol.*, Available online August 19, 2010, doi:10.1021/es101441a, http://pubs.acs.org/doi/abs/10.1021/es101441a. (Subscription required.)

"Mesoscale Carbon Sequestration Site Screening and CCS Infrastructure Analysis." The following is the Abstract of this article: "[The authors] explore CCS at the meso-scale, a level of study between regional carbon accounting and highly detailed reservoir models for individual sites. [The authors] develop an approach to CO_2 sequestration site screening for industries or energy development policies that involves identification of appropriate sequestration basin, analysis of geologic formations, definition of surface sites, design of infrastructure, and analysis of CO_2 transport and storage costs. [The authors'] case study involves carbon management for potential oil shale development in the Piceance-Uinta Basin, CO and UT. This study uses new capabilities of the *CO_2-PENS* model for site screening, including reservoir capacity, injectivity, and cost calculations for simple reservoirs at multiple sites. [The authors] couple this with a model of optimized source-sink-network infrastructure (*SimCCS*) to design pipeline networks and minimize CCS cost for a given industry or region. The *$CLEAR_{uff}$* dynamical assessment model calculates the CO_2 source term for various oil production levels. Nine sites in a 13,300 km^2 area have the capacity to store 6.5 $GtCO_2$, corresponding to shale-oil production of 1.3 Mbbl/day for 50 years (about 1/4 of U.S. crude oil production). [The authors'] results highlight the complex, nonlinear relationship between the spatial deployment of CCS infrastructure and the oil-shale production rate." **Gordon N. Keating, Richard S. Middleton, Philip H. Stauffer, Hari S. Viswanathan, Bruce C. Letellier, Donatella Pasqualini, Rajesh J. Pawar, and Andrew V. Wolfsberg**, *Environ. Sci. Technol.*, Available online August 10, 2010, doi:10.1021/es101470m, http://pubs.acs.org/doi/abs/10.1021/es101470m. (Subscription required.)

November 2010

***Reuters*, "EU to Set CO_2 Offset Limits in ETS…"** The European Commission announced they will set restrictions on the use of United Nation (UN)-backed carbon offsets in the third phase of its emissions trading scheme (ETS). The 27-nation alliance plans to propose how to restrict the number of certified emissions reductions (CERs) from industrial gas projects that can be used in its carbon market from 2013 to 2020. If approved, the European Union (EU) proposals will likely be applied to offsets being used in the post-2012 period – which is expected to impact carbon credit supply and impact. According to the European Commission, action was taken to prevent manipulation of the system and to preserve the credibility of the UN's Clean Development Mechanism (CDM). October 19, 2010, http://www.reuters.com/article/idUSTRE69I3U620101019.

"Geologic and infrastructure factors for delineating areas for clean coal: examples in Texas, USA." The following is the Abstract of this article: "Texas has a wide variety of areas that can be targeted for new clean-coal facilities. These areas are delineated by mapping spatial linkages between coal- and lignite-bearing formations, groundwater and surface-water resources, and CO_2 sinks in brine formations for long-term CO_2 storage or in mature oil fields with potential for EOR. However, a variety of infrastructure factors make it feasible to also target numerous areas outside coal and lignite basins in Texas. These infrastructure factors include pipelines for delivery of CO_2 to subsurface sinks and delivery of coal-produced hydrogen to refineries, ease of connection to existing transmission lines, distribution of nonattainment areas where new clean-coal facilities could be constructed and be compliant with strict air-quality standards, and railroads that can transport coal and other feedstock to new clean-coal facilities. Primary regions in Texas where favorably co-located CO_2 source-sink factors related to coal and lignite trends include the Gulf Coast, the Eastern Shelf of the Permian Basin, and the Fort Worth Basin. However, areas outside coal and lignite basins, particularly the Permian Basin where a new clean-coal facility is being planned, also have clean-coal potential because of existing CO_2 pipelines and proximity to EOR fields that can economically sustain new clean-coal facilities." **W. A. Ambrose, C. Breton, S. D. Hovorka, I. J. Duncan, G. Gülen, M. H. Holtz, and V. Núñez-López**, *Environmental Earth Sciences*, Available online August 29, 2010, doi:10.1007/s12665-010-0720-2, http://www.springerlink.com/content/t47tl05221336p61/. (Subscription required.)

"Environmental analysis of a German strategy for carbon capture and storage of coal power plants." The following is the Abstract of this article: "This paper combines an existing projection of the development of electricity production with a technology-specific environmental assessment. The combination of these two approaches, which so far have only been performed separately, allows a discussion about environmental effects of CCS implementation strategies on a national level. The results identify the future role of lignite and hard coal in German power production. The implementation of CCS technology leads to a considerable loss of efficiency. Due to CCS, about 50 million t of lignite will be additionally required in 2030 in comparison to the reference case without CCS in 2010. Increasing demand, the replacement of old plants and the compensation of efficiency losses lead to highly ambitious expansion rates. In the case of CCS implementation, the global warming potential (GWP) can be reduced by up to 70 percent. However, other environmental impacts increase in part considerably. Compliance with national ceilings for [nitrogen oxide (NO_X)] emissions can only be reached by compensation measures in other sectors. The results of the environmental assessment demonstrate the significant role of the coal composition, coal origin and the required transport. [Carbon dioxide] pipeline transport and CO_2 storage make a fairly minor contribution to the overall environmental impact." **A. Schreiber, P. Zapp, P. Markewitz, and S. Vögele**, *Energy Policy*, Available online October 5, 2010, doi:10.1016/j.enpol.2010.09.006, http://www.sciencedirect.com/science/article/B6V2W-515RHPT-2/2/2b076ac73f368a13d22740fe8ca36cfb. (Subscription may be required.)

December 2010

***EPA News Release*, "EPA Issues Pollution Permitting Guidance for States/Focus is on Improving Energy Efficiency to Reduce GHG Pollution from the Largest Industrial Facilities,"** and ***The New York Times*, "EPA Issues Guidelines for States' Permitting for Greenhouse Gases."** The U.S. Environmental Protection Agency (EPA) released a document that provides guidance and tools to help state and local air permitting authorities identify cost-effective reduction options for greenhouse gases (GHGs) under the Clean Air Act. The guidance document, titled, "PSD and Title V Permitting Guidance For Greenhouse Gases," is part of EPA's approach to permitting the largest GHG emissions sources outlined in the Tailoring Rule. Large-emitting new and modified facilities, such as power plants, refineries, and cement production facilities, will be required to use the best available control technologies (BACT) for GHGs beginning January 2, 2011. (**See Recent Publications section for the Introduction and a link to the "PSD and Title V Permitting Guidance For Greenhouse Gases."**) November 10, 2010, http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/d7348883f0d10676852577d700613835!OpenDocument, and November 10, 2010, http://www.nytimes.com/gwire/2010/11/10/10greenwire-epa-issues-guidelines-for-states-permitting-fo-82460.html.

***EPA News Release*, "EPA Finalizes Rules to Foster Safe Carbon Storage Technology Actions Part of Efforts to Reduce Barriers to Widespread Deployment of Carbon Capture and Sequestration, an Important Set of Technologies to Combat Climate Change."** Two CCS-related rules aimed to protect drinking water and to track the amount of CO_2 stored from geologic storage facilities have been finalized by EPA. The rules are consistent with recommendations made by the CCS Task Force and help to make a consistent national framework for ensuring the safe, effective deployment of technologies. The first rule finalized requirements for geologic CO_2 storage, including the development of a new class of injection well called Class VI, established under EPA's Underground Injection Control (UIC) Program. EPA also finalized a rule on the GHG reporting requirements for facilities that carry out geologic storage, allowing them to track the amount of CO_2 stored by these facilities. November 22, 2010, http://yosemite.epa.gov/opa/admpress.nsf/0/2300005fbc11568d852577e3006058bd?OpenDocument.

"First assessment of sources and [formations] for carbon capture and geological storage in Portugal." The following is the Abstract of this article: "A preliminary study for a source–[formation] match for application of CCS in Portugal is presented. The location of the main CO_2 emission sources in Portugal, existing and planned, was analyzed and three main source clusters, emitting a total of 26.8 Mt/year, were defined. The three source clusters are connected by a natural gas pipeline network. [Carbon dioxide] storage reservoirs are likely to be restricted to deep saline formations. Potential storage formations are described in the Porto, Lusitanian and Algarve sedimentary basins. Due to the large continental shelf, composed mainly of sedimentary rocks, it is important to consider offshore opportunities. A Geographical Information System (GIS), including information on the stratigraphy, seismicity, neotectonics and geothermal features, was used for prioritizing the areas where reservoir identification and characterization studies should be conducted. Despite not showing the most promising geological conditions, the area around the deepwater harbor of Sines is given the highest priority, since sources in the area account for more than 40 [percent] of point source emissions in Portugal." **Júlio F. Carneiro, Dulce Boavida, and Ricardo Silva**, *International Journal of Greenhouse Gas Control*, Available online September 15, 2010, doi:10.1016/j.ijggc.2010.08.002, http://www.sciencedirect.com/science/article/B83WP-511BPR8-1/2/2beb01b9f72e568591659daf579b5bd5. (Subscription may be required.)

January 2011

***Carbon Capture Journal*, "UK Committee Releases Fourth Carbon Budget."** The UK Committee on Climate Change released a report on the fourth carbon budget covering the period of 2023 to 2027; the

UK Government will propose draft legislation for the fourth budget in Spring 2011. Key recommendations and findings of the report include: a 2030 target to reduce emissions by 60 percent relative to 1990 levels (46 percent relative to 2009 levels); a global offer budget of 1,800 $MtCO_2e$; the second and third budgets should be adjusted to reflect the intended budget for the non-traded sector, giving an economy-wide reduction of 37 percent in 2020 relative to 1990; and new policies will be required, including reform of the electricity market. December 7, 2010, http://www.carboncapturejournal.com/displaynews.php?NewsID=701.

"U.S. Department of Energy's Regional Carbon Sequestration Partnership Initiative: Update on Validation and Development Phases." The following is the abstract of this article: ~~"~~DOE is the lead [Federal] agency for the development and deployment of carbon sequestration technologies. The RCSPs are the mechanism DOE utilizes to prove the technology and to develop human capital, stakeholder networks, information for regulatory policy, best practices documents and training to work toward the commercialization of CCS. The RCSPs are tasked with determining the most suitable technologies, regulations, and infrastructure for carbon capture, transport, and storage in their respective geographic areas of responsibility. The seven partnerships include more than 400 state agencies, universities, national laboratories, private companies, and environmental organizations, spanning 43 states and four Canadian provinces. The Regional Partnerships Initiative is being implemented in three phases: Characterization, Validation, and Development. The initial Characterization Phase began in 2003 and was completed in 2005 and focused on characterization of CO_2 storage potential within each region. It was followed by the Validation Phase, which began in 2005 and is nearing completion in 2011. The focus of the Validation Phase has been on small-scale field tests throughout the seven partnerships in various formation types such as saline, oil-bearing, and coal seams. The Validation Phase has characterized suitable CO_2 storage reservoirs and identified the need for comprehensive legal and regulatory frameworks to enable commercial-scale CCS deployment. Finally, the Development Phase will consist of a series of large-scale, one-million-ton, injection tests throughout the United States and Canada. The objective of these large-scale tests is to identify the regulatory path or challenges in permitting CCS projects, to demonstrate the technology can inject CO_2 safely, and to verify its permanence in geologic formations in preparation for the commercialization of geologic storage." **Traci Rodosta, John Litynski, Sean Plasynski, Lee Spangler, Robert Finley, Edward Steadman, David Ball, Gerald Hill, Brian McPherson, Elizabeth Burton, and Derek Vikara**. Presented at the 10th International Conference on Greenhouse Gas Control Technologies (GHGT-10), held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00625%2Epdf.

"Preparing to ramp up large-scale CCS demonstrations: An engineering-economic assessment of CO_2 pipeline transportation in China." The following is the Abstract of this article: ~~"~~An integrated CCS system requires safe and cost-efficient solutions for transportation of the CO_2 from the capturing facility to the location of storage. While growing efforts in China are underway to understand CO_2 capture and storage, comparatively less attention has been paid to CO_2 transportation issues. Also, to the best of [the authors'] knowledge, there are no publicly available China-specific cost models for CO_2 pipeline transportation that have been published in peer-reviewed journals. This paper has been developed to determine a first-order estimate of China's cost of onshore CO_2 pipeline transportation. An engineering-economic model based on China-specific data, codes, and standards to the greatest extent possible has been developed for this purpose. Based on the model, five illustrative case studies on pipelines for transporting captured CO_2 from typical Integrated Gasification Combined Cycle (IGCC) and Ultra-supercritical (USC) generating units of 250 megawatt (MW), 400 MW, 660 MW, 1000 MW, and 2× 1000 MW are carried out. The results show the capital costs of constructing a 100-kilometers (km) pipeline are between $18 million and $102 million, depending on the amount of CO_2 transported. Corresponding figures for the levelized costs are $1.84–$3.06 per tonne of CO_2. Sensitivity analyses are also performed examining the effect of pipeline length and soil temperature on pipeline diameter, as well as flow rate and capital cost on levelized cost. The pipeline length is found to impact the diameter

significantly, whereas soil temperature demonstrates insensitivity to pipeline diameter. Both flow rate and capital cost have significant effects on levelized cost. Comparison to other existing models based on either North American or European data implies a major cost difference between developed countries and China: China's cost of onshore CO_2 pipeline transportation is very likely much lower than those estimated in the developed countries. For a 0.02 $MtCO_2$/d case, for example, the levelized cost of CO_2 transportation in China is about two-thirds that of the developed countries." **Hengwei Liu and Kelly Sims Gallagher**, *International Journal of Greenhouse Gas Control*, Available online December 10, 2010, doi:10.1016/j.ijggc.2010.11.005, http://www.sciencedirect.com/science/article/B83WP-51NN68D-2/2/bd075bd090d8c4bdee093bc0c34b85cb. (Subscription may be required.)

February 2011

***Journal of Accountancy*, "International Greenhouse Gas Assurance Standard Proposed."** The International Auditing and Assurance Standards Board (IAASB), an independent standard-setting board operated by the International Federation of Accountants (IFAC), released a proposed standard to provide assurance on GHG emissions reported by companies. The International Standard on Assurance Engagements (ISAE) 3410, Assurance Engagements on Greenhouse Gas Statements, addresses responsibilities in identifying, assessing, and responding to risks of misstatements. It also contains assurance reports on GHG statements. Comments on the draft are due by June 10, 2011. To view ISAE 3410, Assurance Engagement on Greenhouse Gas Statements, click: http://www.ifac.org/Guidance/EXD-Details.php?EDID=0152. January 13, 2011, http://www.journalofaccountancy.com/Web/20113739.htm.

"Drivers and barriers towards large scale Carbon Capture and Storage (CCS) deployment and possible government responses." The following is the Introduction of this article: ~~L~~Large scale CCS is seen as an important technology to substantially reduce global CO_2 emissions. However, CCS is not a mature technology yet. Value drivers behind (large scale) CCS deployment are currently not sufficient to overcome the current (not only economic) hurdles on the road towards (large scale) CCS projects. Main aim of this paper is to provide an answer to the question ~~'~~What government role or response is most appropriate to tackle the main obstacles towards large scale CCS deployment?' In order to answer this question, a number of sub questions is formulated. The first section of this paper will deal with the question: *What are the main drivers for large scale CCS deployment?* The drivers will be differentiated among the various parts in the CCS value chain (capture, transport and storage). The second section will address the following research question: *What are the main barriers towards large scale CCS deployment?* Based on a recently undertaken CCS stakeholder consultation, a number of regulatory-, financial-, technical-, organizational- and policy issues towards large scale CCS deployment is identified. The third part deals with the question: *What are possible government roles/ responses to stimulate and enable CCS?* On the basis of the answers to the previous research questions, this section will identify which measures and/or other government actions are needed in which part of the CCS chain, to reinforce current drivers and to remove the barriers towards large scale CCS in the Netherlands. In the final section, conclusions will be presented in terms of the most appropriate government role and response needed, in order to realize large scale CCS. The research questions will be answered from a theoretical perspective together with the insights gathered from interviews with almost all CCS stakeholders represented in the Netherlands." **Marten Slagter and Edmund Wellenstein**. Presented at the 10th International Conference on Greenhouse Gas Control Technologies (GHGT-10), held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00883%2Epdf.

"A study on roles of public survey and focus groups to assess public opinions for CCS implementation." The following is the Abstract of this article: ~~T~~The authors conducted a set of focus groups and a public survey to assess awareness and potential acceptability of CCS in the context of national policy formulation in 2009-2010. In 2010, the authors also conducted focus groups to assess

awareness of CCS and to identify information needs to form local opinion for CCS demonstration project in the context of local implementation in a potential project site. By comparing the results of those assessments, roles of focus groups and public survey are clarified. In national policy context, focus group assessment helps to design a public survey as well as provides an example of the public's thought on CCS, and shows some processes of opinion formulation through group dynamics. In local context, qualitative assessments through focus groups and other methodology such as interviews and local meeting would play important role to understand local public opinion. Meanwhile, the cautions that focus group would not provide comprehensive assessments on public opinion and might pick exaggerated opinions are drawn in using focus group data." **Kenshi Itaoka, Aya Saito, and Makoto Akai**. Presented at GHGT-10, held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00961%2Epdf.

March 2011

***Washington Department of Ecology News Release*, "Washington, British Columbia Expand on Climate Action Partnership."** Environmental representatives from Washington and British Columbia signed joint action plans to better prepare for potential climate change. Under the signed action plans, the partnership aims to promote public awareness of sea level rise and the impacts on coastal areas and limiting CO_2 emissions from government operations and facilities. The agreement builds on existing climate-related partnerships between Washington and British Columbia, including: the Pacific Coast Collaborative, a joint effort on energy, transportation, climate change, and ocean issues; the Washington-British Columbia Memorandum of Understanding (MOU) on Coastal Climate Change Adaption, which includes the exchanging of information on sea level rise projections and mapping; and the Western Climate Initiative (WCI), a cooperative effort to reduce GHG emissions in seven U.S. states and four Canadian provinces. February 2, 2011, http://www.ecy.wa.gov/news/2011/034.html.

"Techno-economic appraisal of fossil-fueled power generation systems with carbon dioxide capture and storage." The following is the Abstract of this article: "CCS facilities coupled to power plants provide a climate change mitigation strategy that potentially permits the continued use of fossil fuels whilst reducing the CO_2 emissions. This process involves three basic stages: capture and compression of CO_2 from power stations, transport of CO_2, and storage away from the atmosphere for hundreds to thousands of years. Potential routes for the capture, transport and storage of CO_2 from United Kingdom (UK) power plants are examined. Six indicative options are evaluated, based on 'Pulverized Coal,' 'Natural Gas Combined Cycle,' and 'Integrated Gasification Combined Cycle' power stations. Chemical and physical CO_2 absorption capture techniques are employed with realistic transport possibilities to 'Enhanced Oil Recovery' sites or depleted gas fields in the North Sea. The selected options are quantitatively assessed against well-established economic and energy-related criteria. Results show that CO_2 capture can reduce emissions by over 90 [percent]. However, this will reduce the efficiency of the power plants concerned, incurring energy penalties from 14 to 30 [percent] compared to reference plants without capture. Costs of capture, transport and storage are concatenated to show that the whole CCS chain 'cost of electricity' (COE) rises by 27-142 [percent] depending on the option adopted. This is a significant cost increase, although calculations show that the average 'cost of CO_2 captured' is [$20.85]/t$CO_2$ in 2005 prices (the current base year for official UK producer price indices). If potential governmental carbon penalties were introduced at this level, then the COE would equate to the same as the reference plant, and make CCS a viable option to help mitigate large-scale climate change." **G.P. Hammond, S.S. Ondo Akwe, and S. Williams**, *Energy*, Available online January 13, 2011, doi:10.1016/j.energy.2010.12.012, http://www.sciencedirect.com/science/article/B6V2S-51XWW14-3/2/346cace4ef33b51fc47c229ffc3a7a5d. (Subscription may be required.)

"The CO2QUALSTORE guideline for selection, characterization and qualification of sites and projects for geological storage of CO_2." The following is from the Abstract of this article: "The CO2QUALSTORE guideline has been developed by DNV in collaboration with industrial partners and

with input from a number of national regulators. The guideline is globally applicable and adopts a risk based approach to the selection, characterization and qualification of sites and projects for geological storage of CO_2. This article summarizes the guideline and describes how the document may assist project developers in passing project management milestones during a CO_2 storage project life cycle, simultaneously demonstrating compliance with regulations and stakeholder expectations. A primary objective of the qualification workflow contained in the guideline is to assist operators, authorities, verifiers and other stakeholders in assuring that storage sites are qualified following a transparent, consistent and cost-effective process. The guideline lays the groundwork for a risk-based approach where monitoring programs and contingency measures are derived from preceding risk assessments." **Michael Carpenter, Knut Kvien, and Jørg Aarnes**, *International Journal of Greenhouse Gas Control*, Available online January 22, 2011, doi:10.1016/j.ijggc.2010.12.005, http://www.sciencedirect.com/science/article/B83WP-520VCVK-1/2/1866ad069ff1b6bf0e22d8b7920fa38e. (Subscription may be required.)

April 2011

***Carbon Capture Journal*, "International Experts to Guide CCS Regulatory Review in Alberta."** A panel of international experts will help guide a CCS Regulatory Framework Assessment that will examine the environmental, safety, and assurance CCS processes that exist in the Canadian province of Alberta. In addition, the assessment will determine if any new processes need to be implemented for commercial-scale deployment. The six-member panel will review Alberta's existing regulatory regime and CCS frameworks from other jurisdictions, and also focus on areas including regulatory, environmental, geological, and technical considerations, as well as [monitoring, verification, and accounting (MVA)] requirements. A steering committee will oversee the process and guide the scope of the review, and working groups will develop recommendations for the steering committee's consideration. March 11, 2011, http://www.carboncapturejournal.com/displaynews.php?NewsID=755.

"Assessing the risk for CO_2 transportation within CCS projects, CFD [modeling]." The following is the Abstract of this article: ~~S~~Surface transportation of [CO_2] will be a critical issue in the developing field of CCS. A [release] from a high-pressure transportation facility can result in damage to the environment and hazard to people, depending on the total amount of [CO_2] released to the atmosphere and the concentrations achieved in the proximity of the [release]. Generic Risk Assessments for CO_2 transportation to date have relied on various assumptions about the behavior of [CO_2] after a severe pressure drop. In this study, simulations by two classes of atmospheric dispersion model (Gaussian and computational fluid dynamics, CFD) have been compared, taking representative input parameters concerning high-pressure CO_2 releases from the literature. The CFD model was used to simulate a high-speed release with specified velocities with the aim of evaluating the effect of initial gas dispersion on the downwind length reached by toxic concentrations of the pollutant. Results of this investigation depict a lowering of the Risk involved in the transportation of CO_2 by up to one order of magnitude, when modeling the same releases with a CFD tool, compared to the more widespread Gaussian models. The EU used results from Gaussian modeling for drawing up an Impact Assessment on the CO_2 transportation within CCS. In this paper, suggestions for future preparation of CCS Risk Assessments are presented." **Alberto Mazzoldi, Tim Hill, Jeremy J. Colls**, *International Journal of Greenhouse Gas Control*, Available online February 1, 2011, doi:10.1016/j.ijggc.2011.01.001, http://www.sciencedirect.com/science/article/B83WP-522Y7XF-1/2/e730734ac18832a042720bd726fb0605. (Subscription may be required.)

"The social and political complexities of learning in CCS demonstration projects." The following is the Abstract of this article: ~~D~~Demonstration of a fully integrated power plant with CCS at scale has not yet been achieved, despite growing international political interest in the potential of the technology to contribute to climate change mitigation and calls from multiple constituents for more demonstration projects. Acknowledging the scale of learning that still must occur for the technology to advance towards deployment, multiple CCS demonstration projects of various scales are emerging globally. Current plans

for learning and knowledge sharing associated with demonstration projects, however, seem to be limited and narrowly conceived, raising questions about whether the projects will deliver on the expectations raised. Through a comparison of the structure, framing and socio-political context of three different CCS demonstration projects in different places and contexts, this paper explores the complexity of social learning associated with demonstration projects. Variety in expectations of the demonstration projects' objectives, learning processes, information sharing mechanisms, public engagement initiatives, financing and collaborative partnerships are highlighted. The comparison shows that multiple factors including the process of building support for the project, the governance context and the framing of the project matter for the learning in demonstration projects. This analysis supports a broader conceptualization of learning than that currently found in CCS demonstration plans – a result with implications for both future research and practice." **Nils Markusson, Atsushi Ishii, and Jennie C. Stephens**, *Global Environmental Change*, Available online February 26, 2011, doi:10.1016/j.gloenvcha.2011.01.010, http://www.sciencedirect.com/science/article/B6VFV-5288NV3-1/2/a501e17f05e69c12e500091832968c0d. (Subscription may be required.)

"Characterizing the international carbon capture and storage community." The following is the Abstract of this article: ~~C~~CCS is a climate change mitigation technology that has been receiving increased public and private investment over the past decade in several countries. During this time, a diverse international network of professionals focused on the advancement of CCS technology has emerged. Within this international CCS community, a shared perception of the value of advancing CCS technology is generally assumed, and this community has been influential in lobbying for increased support for the development of CCS in many countries and at the international level. The phenomenon of an apparently shared perspective within a specific community relates to Haas' (1992a) description of the evolution of an epistemic community, or a knowledge-based network of recognized experts who ~~n~~not only hold in common a set of principled and causal beliefs but also have shared notions of validity and a shared policy enterprise". Understanding the extent to which a given community can be characterized as an epistemic community can provide insights about the effectiveness of its policy intervention, its association with the broader public, and the success of communicating the messages that it wants to convey. The goal of this research is to begin to explore the nature of the CCS community; to provide a preliminary characterization of the community, and to consider whether and in what ways the community might be considered to be an epistemic community or a compilation of multiple different epistemic communities. This characterization suggests that although the CCS community may be influencing decision-makers and successfully garnering political support for advancing CCS technology, a potential disconnect with the concerns of a broader public is deserving of more attention and social science research." **Jennie C. Stephens, Anders Hansson, Yue Liu, Heleen de Coninck, and Shalini Vajjhala**, *Global Environmental Change*, Available online February 18, 2011, doi:10.1016/j.gloenvcha.2011.01.008, http://www.sciencedirect.com/science/article/B6VFV-526KFDC-1/2/b418228459d108ebdcbe246bd9f13c07. (Subscription may be required.)

May 2011

***Reuters*, "German Cabinet Relaunches Carbon Storage Bill,"** and ***PhysOrg*, "German Cabinet Approves CO_2 Storage Bill."** The Federal Environment Ministry of Germany has relaunched legislation to back development of CCS technology needed for coal-fired power generation. The draft bill will lay the foundation for testing and demonstration efforts, allowing pilot and demonstration projects to move forward ahead of a viability assessment in 2017. The bill implements a directive from the European Union (EU), and also includes a clause giving Germany's 16 states input on where potential storage sites will be located. If passed by the lower house of parliament, the law would then need to be approved by the upper house, which represents states. April 13, 2011, http://www.reuters.com/article/2011/04/13/us-germany-carbon-storagebill-idUSTRE73C2F520110413, and April 13, 2011, http://www.physorg.com/news/2011-04-german-cabinet-co2-storage-bill.html.

"Carbon capture and storage policy in the United States: A new coalition endeavors to change existing policy." The following is the Abstract of this article: "CCS is considered by some to be a promising technology to reduce [GHG] emissions, and advocates are seeking policies to facilitate its deployment. Unlike many countries, which approach the development of policies for geologic storage (GS) of CO_2 with nearly a blank slate, the [United States] already has a mature policy regime devoted to the injection of CO_2 into deep geologic formations. However, the existing governance of CO_2 injection is designed to manage EOR, and policy changes would be needed to manage the risks and benefits of CO_2 injection for the purpose of avoiding GHG emissions. [The authors] review GS policy developments at both the U.S. [Federal] and state levels, including original research on state GS policy development. By applying advocacy coalition framework theory, [the authors] identify two competing coalitions defined by their beliefs about the primary purpose of CO_2 injection: energy supply or GHG emission reductions. The established energy coalition is the beneficiary of the current policy regime. Their vision of GS policy is protective: to minimize harm to fossil energy industries *if* climate policy were to be enacted. In contrast, the newly formed climate coalition seeks to change existing GS policy to support their proactive vision: to maximize GHG reductions using CCS *when* climate policy is enacted. [The authors] explore where and at what scale legislation emerges and examine which institutions gain prominence as drivers of policy change. Through a detailed textual analysis of the content of state GS legislation, [the authors] find that the energy coalition has had greater success than the climate coalition in shaping state laws to align with its policy preferences. It has enshrined its view of the purpose of CO_2 injection in state legislation, delegated authority for GS to state agencies aligned with the existing policy regime, and protected the EOR status quo, while creating new opportunities for EOR operators to profit from the storage of CO_2. The climate coalition's objective of proactively putting GS policy in place has been furthered, and important progress has been made on commonly held concerns, such as the resolution of property rights issues, but the net result is policy change that does not significantly revise the existing policy regime." **Melisa Pollak, Sarah Johnson Phillips, and Shalini Vajjhala**, *Global Environmental Change*, Available online March 25, 2011, doi:10.1016/j.gloenvcha.2011.01.009, http://www.sciencedirect.com/science/article/B6VFV-52G1RVM-1/2/6d935921b13797f5d23a956261a5088c. (Subscription may be required.)

"The socio-political context for deploying CCS in China and the U.S." The following is the Abstract of this article: "Together, the [United States] and China emit roughly 40 [percent] of world's [GHG] emissions, and these nations have stated their desire to reduce absolute emissions (U.S.) or reduce the carbon intensity of the economy (China). However, both countries are dependent on coal for a large portion of their energy needs, which is projected to continue over the next several decades. They also have large amounts of coal resources, coal-dependent electricity production, and in China's case, extensive use of coal in the industrial sector, making any shift from coal socio-politically difficult. Both nations could use CCS technologies to simultaneously decrease [GHG] emissions and continue the use of domestic coal resources; however, the socio-political context for CCS deployment differs substantially between the two countries and potentially makes large-scale CCS deployment challenging. Here, [the authors] examine and compare the political and institutional contexts shaping CCS policy and CCS deployment, both for initial pilot projects and for the creation of large-scale CCS technology deployment, and analyze how the socio-political context for CCS in China and the United States aligns with national climate, energy security, and economic priorities." **Elizabeth Wilson, Dongjie Zhang, and Li Zheng**, *Global Environmental Change*, Available online March 26, 2011, doi:10.1016/j.gloenvcha.2011.01.012, http://www.sciencedirect.com/science/article/B6VFV-52G7HR6-1/2/d71d91ba05b0e46d31dc45aeb342d8ff. (Subscription may be required.)

"Analysis of Carbon Capture and Sequestration Pore Space Legislation: A Review of Existing and Possible Regimes." The following is the Abstract of this article: "State-level CCS legislation, especially related to pore space designation, has blossomed over the last few years. However, the legislation that has passed does not yet provide an environment that would lead to the successful commercialization of CCS. Allowing the [Federal] government to assume pore space ownership would not solve all the problems, but would certainly simplify some of them by reducing the amount of future litigation."

Elizabeth Lokey Aldrich and Cassandra Koerner, *The Electricity Journal*, Available online March 29, 2011, doi:10.1016/j.tej.2011.03.001, http://www.sciencedirect.com/science/article/B6VSS-52GWV1V-2/2/afb27ac92c284e6b1b51815b049459f0. (Subscription may be required.)

June 2011

***Government of Alberta News Release*, "New Regulations Help Enable Carbon Storage."** A new regulation, titled the "Carbon Sequestration Tenure Regulation," establishes the process for companies to seek tenure rights to evaluate potential carbon storage sites. Under the regulation, which is expected to guide how large-scale CCS projects will proceed in Alberta, companies will apply for pore space tenure following the same model that is currently in place for petroleum and natural gas rights. In addition, the regulation sets out several administrative details and processes that include establishing a five-year evaluation permit to determine storage site suitability; establishing a 15-year storage lease for longer term commercial needs; and requiring permit and lease holders to submit MVA plans, which must be approved and updated every three years. April 28, 2011, http://alberta.ca/home/NewsFrame.cfm?ReleaseID=/acn/201104/302889DAAB79F-0A5B-1418-BA33BB135909F2D8.html.

"Carbon Capture and Sequestration: The U.S. Department of Energy's R&D Efforts to Characterize Opportunities for Deep Geologic Storage of Carbon Dioxide in Offshore Resources." The following is the Abstract of this article: "DOE is the lead Federal agency for the research, development, demonstration, and deployment (RDD&D) of carbon sequestration technologies. This effort is being implemented through several activities, including applied R&D, demonstration projects, and technical support to loan guarantee and tax incentives programs. The sequestration program started in 1997 and has grown significantly. In Fiscal Year 2010, $145 million in Federal funding was received to support CCS-related R&D. The Sequestration Program also received $80 million in funding from the 2009 American Recovery and Reinvestment Act (ARRA) to support the development of resources for geologic storage of CO_2. The goal of the program is to develop a suite of technologies that can support the implementation of commercial CCS projects by 2020. Part of the program funding is being used to assess the potential for storing CO_2 in offshore geologic formations. This paper presents an overview of projects awarded to assess the potential for geologic storage in state and Federal waters in the Gulf of Mexico (GOM), the Atlantic and Pacific Oceans, and in Texas and California state territorial waters, as well as research efforts DOE is supporting world-wide. These efforts are aimed at capacity assessments; monitoring and modeling of sub-seabed storage projects; characterization of projects that are drilling wells and conducting seismic surveys; and assessment of regulatory gaps relative to storing CO_2 in offshore formations. The results are expected to provide a summary of basin-scale suitability and will identify and prioritize potential offshore CO_2 geological storage opportunities." **J.T. Litynski, B.M. Brown, D.M. Vikara, R.D. Srivastava**. Presented at the Offshore Technology Conference, held May 2-5, 2011, in Houston, Texas, http://www.onepetro.org/mslib/app/Preview.do?paperNumber=OTC-21987-MS&societyCode=OTC.

July 2011

***DNV Press Release*, "New DNV Well Integrity Guideline Provides Solution to CO_2 Storage Challenges."** Det Norske Veritas (DNV) released a new guideline for CCS projects, describing a framework process for managing the risks associated with existing wells at both onshore and offshore CO_2 storage sites. When coupled with the previously released CO2QUALSTORE guideline, the CO2WELLS guideline provides a process for CCS projects designed to qualify geologic storage sites through risk and uncertainty reducing measures. The guideline includes direction on: (1) risk assessment of active and abandoned wells during the initial screening of candidate storage sites, and (2) the qualification of wells for continued or modified use in a CCS project. The guideline is consistent with the ISO31000 international standard for risk management and current and emerging regulations for CO_2

geologic storage in the United States, Canada, Europe, and Australia. The CO2WELLS guideline is available for download at: http://www.dnv.com/binaries/CO2WELLS_guideline_tcm4-465269.pdf. July 14, 2011, http://www.dnv.com/press_area/press_releases/2011/newdnvwellintegrityguidelineprovidessolutiontoco2storagechallenges.asp.

"Influencing attitudes towards carbon capture and sequestration: a social marketing approach." The following is the Abstract of this article: "[CCS] is seen as promising because it will allow the United States to continue using its vast fossil fuel resources in a carbon constrained world. The public is an important stakeholder in the national debate about whether or not the [United States] should include CCS as a significant part of its climate change strategy. Understanding how to effectively engage with the public about CCS has become important in recent years, as interest in the technology has intensified. [The authors] argue that engagement efforts should be focused on places where CCS will first be deployed, i.e. places with many 'energy veteran' (EV) citizens. [The authors] also argue that, in addition to information on CCS, messages with emotional appeal may be necessary in order to engage the public. In this paper [the authors] take a citizen-guided social marketing approach towards understanding how to (positively or negatively) influence EV citizens' attitudes towards CCS. [The authors] develop open-ended interview protocols, and a 'CCS campaign activity,' for Wyoming residents from Gillette and Rock Springs. [The authors] conclude that [their] participants believed expert-informed CCS messages, embedded within an emotionally self-referent (ESR) framework that was relevant to Wyoming, to be more persuasive than the expert messages alone. The appeal to core values of Wyomingites played a significant role in the citizen-guided CCS messages." **Gabrielle Wong-Parodi, Hadi Dowlatabadi, Tim McDaniels, and Isha Ray**, *Environ. Sci. Technol.*, Available online July 5, 2011, DOI:10.1021/es201391g, http://pubs.acs.org/doi/abs/10.1021/es201391g. (Subscription may be required.)

"Public perceptions of CCS: Emergent themes in pan-European focus groups and implications for communications." The following is the Abstract of this article: "This paper reports on European public perceptions of CCS as determined through six focus groups, one held in each of the UK, the Netherlands, Poland, Germany, Belgium and Spain. The development of opinion and the emergence of concerns were observed via phased exposure to a specially commissioned film providing an overview of CCS technology, its rationale and associated debates, supplemented by additional information on national energy mixes. In general there was a high level of commonality in opinion and concerns across the six countries, with only minor differences. The concerns that emerged were not allayed by the information provided. On the contrary, there was evidence of a shift from initial uncertainty about CCS to negative positions. CCS was generally perceived as an uncertain, end-of-pipe technology that will perpetuate fossil-fuel dependence. Noting the political context to CCS, [the authors] conclude that advocates will likely find the European public opinion context a challenging one in which to achieve deployment, particularly for onshore storage, except where local communities perceive real economic or other benefits to CCS." **Paul Upham and Thomas Roberts**, *International Journal of Greenhouse Gas Control*, Available online July 6, 2011, doi:10.1016/j.ijggc.2011.06.005, http://www.sciencedirect.com/science/article/pii/S1750583611001149. (Subscription may be required.)

August 2011

***SustainableBusiness.com*, "ISO Releases Greenhouse Gas Verification Standard."** The International Organization for Standardization (ISO) has released a new standard for achieving consistency in the global carbon market and maintaining public confidence in greenhouse gas (GHG) reporting. ISO 14066, which provides guidance on the level of competency required by individuals responsible for verifying GHG emissions, lays out detailed lists of the skills and knowledge that must be possessed by the auditing team. ISO 14066 is the latest of a three-part standard for assessing potential climate change and GHG emissions; these were launched in 2006 with ISO 14064, which focused on assessing GHG emission reduction projects in either voluntary or regulatory schemes. ISO 14065

followed, giving accreditation requirements for organizations that validate or verify resulting GHG emission assertions or claims. August 2, 2011, http://www.sustainablebusiness.com/index.cfm/go/news.display/id/22726.

***U.S. EPA News Release*, "EPA Takes Action on Reducing Barriers to the Use of Carbon Capture and Sequestration Technologies."** The U.S. Environmental Protection Agency (EPA) is proposing a rule to advance the use of CCS technologies while protecting the health and safety of the public and the environment. Under the proposal, CO_2 streams that are injected for geologic storage in wells designated for this purpose under the Safe Drinking Water Act (SDWA) will be excluded from EPA's hazardous waste regulations in an effort to reduce barriers to the use of CCS technologies. According to EPA's review of existing regulatory programs, this proposal concludes that the management of CO_2 streams under the proposed conditions does not present a substantial risk to people's health or to the environment; provides regulatory certainty to industries considering the use of CCS technologies; and encourages the deployment of CCS technologies in a safe, environmentally protective manner. EPA will accept public comments on the proposal for 60 days following publication in the Federal Register. For more information on the proposed rule, visit: http://www.epa.gov/epawaste/nonhaz/industrial/geo-sequester/index.htm. August 4, 2011, http://yosemite.epa.gov/opa/admpress.nsf/1e5ab1124055f3b28525781f0042ed40/fde8d083af16268e852578e10080f49b!OpenDocument.

"Development of a scalable infrastructure model for planning electricity generation and CO_2 mitigation strategies under mandated reduction of GHG emission." The following is the Abstract of this article: ~~I~~n a power-generation system, power plants as major CO_2 sources may be widely separated, so they must be connected into a comprehensive network to manage both electricity and CO_2 simultaneously and efficiently. In this study, a scalable infrastructure model is developed for planning electricity generation and CO_2 mitigation (EGCM) strategies under the mandated reduction of GHG emission. The EGCM infrastructure model is applied to case studies of Korean energy and CO_2 scenarios in 2020; these cases consider combinations of prices of carbon credit and total electricity demand fulfilled by combustion power plants. The results highlight the importance of systematic planning for a scalable infrastructure by examining the sensitivity of the EGCM infrastructure. The results will be useful both to help decision makers establish a power-generation plan, and to identify appropriate strategies to respond to climate change." **Jee-Hoon Han and In-Beum Lee**, *Applied Energy*, Available online August 3, 2011, doi:10.1016/j.apenergy.2011.07.010, http://www.sciencedirect.com/science/article/pii/S0306261911004557. (Subscription may be required.)

Geology

September 2010

"Adsorption and strain: The CO_2-induced swelling of coal." The following is the Abstract of this article: ~~E~~nhanced coal bed methane recovery (ECBM) consists in injecting CO_2 in coal bed methane reservoirs in order to facilitate the recovery of the methane. The injected CO_2 gets adsorbed at the surface of the coal pores, which causes the coal to swell. This swelling in confined conditions leads to a closure of the coal reservoir cleat system, which hinders further injection. In this work [the authors] provide a comprehensive framework to calculate the macroscopic strains induced by adsorption in a porous medium from the molecular level. Using a thermodynamic approach [the authors] extend the realm of poromechanics to surface energy and surface stress. [The authors] then focus on how the surface stress is modified by adsorption and on how to estimate adsorption behavior with molecular simulations. The developed framework is here applied to the specific case of the swelling of CO_2-injected coal, although it is relevant to any problem in which adsorption in a porous medium causes strains." **M. Vandamme, L. Brochard, B. Lecampion, and O. Coussy**, *Journal of the Mechanics and Physics of Solids*, Available online July 21, 2010, doi:10.1016/j.jmps.2010.07.014,

http://www.sciencedirect.com/science/article/B6TXB-50KC70F-2/2/4b43148b0af4dfb43140abf414eedb4e. (Subscription may be required.)

"Coal lithotypes before and after saturation with CO_2; insights from micro- and mesoporosity, fluidity, and functional group distribution." The following is the Abstract of this article: "Four lithotypes, vitrain, bright clarain, clarain, and fusain, were hand-picked from the core of the Pennsylvanian Springfield Coal Member (Petersburg Formation) in Illinois. These lithotypes were analyzed petrographically and for meso- and micropore characteristics, functional group distribution using FTIR techniques, and fluidity. High-pressure CO_2 adsorption isotherm analyses of these lithotypes were performed and, subsequently, all samples were reanalyzed in order to investigate the effects of CO_2. After the high-pressure adsorption isotherm analysis was conducted and the samples were reanalyzed, there was a decrease in BET surface area for vitrain from 31.5 m^2/g in the original sample to 28.5 m^2/g, as determined by low-pressure nitrogen adsorption. Bright clarain and clarain recorded a minimal decrease in BET surface area, whereas for fusain there was an increase from 6.6 m^2/g to 7.9 m^2/g. Using low-pressure CO_2 adsorption techniques, a small decrease in the quantity of the adsorbed CO_2 is recorded for vitrain and bright clarain, no difference is observed for clarain, and there is an increase in the quantity of the adsorbed CO_2 for fusain. Comparison of the FTIR spectra before and after CO_2 injection for all lithotypes showed no differences with respect to functional group distribution, testifying against chemical nature of CO_2 adsorption. Gieseler plastometry shows that: 1) softening temperature is higher for the post-CO_2 sample (389.5°C vs. 386°C); 2) solidification temperature is lower for the post-CO_2 sample (443.5°C vs. 451°C); and 3) the maximum fluidity is significantly lower for the post-CO_2 sample (4 ddpm vs. 14 ddpm)." **M. Mastalerz, A. Drobniak, R. Walker, and D. Morse**, *International Journal of Coal Geology*, Available online July 8, 2010, doi:10.1016/j.coal.2010.06.007, http://www.sciencedirect.com/science/article/B6V8C-50GMM7D-1/2/beabee1ae1c77a9901fa9ad4c23ef984. (Subscription may be required.)

"Corrective measures based on pressure control strategies for CO_2 geological storage in deep aquifers." The following is the Abstract of this article: "A prerequisite to the wide deployment at an industrial scale of CO_2 geological storage is demonstrating that potential risks can be efficiently managed. Corrective measures in case of significant irregularities, such as CO_2 leakage, are hence required as advocated by the recent European directive on CCS operations. In this regard, the objective of the present paper is to investigate four different corrective measures aiming at controlling the overpressure induced by the injection operations in the reservoir: stopping the CO_2 injection and relying on the natural pressure recovery in the reservoir; extracting the stored CO_2 at the injection well; extracting brine at a distant well while stopping the CO_2 injection, and extracting at a distant well without stopping the CO_2 injection. The efficiency of the measures is assessed using multi-phase fluid flow numerical simulations. The application case is the deep carbonate aquifer of the Dogger geological unit in the Paris Basin. A comparative study between the four corrective measures is then carried using a cost-benefit approach. Results show that an efficient overpressure reduction can be achieved by simply shutting-in the well. The overpressure reduction can be significantly accelerated by means of fluid extraction but the adverse consequences are the associated higher costs of the intervention operations." **Thomas Le Guénan and Jérémy Rohmer**, *International Journal of Greenhouse Gas Control*, Available online June 19, 2010, doi:10.1016/j.ijggc.2010.05.009, http://www.sciencedirect.com/science/article/B83WP-50BKNG7-1/2/f52e3435cd1bc8a753209878ef714523. (Subscription may be required.)

October 2010

"Study of Caprock Integrity in Geosequestration of Carbon Dioxide." The following is the Abstract of this article: "The Industrial Revolution has led to a substantial increase in the emission of [GHGs] like CO_2 into the atmosphere, exacerbating the global warming phenomenon. One option to mitigate GHG emission is by capturing and safely storing the CO_2 in suitable deep underground geological formations. This paper provides a literature review on the potential changes in the fluid flow and strength behavior of

the sedimentary reservoir and caprock rock caused by the injected CO_2 under in-situ conditions, highlighting the factors that can potentially hamper the caprock's integrity. A 2D axisymmetric numerical model of an ideal CO_2 reservoir with 30 years of injection and 70 years of monitoring phase is also presented. The model results suggest that, for the parametric values and reservoir conditions used in the model, the injection pressure leads to an increase in pore-pressure, hence reducing the effective stress in the formation. An induced vertical displacement of less than 3 mm is observed at the caprock-reservoir interface at the end of the 100 years period. The observed relationships between injection pressure, effective stress and total displacement are also discussed." **R. Shukla, P. G. Ranjith, S. K. Choi, and A. Haque**, *International Journal of Geomechanics*, Available online July 31, 2010, doi: 10.1061/(ASCE)GM.1943-5622.0000015, http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=IJGNXX000001000001000041000001&idtype=cvips&gifs=yes&ref=no. (Subscription may be required.)

"Assessing drilling mud and technical fluid contamination in rock core and brine samples intended for microbiological monitoring at the CO_2 storage site in Ketzin using fluorescent dye tracers." The following is the Abstract of this article: "The CO_2SINK project in Ketzin represents a field laboratory for the storage of CO_2 in a 650-m deep saline aquifer. The project is accompanied by a microbiological monitoring program to characterize the composition and activity of the autochthonous microbial community in rock and brine samples and their changes in response to CO_2 storage. A prerequisite of these studies is the acquisition of samples free of contamination from microorganisms and organic and inorganic components. Drilling mud and technical fluids are the main sources of contamination. This study describes the application of the fluorescent dye tracers fluorescein and rhodamine B as contamination controls for rock core and brine samples. Fluorescein was added to drilling mud that was used during the coring phase of the Ketzin wells Ktzi 200, 201 and 202. In addition, total organic carbon (TOC) concentrations, reflecting the carboxymethyl cellulose (CMC) component of the drilling mud, were determined to verify the tracer results. The fluorescence and TOC analyses revealed that drilling mud filtrate penetrated the outer 20 mm of mildly permeable sandstone cores. Rhodamine B was added to brines that were used to displace the drilling mud and to flush the wells after completion. The tracer monitoring during the discharge of drilling mud and displacement brines from the wells during hydraulic tests and nitrogen lifts enabled the quantification of reservoir fluid quality. After the production of 140–190 m^3 (16–21 borehole volumes) of fluid, the drilling mud concentration was reduced to about 0.05 [percent]. The use of fluorescein emerged as a field-capable, sensitive and reliable method during the sampling of rock core and formation brine samples." **Maren Wandrey, Daria Morozova, Michael Zettlitzer, Hilke Würdemann, and the CO_2SINK Group**, *International Journal of Greenhouse Gas Control*, Available online August 21, 2010, doi:10.1016/j.ijggc.2010.05.012, http://www.sciencedirect.com/science/article/B83WP-50V4VW9-1/2/9cf9b4464b637edc916b295e6a2d9f70. (Subscription may be required.)

"Swelling and sorption experiments on methane, nitrogen and carbon dioxide on dry Selar Cornish coal." The following is the Abstract of this article: "Sorption isotherms of CO_2, [methane (CH_4)] and [nitrogen (N_2)] are determined at 318 K and 338 K for pressures up to 16 MPa in dry Selar Cornish coal using the manometric method. Both equilibrium sorption and desorption were measured. The desorption isotherms show that there is no hysteresis in N_2, CH_4 sorption/desorption on coal. The time to achieve equilibrium depends on the gases and is increasing in the following order: [helium (He)], N_2, CH_4, CO_2. The results show that the sorption ratio between the maximum in the excess sorption N_2:CH_4:CO_2 = 1:1.5:2.6 at 318 K and 1:1.5:2.0 at 338 K. Obtained ratios are within the range quoted in the literature. Swelling and shrinkage induced by CO_2 injection and extraction from Selar Cornish coal have been measured. The experiments have been conducted on unconfined cubic samples using strain gauges measurements at 321 K for pressures up to 4.1 MPa. It has been found that the mechanical deformation is fully reversible. The density of CO_2 in its sorbed phase, has been extrapolated from the excess sorption isotherm calculated including the swelling. The resulting value is unrealistically high. Possible reasons for this behavior are discussed in the text. Absolute sorption for CO_2 has been estimated considering also the change in the coal volume due to swelling. The resulting isotherm

calculated with or without the swelling are almost the same." **Elisa Battistutta, Patrick van Hemert, Marcin Lutynski, Hans Bruining, and Karl-Heinz Wolf**, *International Journal of Coal Geology*, Available online August 19, 2010, doi:10.1016/j.coal.2010.08.002, http://www.sciencedirect.com/science/article/B6V8C-50THX53-1/2/820923373114c329b534c8ca8729bd9c. (Subscription may be required.)

November 2010

"CO_2 storage potential of deep saline [formations]: The case of Italy." The following is the Abstract of this article: ~~—~~CCS, along with improvements in energy efficiency and a wider use of renewable resources, can represent a key instrument for the reduction of CO_2 emissions to the atmosphere. Deep saline [formations] offer the largest storage potential of all the geological CO_2 storage options and are widely distributed throughout the Earth. This study proposes that CO_2 geological storage is a viable option in Italy and provides the first systematic evaluation of the potential reservoirs in the country. An estimation of the potential CO_2 storage capacity of the selected Italian deep saline [formations] is presented. Most of the 14 identified areas lie in the major Italian sedimentary basins, i.e. the Apennine foredeep and the Adriatic foreland, which are characterized by thick accumulations of sediments. The potential reservoirs mainly comprise permeable terrigenous deep saline formations, whose capacity ranges from 30 to more than 1,300 Mt. Based on very conservative estimates these areas would be able to contain the entire volume of CO_2 emitted in Italy for at least the next [50] years. Although these evaluations have not been considered as definitive, this study highlights the great potential of such formations in terms of application of the CCS techniques, even in complex tectonic settings such as those found in Italy." **F. Donda, V. Volpi, S. Persoglia, and D. Parushev**, *International Journal of Greenhouse Gas Control*, Available online September 19, 2010, doi:10.1016/j.ijggc.2010.08.009, http://www.sciencedirect.com/science/article/B83WP-5124YMH-2/2/b345bc59ed47438842d7408e4bd810ff. (Subscription may be required.)

"High-pressure methane and carbon dioxide sorption on coal and shale samples from the Paraná Basin, Brazil." The following is the Abstract of this article: ~~—~~An experimental study has been conducted to assess the potential for coalbed methane [(CBM)] production and [CO_2] storage in coals, carbonaceous shales and source rocks in the Paraná Basin in Brazil. High-pressure sorption tests with methane and [CO_2] were performed on coal and carbonaceous shales from the Santa Terezinha Coalfield and samples from two principal petroleum source rocks. Measured excess sorption capacities ranged from 0.03 to 0.47 mmol/g for methane and 0.14 to 0.81 mmol/g for [CO_2], showing a decrease with decreasing organic matter content. Linear regression lines for methane sorption capacity vs. TOC extrapolated to approximately zero, whereas for [CO_2] the intercept of the regression line indicated a residual sorption capacity of ~0.2 mmol/g on the mineral matter. Present-day gas contents of coals collected from the first CBM well in the Santa Terezinha Coalfield correspond to 13-38 [percent] of the measured maximum sorption capacities. Carbon dioxide sorption capacities exceed methane sorption capacities by a factor of 1.9 to 6.9 for these coals. Free sorption capacities of the under-saturated coals in combination with preferential sorption of [CO_2] could favor CO_2-enhanced methane recovery and CO_2 storage in coals and shales of the study area. Based upon the calculated coal reserves, gas contents and measured sorption capacities, a total storage potential of 15.4 Gt CO_2 was estimated for an area of 20 × 40 km^2 in the Santa Terezinha coal field, assuming a combined CO_2 enhanced coalbed methane (ECBM) production and CO_2 storage operation. To fully evaluate the potential for [CO_2] storage and [CBM] production, further studies are required to assess producibility of methane and efficiency of long-term CO_2 storage in the study area." **Philipp Weniger, Wolfgang Kalkreuth, Andreas Busch, and Bernhard M. Krooss**, *International Journal of Coal Geology*, Available online August 26, 2010, doi:10.1016/j.coal.2010.08.003, http://www.sciencedirect.com/science/article/B6V8C-50W1T8B-1/2/512b3342e0aca74e91dd0851ff96faa0. (Subscription may be required.)

December 2010

"Evolution of hydrogen sulfide in sour saline [formations] during carbon dioxide sequestration." The following is the Abstract of this article: ~~"~~Many deep saline [formations] suitable for CO_2 sequestration contain measurable concentrations of hydrogen sulfide (H_2S). These [formations] are described here as sour saline [formations] and the other ones as ordinary saline [formations]. Sour saline [formations] occur wherever even minor amounts of anhydrite or other sulfate sources are present in the formation. In this paper, compositional modeling of CO_2 injection into such [formations] is studied. When CO_2 is injected into a sour saline [formation], the H_2S initially dissolved in the brine will be exsolved and released into an expanding CO_2 plume. At any time after the start of CO_2 injection, the region swept by the plume consists of two sub-regions. The first of these is an inner sub-region extending from the injection well, and is characterized by the absence of H_2S in both aqueous and gaseous phases. The dissolved H_2S in this inner sub-region is nearly completely removed from the brine via an exsolution process. The second sub-region extends from the outer edge of the inner sub-region to the leading edge of the plume. In this outer sub-region, the mole fraction of H_2S in the gas plume gradually increases toward the leading edge and reaches a peak value. While the gas plume is expanding the size of the outer sub-region enlarges. Following the discussion of these phenomena, in the next part of the paper, injection of acid gases (mixtures of H_2S and CO_2) into sour saline [formations] and ordinary saline [formations] is explored. In contrast to sour [formations], unsaturated water in an ordinary [formation] will strip away H_2S from the CO_2 stream and consequently the mole fraction of H_2S toward the gas front decreases. The highly toxic nature of H_2S gas suggests the need to account for dissolved H_2S in sour saline [formations] when establishing risk assessment, monitoring, and management strategies at CO_2 storage sites." **Seyyed M. Ghaderi, David W. Keith, Rob Lavoie, and Yuri Leonenko**, *International Journal of Greenhouse Gas Control*, Available online October 30, 2010, doi:10.1016/j.ijggc.2010.09.008, http://www.sciencedirect.com/science/article/B83WP-51BX6S1-1/2/a41558c879de83dc094bb13bf796fb42. (Subscription may be required.)

"Simultaneous CO_2 injection and water production to optimize [formation] storage capacity." The following is the Abstract of this article: ~~"~~The estimates for geologic CO_2 storage capacity worldwide vary, but it is generally believed that the capacity in saline [formations] will be sufficient for the amounts of CO_2 that will need to be stored. The effort required to select and qualify a geological storage site for safe storage will, however, be significant and storage capacity may be a limited resource regionally. Both from a economic and resource management perspective it is therefore important that potential storage sites are exploited to their full potential. In static capacity estimates, where the maximum stored amount of CO_2 is given as a fraction of the formation pore volume, typically arrive at efficiency factors in the range of a few per cents. Recent work has shown that when the dynamic behavior of the injected CO_2 is taken into account, the efficiency factor will be reduced because of the increase in pore pressure in the region around the injection well(s). The increase in pore pressure will propagate much further than the CO_2. The EU directive on geological CO_2 storage specifically addresses the restriction that will apply when different storage sites are interacting due to pressure communication. Consequently, the pore pressure increase at the boundary of the storage license area will be an important limiting factor for the amount of CO_2 that can be injected. One obvious method to control the pore pressure is to produce water from the [formation] at some distance from the CO_2 injection wells. This paper discusses results from simulations of CO_2 injection in two [formations] on the Norwegian Continental Shelf; the Johansen [formation] and the southern part of the Utsira [formation]. These [formations] are candidates for injection of CO_2 shipped out via pipeline from the Norwegian West Coast. The injected amounts of CO_2 over a period of 50 years are 0.518 Gt for the Johansen [formation] and 1.04 Gt for the Utsira [formation]. Several design options for the injection operations are investigated: Injection of CO_2 without water production; injection into several wells to distribute the injected fluids and reduce the local pressure increase around each injection well; and injection with simultaneous production of water from one or more wells. The boundaries of the formations are assumed closed in all simulations. The possible consequences of other types of boundary conditions (semi-closed or open) are briefly discussed." **Per Eirik S. Bergmo, Alv-Arne Grimstad, and Erik Lindeberg**, *International Journal of Greenhouse Gas Control*, Available online November 3, 2010,

doi:10.1016/j.ijggc.2010.09.002, http://www.sciencedirect.com/science/article/B83WP-51CRWN0-1/2/952a2238f859ddcdacff14f242b32cd6. (Subscription may be required.)

January 2011

"U.S. Department of Energy's Site Screening, Site Selection, and Initial Characterization for Storage of CO_2 in Deep Geological Formations." The following is the abstract of this article: "DOE is the lead Federal agency for the development and deployment of carbon sequestration technologies. As part of its mission to facilitate technology transfer and develop guidelines from lessons learned, DOE is developing a series of best practices manuals (BPMs) for CCS. The "Site Screening, Site Selection, and Initial Characterization for Storage of CO_2 in Deep Geological Formations" BPM is a compilation of best practices and includes flowchart diagrams illustrating the general decision making process for Site Screening, Site Selection, and Initial Characterization. The BPM integrates the knowledge gained from various programmatic efforts, with particular emphasis on the Characterization Phase through pilot-scale CO_2 injection testing of the Validation Phase of the RCSP Initiative. Key geologic and surface elements that suitable candidate storage sites should possess are identified, along with example Site Screening, Site Selection, and Initial Characterization protocols for large-scale geologic storage projects located across diverse geologic and regional settings. This manual has been written as a working document, establishing a framework and methodology for proper site selection for CO_2 geologic storage. This will be useful for future CO_2 emitters, transporters, and storage providers. It will also be of use in informing local, regional, state, and national governmental agencies of best practices in proper sequestration site selection. Furthermore, it will educate the inquisitive general public on options and processes for geologic CO_2 storage. In addition to providing best practices, the manual presents a geologic storage resource and capacity classification system. The system provides a 'standard' to communicate storage and capacity estimates, uncertainty and project development risk, data guidelines and analyses for adequate site characterization, and guidelines for reporting estimates within the classification based on each project's status." **Traci Rodosta, John Litynski, Sean Plasynski, Scott Hickman, Scott Frailey, and Larry Myer**. Presented at the 10th International Conference on Greenhouse Gas Control Technologies (GHGT-10), held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00586%2Epdf.

"The pressure impact of CO_2 storage on neighboring sites." The following is the abstract of this article: "In this paper, [the authors] present a saline [formation] showcase model from the North German Basin, predicting the regional pressure impact of a small industrial scale CO_2 storage operation on its surroundings. The static model is based on real geology while the injection program is fictitious. [The authors] simulated a rate controlled injection of 2.5 Million tons CO_2 per year through a single vertical well into the structural top of a dome shaped anticline, over a period of 10 years. The target is a 20 m thick sandstone layer intercalated in low permeability claystone sequences. [The authors] used ECLIPSE300 with its CO_2 storage module and MUFTE-UG to predict pressure at the top of the target sandstone layer in 1, 5, 10, and roughly 31 km distance to the injection point. The farthest point represents the structural top of a neighboring anticlinal dome, another favorable potential storage site. [The authors] varied the model's boundary conditions, permeability, permeability anisotropy, rock compressibility, and injection temperature. A total of nine model scenarios were run, five with MUFTE-UG and another four with ECLIPSE. Comparison of reference scenarios showed that the results of both simulators match well. In the open boundary model, pressure increase is lowest and dissipates back to the pre-injection state within 30 years after injection shutdown. In the fully closed models, pressure peaks are high, equilibrating to a remnant, model-wide overpressure several decades after the end of injection. In the distance, this equilibrated, model-wide overpressure is the actual maximum pressure. In the model scenarios which are laterally half open, half closed, pressure relief is seriously retarded in comparison to the fully open model. In all cases, the pressure maximum arrives at the neighboring structure (31 km distance) years after the actual injection shutdown. Rock compressibility impacts both the peak pressure and the speed of the pressure build-up and relief. High permeabilities are more important in the

immediate injection area than for the regional footprint. In all of our fully closed (i.e. the most pressurized) models, the remnant regional overpressure amounted to about 9 bars. If 10 bars are taken as the maximum tolerable overpressure, then the volumetric storage capacity of the target structure itself is not affected. However, injection into the target structure does affect the storage capacity of the neighboring site. While a purely volumetric approach yields a cumulative storage capacity of roughly 175 Mt for both structures, a tolerable regional overpressure of 10 bars lowers the joint storage capacity to about 32 Mt CO_2. Exactly what regional pressures are tolerable for a given [formation], however, needs to be determined on a site specific base." **Frauke Schäfer, Lena Walter, Holger Class, Christian Müller**, Presented at the 10th International Conference on Greenhouse Gas Control Technologies (GHGT-10), held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00642%2Epdf.

February 2011

"CO_2-porewater-rock reactions - Large-scale column experiment." The following is the Abstract of this article: "This study focused on the reactions between CO_2, porewater and host rock during geological CO_2 storage in deep reservoirs. The aim of this work was to provide a well-constrained laboratory experiment reacting known quantities of minerals with CO_2-rich fluids, to simulate situations where CO_2 is being injected into lithologies deep underground. The experiment was undertaken using a Ti-column, 100 cm long, held within a large pressure vessel. The column was packed with a simplified mineral assemblage. The reactant fluid was equilibrated with CO_2 at a temperature of 130°C and a pressure of 300 bar, before being pumped into the column held under the same conditions. Fluid was passed along the column at a constant flow rate for approximately 3.5 months. Fluids collected from the outlet end of the column were analyzed to provide data on the fate of the dissolved species. On completion of the experiment, the column was then examined for mineralogical changes. The experimental results can be used as a test case for predictive geochemical computer modelling. Such models will help improve [the] ability to predict the long-term fate of CO_2 stored underground." **Keith Bateman, Christopher Rochelle, Alicja Lacinska, and Doris Wagner**. Presented at GHGT-10, held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00149%2Epdf.

"Effect of time on the carbonation reaction of saline aquifers with controlled pH." The following is the Abstract of this article: "This work investigated the effect of time on the carbonation reaction in synthetic saline solution, under mild conditions and with a controlled pH, aiming the mineral trapping of CO_2 on saline aquifers. The experiments were performed in a glass reactor at 40°C, [six] hours and atmospheric pressure. The saline solution and solid phase were characterized by Flame Atomic Absorption Spectroscopy (FAAS), Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR). This work demonstrated that the saline solution pH lowers to approximately 7-8 in the first hour of reaction (initial pH of approximately 10), remaining constant until the end of the reaction. Through the analysis by AAS, it was found that the concentration of [calcium (Ca)] ions in the brine decreases with time. A greatest reduction in the Ca ions concentration occurs within the first two hours of reaction, remaining constant in the others hours. The [magnesium (Mg)] concentration showed the trend of the final concentration remains close to initial concentration, even with the carbonates precipitation. SEM analysis indicated that the precipitates obtained had morphology similar to that found for various forms of calcium carbonate (i.e. calcite and aragonite). FTIR analysis shows characteristic bands of carbonates, which agrees with the results of the analysis by SEM." **Marta Kerber Schütz, Natália Lopes, Angélica Cenci, Rosane Ligabue, Jeane Dullius, Sandra Einloft, and João Marcelo Ketzer**. Presented at GHGT-10, held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final01199%2Epdf.

March 2011

"On the potential of CO_2-water-rock interactions for CO_2 storage using a modified kinetic model." The following is from the Abstract of this article: "During CO_2 storage, mineral trapping is the safest long-term storage mechanism, and it is therefore important to estimate the correct CO_2 portion trapped in secondary mineral phases. The storage potential for cold, quartz-rich reservoirs, hereafter termed Utsira-type reservoirs, were solved using the numerical code PHREEQC, using a rate model that took into account both nucleation and growth of secondary mineral phases. This represented a modification of earlier simulations where growth rates were calculated from dissolution rate data. Because growth rate and nucleation rate parameters were largely unknown for the secondary carbonates, [the authors] did a sensitivity study on the potential for carbonate growth on rate parameters. The simulations suggest that the total amount of CO_2 trapped as mineral carbonates is given by the amount of glauconite, chlorite, and smectite present in the reservoir prior to injection, as they were nearly completely dissolved. The fast dissolution of the silicates provided divalent cations for the growth of ankerite and siderite. The timing of precipitation and the secondary mineral assemblage were seen to be highly sensitive to the nucleation and growth rates. Moreover, at high nucleation rates, the secondary carbonates started to precipitate at fairly low supersaturations and formed rapidly after the dissolution of the primary minerals. Finally, a comparison of earlier simulations on the Utsira-type system with the present model and natural analogues, suggests that the earlier models have largely overestimated the growth potential of carbonates such as dolomite, magnesite and dawsonite." **V.T.H. Pham, P. Lu, P. Aagaard, C. Zhu, and H. Hellevang**, *International Journal of Greenhouse Gas Control*, Available online January 15, 2011, doi:10.1016/j.ijggc.2010.12.002, http://www.sciencedirect.com/science/article/B83WP-51YB6H1-1/2/bd7732c2383fd9a8510bbc2e66f5c8a3. (Subscription may be required.)

"Safe Storage Of CO_2 Together With Improved Oil Recovery By CO_2-Enriched Water Injection." The following is the Abstract of this article: "The 2007 IEA World Energy Outlook report predicts that the world's energy needs will grow by 55 [percent] from 2005 to 2030, with fossil fuels accounting for 84 [percent] of this massive projected increase in energy demand. An undesired side effect of burning fossil fuels is CO_2 emission which is now widely believed to be responsible for the problem of global warming. Various strategies are being considered for addressing the increased in demand for energy and at the same time developing technologies to make energy greener by reducing CO_2 emissions. One of these strategies is to 'capture' produced CO_2 instead of releasing it into the atmosphere. Capturing CO_2 and its injection in oil reservoirs can lead to improved oil recovery as well as CO_2 retention and storage in these reservoirs. The technology is referred to as CCS. Large point sources of CO_2 (e.g. coal-fired power plants) are particularly good candidates for capturing large volumes of CO_2. However, CO_2 capture from power plants is currently very expensive. In addition to high costs of CO_2 capture, the very low pressure of the flue gas (1 atm) and its low CO_2 content (typically 10-15 [percent]) contribute to the high cost of CO_2 capture from power plants and the subsequent compression. This makes conventional CO_2 flooding (which requires very large volumes of CO_2) uneconomical in many oil reservoirs around the world which would otherwise be suitable candidates for CO_2 injection. Alternative strategies are therefore needed to utilize smaller sources of CO_2 that are usually available around oil and gas fields and can be captured at lower costs (due to their higher pressure and higher CO_2 concentration). [The authors] investigate the potential of carbonated (CO_2-enriched) water injection (CWI) as an injection strategy for improving recovery from oil reservoirs with the added benefit of safe storage of CO_2. The performance of CWI was investigated by conducting high-pressure flow visualization as well as coreflood experiments at reservoir conditions. The results show that CWI significantly improves oil recovery from water flooded porous media. A relatively large fraction of the injected CO_2 was retained (stored) in the porous medium in the form of dissolved CO_2 in water and oil. The results clearly demonstrate the huge potential of CWI as a productive way of utilizing CO_2 for improving oil recovery and safe storage of potentially large cumulative quantities of CO_2." **Mehran Sohrabi, Nor Idah Kechut, Masoud Riazi, Mahmoud Jamiolahmady, Shaun Ireland, and Graeme Robertson**, *Chemical Engineering Research and Design*, Available online February 5, 2011, doi:10.1016/j.cherd.2011.01.027, http://www.sciencedirect.com/science/article/B8JGF-523V3NP-3/2/908ab65aa70abf2068a0192a95725056. (Subscription may be required.)

April 2011

"Swelling of moist coal in carbon dioxide and methane." The following is the Abstract of this article: "Determining the feasibility of injecting CO_2 into coal seams for enhanced coalbed methane (ECBM) recovery as well as providing long-term carbon sequestration is an active area of research. It is now well known that coal swells in the presence of water and gases, which in turn may affect its in-seam permeability. If the swelling of the coal matrix by each component can be quantified, it may be possible to make better predictions about the suitability of particular seams for ECBM and carbon sequestration. Despite numerous studies where coal swelling has been measured in gases or water, there is relatively little information relating to how swelling of coals by gases is affected by water. In this paper [the authors] report on the gas-induced swelling behavior of four moist Australian coals. Blocks of coal, nominally 30 × 9 × 9 mm, were cut parallel and perpendicular to the bedding plane from larger lumps. Samples were moisture-equilibrated at 97 [percent] relative humidity before being exposed to CO_2 or [methane (CH_4)] at pressures up to 16 MPa and a temperature of 55°C. Swelling of each sample was measured directly using digital cameras to monitor the change in length of the block as a function of pressure. Results show that swelling was greater in CO_2 than CH_4, with lower rank coals swelling more than high rank material. The presence of moisture significantly reduced the amount of additional swelling by the gas compared to dry coals; however, the degree to which the swelling of the coals was affected by moisture depended on the rank of the coal. It was also found that, proportionally, CH_4-induced swelling was more affected by the presence of moisture than CO_2-induced swelling. Although moist coals swelled less in CO_2 or CH_4 than dry coals, if the swelling due to moisture is included, the total swelling is more than that induced by the corresponding gas in the dry coal." **Stuart Day, Robyn Fry, and Richard Sakurovs**, *International Journal of Coal Geology*, Available online February 2, 2011, doi:10.1016/j.coal.2011.01.008, http://www.sciencedirect.com/science/article/B6V8C-5236R4F-1/2/c33e38bfe1b68e5a4c0dc9fa78cf1439. (Subscription may be required.)

"Some implications of cold CO_2 injection into deep saline [formations]." The following is the Abstract of this article: "When CO_2 is injected down a well, the temperature at the bottom of the well depends on surface conditions, heat exchange with the wall of the well and pressure work within the well. Typically, the temperature of the CO_2 at the bottom of the well is lower than the local geothermal temperature. As this relatively cold CO_2 flows into the porous matrix, local thermal equilibrium manifests a thermal front, behind which the porous matrix and CO_2 adjust to the cold injection temperature. As the temperature of the injected CO_2 increases across the thermal front, the CO_2 becomes less viscous and less dense. In relatively high permeability rock, as the flow spreads from the well, it becomes buoyancy-driven, and so at the thermal front, the flow adjusts from a deep, slow flow to a relatively shallow, fast flow. The increased depth in the near source cold region has two significant implications. First, it increases the near source storage potential as more rock is flooded with CO_2, but it may also enhance the [release] into the seal rock which occurs in regions where the current is sufficiently deep for the pressure to exceed the capillary entry pressure." **W. J. Rayward-Smith and Andrew W. Woods**, *Geophysical Research Letters*, Available online March 23, 2011, doi:10.1029/2010GL046412, http://www.agu.org/pubs/crossref/2011/2010GL046412.shtml. (Subscription may be required.)

May 2011

"Enhancing serpentine dissolution kinetics for mineral carbon dioxide sequestration." The following is the Abstract of this article: "Mineral [CO_2] sequestration binds [CO_2] by reacting it with magnesium silicate minerals to form solid magnesium carbonates that are ready for disposal. Research on mineral sequestration has focused on enhancing process kinetics in aqueous processing schemes. High costs of these processes are associated with mineral processing, such as ultrafine grinding, or the consumption of acids and bases, which are required to speed up silicate mineral dissolution kinetics. Neutral organic salts such as sodium oxalate, and citrate enhance dissolution kinetics of serpentine in

the circum-neutral pH range appropriate for mineral carbonate precipitation and have potential for use in an enhanced carbonation process. Concentration and temperature dependencies for the dissolution of antigorite serpentine in the presence of the citrate ion are experimentally derived under weakly acidic conditions. Rates are shown to be several orders of magnitude higher in the presence of citrate than in the weakly acidic solution alone." **Samuel C.M. Krevor and Klaus S. Lackner**, *International Journal of Greenhouse Gas Control*, Available online February 8, 2011, doi:10.1016/j.ijggc.2011.01.006, http://www.sciencedirect.com/science/article/B83WP-524FFMD-1/2/e8cc3058889d7334225bedd24be056ba. (Subscription may be required.)

"Effect of impurity gases in carbon dioxide on sorption behavior and mineral matter in an Australian bituminous coal." The following is the Abstract of this article: ~~I~~njection of CO_2 into coal seams is considered a potential approach for sequestering it. However, the [CO_2] that is injected into seams may contain other gases that could potentially react with the coal and change its sorption behavior. Here [the authors] exposed samples of a moistened bituminous coal to small amounts of [sulfur dioxide (SO_2), water (H_2S), nitrogen dioxide (NO_2), ammonia (NH_3)] and a number of potential amine capture agents in sealed containers for up to two years, evacuated them and measured their sorption behavior and determined their mineralogy using low temperature ashing followed by quantitative X-ray diffraction analysis of the residue. Exposure of the coal to amines, H_2S or NO_2 had no effect on the sorption characteristics of the coal. However, SO_2 markedly reduced the CO_2 sorption capacity of the coal (by 25 [percent]). The minerals in the coal consisted mainly of quartz, kaolinite, illite and carbonates. Of the gases tested, only SO_2 modified the mineral matter extensively. It attacked the clays as well as carbonates, producing a range of sulfate minerals and amorphous material. This shows that the effects of SO_2 on sorption behavior and mineralogy of the coals need to be included in any prediction of sorption potential of coals if it is present in the CO_2 that is to be injected into the coal." **Richard Sakurovs, Steve Weir, David French, and Stuart Day**, *International Journal of Greenhouse Gas Control*, Available online April 9, 2011, doi:10.1016/j.coal.2011.04.001, http://www.sciencedirect.com/science/article/B6V8C-52K9DMB-1/2/84bb42ee88592ecbfbe68ff6e7b7ee51. (Subscription may be required.)

June 2011

"A review of physical [modeling] and numerical simulation of long-term geological storage of CO_2." The following is the Abstract of this article: ~~N~~umerical simulations are essential to the understanding of the long-term geological storage of CO_2. Physical [modeling] of geological storage of CO_2 has been based on Darcy's law, together with the equations of conservation of mass and energy. [Modeling] and simulations can be used to predict where CO_2 is likely to flow, to interpret the volume and spatial distribution of CO_2 under storage conditions, and to [optimize] injection operations. The state of the art of physical [modeling] and numerical simulation of CO_2 dispersion is briefly reviewed in this paper, which calls for more accurate and more efficient [modeling] approaches. A systematic evaluation of the numerical methods used and a comparison between the streamline based methods and the grid based methods would be valuable. Multi-scale [modeling] may prove to be of great value in predicting the long-term geological storage of CO_2, while highly accurate numerical methods such as high-order schemes may be employed in numerical simulations of CO_2 dispersion for local transport calculations." **Xi Jiang**, *Applied Energy*, Available online May 31, 2011, doi:10.1016/j.apenergy.2011.05.004, http://www.sciencedirect.com/science/article/pii/S0306261911002959. (Subscription may be required.)

"Permeability evolution in fractured coal: The roles of fracture geometry and water-content." The following is the Abstract of this article: ~~T~~The authors] report laboratory experiments that investigate the permeability evolution of an anthracite coal as a function of applied stress and pore pressure at room temperature as an analog to other coal types. Experiments are conducted on 2.5 cm diameter, 2.5-5 cm long cylindrical samples at confining stresses of 6 to 12 MPa. Permeability and sorption characteristics are measured by pulse transient methods, together with axial and volumetric strains for both inert (helium [He]) and strongly adsorbing (methane [CH_4] and CO_2) gases. To explore the interaction of swelling and fracture geometry [the authors]measure the evolution of mechanical and transport characteristics for

three separate geometries — sample A containing multiple small embedded fractures, sample B containing a single longitudinal through-going fracture and sample C containing a single radial through-going fracture. Experiments are conducted at constant total stress and with varied pore pressure — increases in pore pressure represent concomitant (but not necessarily equivalent) decreases in effective stress. For the samples with embedded fractures (A and C) the permeability first decreases with an increase in pressure (due to swelling and fracture constraint) and then increases near-linearly (due to the over-riding influence of effective stresses). Conversely, this turnaround in permeability from decreasing to increasing with increasing pore pressure is absent in the discretely fractured sample (B) — the influence of the constraint of the connecting fracture bridges in limiting fracture deformation is importantly absent as supported by theoretical considerations. Under water saturated conditions, the initial permeabilities to all gases are nearly two orders of magnitude lower than for dry coal and permeabilities increase with increasing pore pressure for all samples and at all gas pressures. [The authors] also find that the sorption capacities and swelling strains are significantly reduced for water saturated samples — maybe identifying the lack of swelling as the primary reason for the lack of permeability decrease. Finally, [the authors] report the weakening effects of gas sorption on the strength of coal samples by loading the cores to failure. Results surprisingly show that the strength of the intact coal (sample A) is smaller than that of the axially fractured coal (sample B) due to the extended duration of exposure to CH_4 and CO_2. Average post-failure particle size for the weakest intact sample (A) is found to be three times larger than that of the sample B, based on the sieve analyses from the samples after failure. [The authors] observe that fracture network geometry and saturation state exert important influences on the permeability evolution and strength of coal under in situ conditions." **Shugang Wang, Derek Elsworth, and Jishan Liu**, *International Journal of Coal Geology*, Available online May 1, 2011, doi:10.1016/j.coal.2011.04.009, http://www.sciencedirect.com/science/article/pii/S0166516211000851. (Subscription may be required.)

July 2011

"A natural analogue for CO_2 mineral sequestration in Miocene basalt in the Kuanhsi-Chutung area, Northwestern Taiwan." The following is the Abstract of this article: ~~In~~ general, CO_2 sequestration by carbonation is estimated by laboratory experimentation and geochemical simulation. In this study, however, estimation is based on a natural analogue study of the Miocene basalt in the Kuanhsi-Chutung area, Northwestern Taiwan. This region has great potential in terms of geological and geochemical environments for CO_2 sequestration. Outcropping Miocene basalt in the study area shows extensive serpentinization and carbonation. The carbon stable isotopes of carbonates lie on the depleted side of the Lohmann meteoric calcite line, which demonstrates that the carbonates most probably precipitate directly from meteoric fluid, and water–rock interaction is less involved in the carbonation process. Oxygen stable isotope examinations also show much depleted ratios, representative of product formation under low temperatures (50-90°C). This translates to a depth of 1-2 km, which is a practical depth for a CO_2 sequestration reservoir. According to petrographic observation and electron microprobe analysis, the diopside grains in the basalt are resistant to serpentinization and carbonation; therefore, the fluid causing alteration is likely enriched with calcium and there must be additional sources of calcium for carbon mineralization. These derived geochemical properties of the fluid support the late Miocene sandstone and enclosed basalts as having high potential for being a CO_2 sequestration reservoir. Moreover, the existing geochemical environments allow for mineralogical assemblages of ultramafic xenoliths, indicating that forsterite, orthopyroxene and feldspar minerals are readily replaced by carbonates. Based on the mineral transformation in xenoliths, the capacity of CO_2 mineral sequestration of the Miocene basalt is semi-quantitatively estimated at 94.15 kg CO_2 chemically trapped per 1 m^3 basalt. With this value, total CO_2 sequestration capacity can be evaluated by a geophysical survey of the amount of viable Miocene basalt at the potential sites. Such a survey is required in the near future." **Hsueh-Yu Lu, Cheng-Kuo Lin, Wayne Lin, Tai-Sheng Liou, Wen-Fu Chen, and Ping-Yu Chang**, *International Journal of Greenhouse Gas Control*, Available online June 28, 2011, doi:10.1016/j.ijggc.2011.05.037, http://www.sciencedirect.com/science/article/pii/S1750583611000971. (Subscription may be required.)

"In Situ Infrared Spectroscopic Study of Forsterite Carbonation in Wet Supercritical CO_2." The following is the Abstract of this article: "Carbonation reactions are central to the prospect of CO_2 trapping by mineralization in geologic reservoirs. In contrast to the relevant aqueous-mediated reactions, little is known about the propensity for carbonation in the key partner fluid: supercritical [CO_2] containing dissolved water ('wet' $scCO_2$). [The authors] employed in situ mid-infrared spectroscopy to follow the reaction of a model silicate mineral (forsterite, Mg_2SiO_4) for 24 [hours] with wet $scCO_2$ at 50°C and 180 atm. The results show a dramatic dependence of reactivity on water concentration and the presence of liquid water on the forsterite particles. Exposure to neat $scCO_2$ showed no detectable carbonation reaction. At 47 [percent] and 81 [percent] water saturation, an ngstrom-thick liquid-like water film was detected on the forsterite particles and less than 1 [percent] of the forsterite transformed. Most of the reaction occurred within the first [three hours] of exposure to the fluid. In experiments at 95 [percent] saturation and with an excess of water (36 [percent] above water saturation), a nanometer-thick water film was detected, and the carbonation reaction proceeded continuously with approximately 2 [percent] and 10 [percent] conversion, respectively. [The authors'] collective results suggest constitutive links between water concentration, water film formation, reaction rate and extent, and reaction products in wet $scCO_2$." **John S. Loring, Christopher J. Thompson, Zheming Wang, Alan G. Joly, Deborah S. Sklarew, H. Todd Schaef, Eugene S. Ilton, Kevin M. Rosso, and Andrew R. Felmy**, *Environ. Sci. Technol.*, Available online June 23, 2011, DOI:10.1021/es201284e, http://pubs.acs.org/doi/abs/10.1021/es201284e. (Subscription may be required.)

August 2011

"Supercritical carbon dioxide and sulfur in the Madison Limestone: A natural analog in southwest Wyoming for geologic carbon–sulfur co-sequestration." The following is the Abstract of this article: "The Madison Limestone on the Moxa Arch, southwest Wyoming, USA, contains large volumes (65-95 [percent]) of supercritical CO_2 that it has stored naturally for 50 million years. This reservoir also contains supercritical [hydrogen sulfide (H_2S)], aqueous sulfur complexes (SO_4^{2-} and HS^-), and sulfur-bearing minerals (anhydrite and pyrite). Although [sulfur dioxide (SO_2)] is not present, these sulfur-bearing phases are known products of SO_2 disproportionation in other water–rock systems. The natural co-occurrence of SO_4^{2-}, S^{2-}, supercritical CO_2 and brine affords the opportunity to evaluate the fate of a carbon–sulfur co-sequestration scenario. Mineralogic data was obtained from drill core and aqueous geochemical data from wells outside and within the current supercritical CO_2–sulfur–brine–rock system. In addition to dolomite, calcite, and accessory sulfur-bearing minerals, the Madison Limestone contains accessory quartz and the aluminum-bearing minerals feldspar, illite, and analcime. Dawsonite ($NaAlCO_3(OH)_2$), predicted as an important carbon sink in sequestration modeling studies, is not present. After confirming equilibrium conditions for the Madison Limestone system, reaction path models were constructed with initial conditions based on data from outside the reservoir. Addition of supercritical CO_2 to the Madison Limestone was simulated and the results compared to data from inside the reservoir. The model accurately predicts the observed mineralogy and captures the fundamental changes expected in a Madison Limestone-brine system into which CO_2 is added. The pH decreases from 5.7 to 4.5 at 90°C and to 4.0 at 110°C, as expected from dissolution of supercritical CO_2, creation of carbonic acid, and buffering by the carbonate rock. The calculated redox potential increases by 0.1 V at 90°C and 0.15 V at 110°C due to equilibrium among CO_2, anhydrite, and pyrite. Final calculated Eh and pH match conditions for the co-existing sulfur phases present in produced waters and core from within the reservoir. Total dissolved solids increase with reaction progress, mostly due to dissolution of calcite with an accompanying increase in dissolved bicarbonate. The Madison Limestone is a natural example of the thermodynamic end point that similar fluid–rock systems will develop following emplacement of a supercritical CO_2–sulfur mixture and is a natural analog for geologic carbon–sulfur co-sequestration." **John P. Kaszuba, Alexis Navarre-Sitchler, Geoffrey Thyne, Curtis Chopping, and Tom Meuzelaar**, *Earth and Planetary Science Letters*, Available online July 20, 2011, doi:10.1016/j.epsl.2011.06.033, http://www.sciencedirect.com/science/article/pii/S0012821X11004043. (Subscription may be required.)

"Dedolomitization as an analogue process for assessing the long-term behavior of a CO_2 deep geological storage: The Alicún de las Torres thermal system (Betic Cordillera, Spain)." The following is from the Abstract of this article: "The study of natural analogues represents the best source of reliable information about the expected hydrogeochemical processes involved in the CO_2 storage in such deep saline aquifers. In this work, a comprehensive study of the hydrogeochemical features and processes taking place at the natural analogue of the Alicún de las Torres thermal system (Betic Cordillera) has been conducted. Thus, the main water/CO_2/rock interaction processes occurring at the thermal system have been identified, quantified and modeled, and a principle conclusion is that the hydrogeochemical evolution of the thermal system is controlled by a global dedolomitization process triggered by gypsum dissolution. This geochemical process generates a different geochemical environment to that which would result from the exclusive dissolution of carbonates from the deep aquifer, which is generally considered as the direct result of CO_2 injection in a deep carbonate aquifer. Therefore, discounting of the dedolomitization process in any CO_2 deep geological storage may lead to erroneous conclusions. This process will also influence the porosity evolution of the CO_2 storage formation, which is a very relevant parameter when evaluating a reservoir for CO_2 storage. The geothermometric calculation performed in this work leads to estimate that the thermal water reservoir is located between 650 and 800 m depth, which is very close to the minimum required to inject CO_2 in a deep geological storage. It is clear that the proper characterization of the features and hydrogeochemical processes taking place at a natural system analogous to a man-made deep geological storage will provide useful conceptual, semi-quantitative and even quantitative information about the processes and consequences that may occur at the artificial storage system." **Antonio J. Prado-Pérez and Luís Pérez del Villar**, *Chemical Geology*, Available online August 3, 2011, doi:10.1016/j.chemgeo.2011.07.017, http://www.sciencedirect.com/science/article/pii/S0009254111003056. (Subscription may be required.)

"CarbFix: a CCS pilot project imitating and accelerating natural CO_2 sequestration." The following is the Abstract of this article: "CarbFix, a combined industrial-academic pilot program, was developed in order to assess the feasibility of *in situ* CO_2 mineral sequestration in basaltic rocks. Unique to CarbFix is its connection to the Hellisheidi geothermal power plant, allowing for capture of otherwise emitted CO_2 in addition to CO_2 transport and mineral sequestration. Extensive research has been conducted in order to characterize physical properties of the pilot injection site in Hellisheidi. Tracer tests have been carried out and continuous well-logging confirmed separation of the target formation from shallower groundwater systems. Alteration mineralogy in natural analogs has been mapped out in order to predict which minerals are likely to precipitate upon CO_2 injection. In addition to carbonates, these include clays, zeolites, and poorly crystalline hydroxides. Some of the secondary minerals will compete with carbonates for cations dissolved from the rock matrix. Numerical modeling plays an important role in the CarbFix project as it provides tools to predict and optimize long-term management of the injection site as well as to quantify the amount of CO_2 that can be mineralized. A reactive transport model has been developed and numerical simulations of the pilot CO_2 injection are ongoing. Extensive monitoring provides the basis for testing, validating, and calibrating reactive transport models. It is anticipated that the results of CarbFix will be used to optimize the *in situ* carbon mineralization process, enabling it in basalt and ultramafic rock formations throughout the world." **Edda S.P. Aradóttir, Hólmfrídur Sigurdardóttir, Bergur Sigfússon, and Einar Gunnlaugsson**, *Greenhouse Gases: Science and Technology*, Available online May 25, 2011, doi:10.1002/ghg.18, http://onlinelibrary.wiley.com/doi/10.1002/ghg.18/abstract. (Subscription may be required.)

Technology

September 2010

"Valuing national and basin level geologic CO_2 storage capacity assessments in a broader context." The following is the Abstract of this article: "By their very nature, early national and basin scale assessments of geologic CO_2 storage capacity must rely on simplifying assumptions and generalizations

across a broad range of deep geologic structures. Key aspects of the technical literature and much of the public policy dialogue surrounding these assessments tend to emphasize the lack of detailed data and uncertainties at these scales. However, looking beyond the imperfections of data and methodology, the results of such assessments offer significant value in helping to understand the potential for CCS technologies to deploy across various regions of the world." **James J. Dooley**, *International Journal of Greenhouse Gas Control*, Available online August 2, 2010, doi:10.1016/j.ijggc.2010.07.002, http://www.sciencedirect.com/science/article/B83WP-50NY968-2/2/54fc0537707a9beb04d3e5c10a8bafd0. (Subscription may be required.)

"Modeling the geoelectric and seismic reservoir response caused by carbon dioxide injection based on multiphase flow simulation: Results from the CO_2SINK project." The following is from the Abstract of this article: ~~–~~Results from crosshole geoelectric and surface seismic monitoring for geological storage of CO_2 were investigated by forward [modeling] within the framework of the CO_2SINK project. Selected geological and petrophysical parameters reflect the conditions of the CO_2SINK site. CO_2 saturation distributions were derived from multiphase flow [modeling], whereas the alteration of geophysical rock properties by CO_2 was obtained from laboratory experiments. Crosshole geoelectric [modeling] was performed for three electrode combinations and three time-dependent CO_2 migration scenarios with different reservoir permeabilities. The magnitude and alteration of [modeled] resistances were analyzed in the pre-inversion domain. Time-lapse alterations were observable on the synthetic data, with diverse characteristics dependent on applied electrode configuration. Analysis of the alterations showed the opportunity to differentiate migration scenarios within the constraints of the ambient noise level. The synthetic time-lapse seismic reflection experiment was performed for the anticline used for CO_2 storage. The geological model incorporates the structural framework, as determined from the seismic interpretation, and velocities derived from seismic processing and velocity logs. Common depth point (CDP) processing of synthetic shot gathers of a baseline and repeat experiment provided the data for a difference stack section exhibiting a CO_2 induced time-lapse signature. Interpretation of the signature in conjunction with the underlying CO_2 distribution has shown that lateral extent of the plume may be accurately detected. The vertical plume extent is concealed in the waveform coda and is unlikely to be retrievable from standard seismic processing." **Peter Bergmann, Ursula Lengler, Cornelia Schmidt-Hattenberger, Rüdiger Giese, and Ben Norden**, *Chemie der Erde*, Available online July 10, 2010, doi:10.1016/j.chemer.2010.05.007, http://www.sciencedirect.com/science/article/B7CW6-50H3RPH-1/2/403437431b085159fa4a69d9f4cb431b. (Subscription may be required.)

"Modeling of the CO_2 process- and transport chain in CCS systems- Examination of transport and storage processes." The following is the Abstract of this article: ~~–~~Given the development of power plants with integrated capture of CO_2 and the subsequent storage of this captured CO_2 (CCS) the future fossil fuel-based energy system will most likely consist of very different types of processes and units. Past studies mostly focused on a very specific part of this CCS system. The effects and reactions on bordering processes were often only rudimentally considered. Due to these complex interactions between individual parts of a CCS system it is necessary to examine the [behavior] of the whole system in order to achieve secure and efficient operation. This article intends to highlight problems that will occur when such interactions are not considered and examined properly. This work presents an approach for the examination of a system consisting of a power plant, capture unit, transport system and CO_2 storage facility. A number of typical problems are shown, with focus on the examination of thermodynamic [behavior] of the captured CO_2 in a pipeline followed by a well in a saline aquifer storage site. It is shown that, under special conditions, the combination of a CO_2 pipeline and a well down to a saline aquifer will not work due to phase changes and pressure conditions, which would lead to operational problems or at the very least to partial destruction of either the pipes or the sedimentary storage rock." **Michael Nimtz, Matthias Klatt, Bernd Wiese, Michael Kühn, and Hans Joachim Krautz**, *Chemie der Erde*, Available online June 19, 2010, doi:10.1016/j.chemer.2010.05.011, http://www.sciencedirect.com/science/article/B7CW6-50BKDX0-1/2/17cfa8a2c2d9911ace7b3a8ecc90b9ae. (Subscription may be required.)

October 2010

"Designing a cost-effective CO_2 storage infrastructure using a GIS based linear optimization energy model." The following is the Abstract of this article: ~~L~~Large-scale deployment of [CCS] needs a dedicated infrastructure. Planning and designing of this infrastructure require incorporation of both temporal and spatial aspects. In this study, a toolbox has been developed that integrates ArcGIS, a geographical information system [GIS] with spatial and routing functions, and MARKAL, an energy bottom-up model based on linear optimization. Application of this toolbox led to blueprints of a CO_2 infrastructure in the Netherlands. The results show that in a scenario with 20 [percent] and 50 [percent] CO_2 emissions reduction targets compared to their 1990 level in respectively 2020 and 2050, an infrastructure of around 600 km of CO_2 trunklines may need to be built before 2020. Investment costs for the pipeline construction and the storage site development amount to around 720 m€ and 340 m€, respectively. The results also show the implication of policy choices such as allowing or prohibiting CO_2 storage onshore on CO_2 CCS and infrastructure development. This paper illustrates how the ArcGIS/MARKAL-based toolbox can provide insights into a CCS infrastructure development, and support policy makers by giving concrete blueprints over time with respect to scale, pipeline trajectories, and deployment of individual storage sites." **Machteld van den Broek, Evelien Brederode, Andrea Ramírez, Leslie Kramers, Muriel van der Kuip, Ton Wildenborg, Wim Turkenburg, and André Faaij**, *Environmental Modelling & Software*, Available online August 7, 2010, doi:10.1016/j.envsoft.2010.06.015, http://www.sciencedirect.com/science/article/B6VHC-50R0F29-1/2/81f41a3e334d7126ae72687e51f2a6e2. (Subscription may be required.)

"Lessons learned from natural and industrial analogues for storage of carbon dioxide." The following is the Abstract of this article: ~~T~~The deployment of CCS at industrial scale implies the development of effective monitoring tools. Noble gases are tracers usually proposed to track CO_2. This methodology, combined with the geochemistry of carbon isotopes, has been tested on available analogues. At first, gases from natural analogues were sampled in the Colorado Plateau and in the French carbogaseous provinces, in both well-confined and leaking-sites. Second, [the authors] performed a [two]-years tracing experience on an underground natural gas storage, sampling gas each month during injection and withdrawal periods. In natural analogues, the geochemical fingerprints are dependent on the containment criterion and on the geological context, giving tools to detect a leakage of deep-CO_2 toward surface. This study also provides information on the origin of CO_2, as well as residence time of fluids within the crust and clues on the physico-chemical processes occurring during the geological story. The study on the industrial analogue demonstrates the feasibility of using noble gases as tracers of CO_2. Withdrawn gases follow geochemical trends coherent with mixing processes between injected gas end-members. Physico-chemical processes revealed by the tracing occur at transient state. These two complementary studies proved the interest of geochemical monitoring to survey the CO_2 behavior, and gave information on its use." **Elodie Jeandel, Anne Battani, and Philippe Sarda**, *International Journal of Greenhouse Gas Control*, Available online August 5, 2010, doi:10.1016/j.ijggc.2010.06.005, http://www.sciencedirect.com/science/article/B83WP-50PJJFX-1/2/f55bb2fb835a6de037e5ab4d692f881d. (Subscription may be required.)

November 2010

"Design and operation of pilot plant for CO_2 capture from IGCC flue gases by combined cryogenic and hydrate method." The following is the Abstract of this article: ~~T~~This project is a trial conducted under contract with CO_2CRC, Australia of a new CO_2 capture technology that can be applied to integrated gasification combined cycle power plants and other industrial gasification facilities. The technology is based on combination of two low temperature processes, namely cryogenic condensation and the formation of hydrates, to remove CO_2 from the gas stream. The first stage of this technology is condensation at −55°C where CO_2 concentration is expected to be reduced by up to 75 mol%.

Remaining CO_2 is captured in the form of solid hydrate at about 1°C reducing CO_2 concentration down to 7 mol% using hydrate promoters. This integrated cryogenic condensation and CO_2 hydrate capture technology hold promise for greater reduction of CO_2 emissions at lower cost and energy demand. Overall, the process produced gas with a hydrogen content better than 90 mol%. The concentrated CO_2 stream was produced with 95–97 mol% purity in liquid form at high pressure and is available for re-use or sequestration. The enhancement of [CO_2] hydrate formation and separation in the presence of new hydrate promoter is also discussed. A laboratory scale flow system for the continuous production of condensed CO_2 and [CO_2] hydrates is also described and operational details are identified." **Daria Surovtseva, Robert Amin, and Ahmed Barifcani**, *Chemical Engineering Research and Design*, Available online September 6, 2010, doi:10.1016/j.cherd.2010.08.016, http://www.sciencedirect.com/science/article/B8JGF-50YF6PM-1/2/4d34e18c6c15262d5177b69acf0b3c8e. (Subscription may be required.)

"CO_2SINK – From site characterization and risk assessment to monitoring and verification: One year of operational experience with the field laboratory for CO_2 storage at Ketzin, Germany." The following is the Abstract of this article: ~~"~~The CO_2SINK pilot project at Ketzin is aimed at a better understanding of geological CO_2 storage operation in a saline aquifer. The reservoir consists of fluvial deposits with average permeability ranging between 50 and 100 mDarcy. The main focus of CO_2SINK is developing and testing of monitoring and verification technologies. All wells, one for injection and two for observation, are equipped with smart casings (sensors behind casing, facing the rocks) containing a Distributed Temperature Sensing (DTS) and electrodes for Electrical Resistivity Tomography (ERT). The in-hole Gas Membrane Sensors (GMS) observed the arrival of tracers and CO_2 with high temporal resolution. Geophysical monitoring includes Moving Source Profiling (MSP), Vertical Seismic Profiling (VSP), crosshole, star and 4-D seismic experiments. Numerical models are benchmarked via the monitoring results indicating a sufficient match between observation and prediction, at least for the arrival of CO_2 at the first observation well. Downhole samples of brine showed changes in the fluid composition and biocenosis. First monitoring results indicate anisotropic flow of CO_2 coinciding with the ~~"~~on-time' arrival of CO_2 at observation well one (Ktzi 200) and the later arrival at observation well two (Ktzi 202). A risk assessment was performed prior to the start of injection. After one year of operations about 18,000 t of CO_2 were injected safely." **Hilke Würdemann, Fabian Möller, Michael Kühn, Wolfgang Heidug, Niels Peter Christensen, Günter Borm, Frank R. Schilling, and the CO_2SINK Group**, *International Journal of Greenhouse Gas Control*, Available online October 15, 2010, doi:10.1016/j.ijggc.2010.08.010, http://www.sciencedirect.com/science/article/B83WP-517PW5R-1/2/2faba0f2a2ec05f5222a921216548c45. (Subscription may be required.)

December 2010

"Co-optimization of Enhanced Oil Recovery and Carbon Sequestration." The following is from the Abstract of this article: ~~"~~In this paper, [the authors] present an economic analysis of CO_2-enhanced oil recovery (EOR). This technique entails injection of CO_2 into mature oil fields in a manner that reduces the oil's viscosity, thereby enhancing the rate of extraction. As part of this process, significant quantities of CO_2 remain sequestered in the reservoir. If CO_2 emissions are regulated, oil producers using EOR should therefore be able to earn revenues from sequestration as well as from oil production. [The authors] develop a theoretical framework that analyzes the dynamic co-optimization of oil extraction and CO_2 sequestration, through the producer's choice of the fraction of CO_2 in the injection stream at each moment. [The authors] find that the optimal fraction of CO_2 is likely to decline monotonically over time, and reach zero before the optimal termination time. Numerical simulations, based on an ongoing EOR project in Wyoming, confirm this result. [The authors] also find that cumulative sequestration is less responsive to the carbon tax than to the oil price. Only at high taxes does a tradeoff between revenues from oil output and sequestration arise." **Andrew Leach, Charles F. Mason, and Klaas van't Veld**, *Resource and Energy Economics*, Available online November 26, 2010, doi:10.1016/j.reseneeco.2010.11.002, http://www.sciencedirect.com/science/article/B6VFJ-51JPWPY-1/2/9986a08fe2875a499d02f2833121cbcc. (Subscription may be required.)

"Post-combustion CO_2 Capture with Chemical Absorption: A State-of-the-art Review." The following is the Abstract of this article: ~~–~~Global concentration of CO_2 in the atmosphere is increasing rapidly. [Carbon dioxide] emissions have an impact on global climate change. Effective CO_2 emission abatement strategies such as CCS are required to combat this trend. There are three major approaches for CCS: Post-combustion capture, Pre-combustion capture and Oxyfuel process. Post-combustion capture offers some advantages as existing combustion technologies can still be used without radical changes on them. This makes post-combustion capture easier to implement as a retrofit option (to existing power plants) compared to the other two approaches. Therefore, post-combustion capture is probably the first technology that will be deployed. This paper aims to provide a state-of-the-art assessment of the research work carried out so far in post-combustion capture with chemical absorption. The technology will be introduced first, followed by required preparation of flue gas from power plants to use this technology. The important research programs worldwide and the experimental studies based on pilot plants will be reviewed. This is followed by an overview of various studies based on modeling and simulation. Then the focus is turned to review development of different solvents and process intensification. Based on these, [the authors] try to predict challenges and potential new developments from different aspects such as new solvents, pilot plants, process heat integration (to improve efficiency), modeling and simulation, process intensification and government policy impact." **M. Wang, A. Lawal, P. Stephenson, J. Sidders, and C. Ramshaw**, *Chemical Engineering Research and Design*, Available online November 13, 2010, doi:10.1016/j.cherd.2010.11.005, http://www.sciencedirect.com/science/article/B8JGF-51FXRGB-1/2/3fc82f9cb694031b0198884ad1dcf33e. (Subscription may be required.)

"Effective retrofitting of post-combustion CO_2 capture to coal-fired power plants and insensitivity of CO_2 abatement costs to base plant efficiency." The following is the Abstract of this article: ~~–~~Existing coal-fired power plants were not designed to be retrofitted with [CO_2] post-combustion capture (PCC) and have tended to be disregarded as suitable candidates for [CCS] on the grounds that such a retrofit would be uneconomical. Low plant efficiency and poor performance with capture compared to new-build projects are often cited as critical barriers to capture retrofit. Steam turbine retrofit solutions are presented that can achieve effective thermodynamic integration between a post-combustion CO_2 capture plant and associated CO_2 compressors and the steam cycle of an existing retrofitted unit for a wide range of initial steam turbine designs. The relative merits of these capture retrofit integration options with respect to flexibility of the capture system and solvent upgradability will be discussed. Provided that effective capture system integration can be achieved, it can be shown that the abatement costs (or cost per tonne of CO_2 to justify capture) for retrofitting existing units is independent of the initial plant efficiency. This then means that a greater number of existing power plants are potentially suitable for successful retrofits of post-combustion capture to reduce power sector emissions. Such a wider choice of retrofit sites would also give greater scope to exploit favorable site-specific conditions for CCS, such as ready access to geological storage." **Mathieu Lucquiaud and Jon Gibbins**, *International Journal of Greenhouse Gas Control*, doi:10.1016/j.ijggc.2010.09.003, http://www.sciencedirect.com/science/article/B83WP-51FX0CW-1/2/d52a7934a24eea381f745dc993e0ef5c. (Subscription may be required.)

January 2011

"The gas membrane sensor (GMS): A new method for gas measurements in deep boreholes applied at the CO_2SINK site." The following is the abstract of this article: ~~–~~A newly developed geochemical monitoring tool for the real time and in situ determination of CO_2 and other gases in the underground and in boreholes was successfully applied for the first time at the CO_2SINK test site in Ketzin, Germany. The method uses a phase separating membrane to separate gases dissolved in borehole fluids, water and brines. Ar is used as a carrier gas to conduct the collected gases through capillaries to the surface, where the gas phase is analyzed in real-time with a portable mass spectrometer for all permanent gases. In the observation wells of the CO_2SINK storage site, the

dissolved CO_2 concentrations in the borehole fluid were quantified using permeation rates determined in the laboratory for the applied membrane type. Increasing reservoir gas concentrations of He, H_2, CH_4 and N_2 as well as the arrival of the injected Kr tracer gas and of N_2, used for technical operations, at the monitoring wells were observed. The breakthrough of the CO_2 front into both observation wells, at a distance of 50 m and 112 m was recorded after the injection of about 500 and 11.000 tons CO_2, respectively." **Martin Zimmer, Joerg Erzinger, Christian Kujawa, and CO_2-SINK Group**, *International Journal of Greenhouse Gas Control*, Available online December 14, 2010, doi:10.1016/j.ijggc.2010.11.007, http://www.sciencedirect.com/science/article/B83WP-51PGM1R-1/2/1afbb483710a8217d1910adec05bbfa2. (Subscription may be required.)

"Carbon Dioxide Sequestration through Novel Use of Ion Exchange Fibers (IX-Fibers)." The following is the Abstract of this article: "Electrical power generation and metal removal processes are practiced globally and share two common attributes that make them ideal candidates to be incorporated in a novel [CO_2] sequestration scheme using ion exchange fibers (IX-fibers). First, the softening of boiler feed water used in power generation and the removal of metals from finishing wastewaters often employs the use of ion exchange for the purpose of selective separation. Second, both processes represent significant point source CO_2 emissions. This investigation demonstrated that by using IX-fibers it is possible to sequester a portion of the CO_2 produced in these practices as carbonate alkalinity during the regeneration step of both the water softening and trace heavy metal removal processes. Weak acid IX-fibers were used for hardness removal while hybrid cation exchange fibers (HCIX-F) loaded with hydrated Zr(IV) oxide (HZO) were used to remove toxic heavy metals such as zinc, cadmium, and copper. IX-fibers offer the unique capability to use and consume CO_2 during the efficient regeneration of IX-fibers, whereas commercial ion exchange resins are not amenable to regeneration with CO_2. A much shorter intraparticle diffusion path length in cylindrical IX-fibers as compared to resin beads is the underlying reason for a highly efficient regeneration of the fibers. In addition to sequestering CO_2, no hazardous or aggressive chemicals/brine solutions are present in the regenerant wastes as compared with traditional ion exchange processes." **S. Padungthon, J.E. Greenleaf, and A.K. Sengupta**, *Chemical Engineering Research and Design*, Available December 5, 2010, doi:10.1016/j.cherd.2010.11.012, http://www.sciencedirect.com/science/article/B8JGF-51MJYSG-1/2/438a5cee3f4e65ebe611dff727730a87. (Subscription may be required.)

"Reactive transport modeling of effects of convective mixing on long-term CO_2 geological storage in deep saline formations." The following is the Abstract of this article: "The existing form of the injected CO_2 gas is very important to the feasibility and security of CO_2 storage projects in specific geological formations. The residual gas, solubility and mineral trapping mechanisms are safer forms for CO_2 geological storage than the gas trapping. Dissolution of the injected CO_2 accumulated beneath a low-permeability caprock causes an increase in the water density, resulting in a 'convective mixing' phenomenon. In this paper, a series of reactive transport simulations were performed to investigate the dissolution–diffusion–convection process of CO_2 in the formation water, coupled with geochemical reactions between the gas, and formation water and rocks in a two-dimensional model based on the mineralogical composition in Songliao Basin of China. According to the changes in gaseous and aqueous CO_2, [the authors] divided the simulation process into four stages: (1) dissolution-dominated period; (2) diffusion-dominated period; (3) early convection-dominated period; and (4) late convection-dominated period. Sensitivity modeling indicated brine salinity, initial CO_2 gas saturation accumulated beneath the caprock, geochemical reactions, mineralogical compositions, vertical and horizontal permeabilities, and height and width of the model used in this study have an influence on the onset and/or evolution of the convection process." **Wei Zhang, Yilian Li, and Anne Nyatichi Omambia**, *International Journal of Greenhouse Gas Control*, Available online November 24, 2010, doi:10.1016/j.ijggc.2010.10.007, http://www.sciencedirect.com/science/article/B83WP-51J7KB3-1/2/34bdd75d8a8dbc7c2e0f7288da279ffa. (Subscription may be required.)

February 2011

"Geological investigations for CO_2 storage: from seismic and well data to 3D modeling." The following is the Abstract of this article: ~~"~~This work is part of the CPER Artenay project that aims at quantifying the environmental benefits and the technico-economic feasibility of storing CO_2 issued from a bio-ethanol distillery into a deep saline aquifer in the Paris Basin, France. This communication focuses on the geological investigations that ultimately lead to defining an optimal location for an injection site in CCS project. This paper presents a new approach for the pre-site characterization going from seismic and well data analyses to storage design. First, the general context of the area has been set follow by seismic interpretation. Those investigations leads to a geological surfaces modeling taking into account the basin border location of the project. The next step is the properties modeling made using sequence stratigraphy surfaces and *Petrel* software. This work will conduct to choose the optimal injection location regarding this geological investigation and the environmental constrains." **F. Chapuis, H. Bauer, S. Grataloup, A. Leynet, B. Bourgine, C. Castagnac, S. Fillacier, A. Lecomte, Y. Le Gallo, and D. Bonijoly**. Presented at GHGT-10, held September 19-23, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00351%2Epdf.

"Coupled reactive flow and transport modeling of CO_2 sequestration in the Mt. Simon sandstone formation, Midwest U.S.A." The following is the Abstract of this article: ~~"~~Multi-phase reactive flow and transport modeling is an effective tool for [MVA] of CO_2 sequestration in deep geological formations. In the current study, modeling is performed to simulate large scale CO_2 injection (a million tons per year for 100 years) into Mt. Simon sandstone, a major candidate saline reservoir in the Midwest of USA. The long term fate of CO_2 was simulated by extending the modeling period to 10,000 years. The results indicate that most of the injected CO_2 remains within a radius of 3300 m lateral distribution. Four major trapping mechanisms and their spatial and temporal variations are evaluated in [the authors'] simulations: hydrodynamic, solubility, residual, and mineral trapping. A strongly acidified zone (pH 3–5) forms in the areas affected by the injected CO_2 (0–3300 m), and consequently causes extensive mineral precipitation and dissolution. The predicted long-term fate of CO_2 is closely linked to the geochemical reactions conceptualized in the models. In [the authors'] model, the replenishing upstream water continues to dissolve CO_2 long after the injection, which results in total dissolution of hydrodynamically trapped CO_2 at the end of 10,000 years. In contrast, most previous models neglected the regional flow after injection and hence artificially limited the extent of geochemical reactions as if in a batch system. Consequently, a supercritical CO_2 plume (hydrodynamic trapping) would persist after 10,000 years. The continued supply of acidified water from interaction between replenishing water and CO_2 also results in extensive dissolution of feldspars and precipitation of secondary clay minerals, to a much more extent than what predicted in models without including regional flow. However, the prediction of complete dissolution of feldspars in 10,000 years can also result from the artifact that the linear rate laws are used in [the authors'] model (as well as all previous work), which overestimates the rates of feldspar dissolution near equilibrium. Nevertheless, [the authors'] simulations indicate the prolonged existence of an acidic brine plume, which suggests long-term risk assessment should transfer from the primary risk of CO_2 leakage to secondary risk of acidic plume leakage after all CO_2 is dissolved." **Faye Liu, Peng Lu, Chen Zhu, and Yitian Xiao**, *International Journal of Greenhouse Gas Control*, Available online September 23, 2010, doi:10.1016/j.ijggc.2010.08.008, http://www.sciencedirect.com/science/article/B83WP-5132XXW-1/2/755c4975b7db2d5311e326a738f8c81f. (Subscription may be required.)

March 2011

"Evaluation of power generation schemes based on hydrogen-fuelled combined cycle with carbon capture and storage (CCS)." The following is from the Abstract of this article: ~~"~~Integrated gasification combined cycle (IGCC)] is a power generation technology in which the solid feedstock is partially oxidized to produce syngas. In a modified IGCC design for carbon capture, there are several

technological options which are evaluated in this paper. The first two options involve pre-combustion arrangements in which syngas is processed, either by shift conversion or chemical looping, to maximize the hydrogen level and to concentrate the carbon species as CO_2. After CO_2 capture by gas–liquid absorption or chemical looping, the hydrogen-rich gas is used for power generation. The third capture option is based on post-combustion arrangement using chemical absorption. Investigated coal-based IGCC case studies produce 400–500 MW net power with more than 90 [percent] carbon capture rate. Principal focus of the paper is concentrated on evaluation of key performance indicators for investigated carbon capture options, the influence of various gasifiers on carbon capture process, optimization of energy efficiency by heat and power integration, quality specification of captured CO_2. The capture option with minimal energy penalty is based on chemical looping, followed by pre-combustion and post-combustion." **Calin-Cristian Cormos**, *International Journal of Hydrogen Energy*, Available online January 12, 2011, doi:10.1016/j.ijhydene.2010.12.042, http://www.sciencedirect.com/science/article/B6V3F-51XNX4S-4/2/e2af9974f317c0b9c82d4a6a8fde3c27. (Subscription may be required.)

"A dual poroelastic model for CO_2-Enhanced coalbed methane recovery." The following is from the Abstract of this article: "Although CO_2-enhanced coalbed methane (ECBM) recovery has been comprehensively investigated, the impact of coal matrix-fracture interactions on the evolution of coal permeability under in-situ conditions is still unclear. In prior studies on this issue, the influences of coal matrix-fracture interactions have not rigorously coupled with the binary gas transport system. In this work, general porosity and permeability models are developed to explicitly quantify the interactions between binary mixtures (CO_2 and [methane (CH_4)]) and dual solid media (coal matrix and fracture) under the full spectrum of mechanical conditions spanning prescribed in-situ stresses through constrained displacement. These models are implemented into a fully coupled finite element (FE) model of coal deformation, binary gas flow and transport in the matrix system, and binary gas flow and transport in the fracture system. The FE model represents important non-linear responses due to the effective stress effects that cannot be recovered where mechanical influences are not rigorously coupled with the binary gas transport system. The FE model is applied to simulate the results of a single well injection micro-pilot test performed in the anthracitic coals of the South Qinshui basin, Shanxi Province, China. The modeled CH_4 production rates are in good agreement with the observed production history. In addition to this agreement, model results also demonstrate (1) CO_2 injection increases the total pressure gradients; (2) as the CO_2 injection progresses the partial CO_2 pressure increases while the partial CH_4 pressure decreases; (3) without CO_2 injection the CH_4 content at a specific point decreases almost linearly while with the CO_2 injection the CH_4 content at a specific point decreases exponentially; (4) without CO_2 injection the CH_4 production rate decreases linearly while with CO_2 injection the CH_4 production rate increases dramatically; (5) without CO_2 injection coal permeability increases almost linearly while with CO_2 injection coal permeability decreases near exponentially; (6) CO_2 injection enhances cumulative CH_4 production and the enhancement is proportional to the injection pressure; and (7) cumulative CO_2 injection volume is also proportional to the injection pressure." **Yu Wu, Jishan Liu, Zhongwei Chen, Derek Elsworth, and Denis Pone**, *International Journal of Coal Geology*, Available online January 22, 2011, doi:10.1016/j.coal.2011.01.004, http://www.sciencedirect.com/science/article/B6V8C-520TJJS-1/2/3214b23b0c4b84704eff69a9bc9a5aa5. (Subscription may be required.)

April 2011

"Safe storage of CO_2 together with improved oil recovery by CO_2-enriched water injection." The following is the Abstract of this article: "The 2007 [International Energy Agency's (IEA)] World Energy Outlook report predicts that the world's energy needs will grow by 55 [percent] between 2005 and 2030, with fossil fuels accounting for 84 [percent] of this massive projected increase in energy demand. An undesired side effect of burning fossil fuels is CO_2 emission which is now widely believed to be responsible for the problem of global warming. Various strategies are being considered for addressing the increase in demand for energy and at the same time developing technologies to make energy

greener by reducing CO_2 emissions. One of these strategies is to ‗capture' produced CO_2 instead of releasing it into the atmosphere. Capturing CO_2 and its injection in oil reservoirs can lead to improved oil recovery as well as CO_2 retention and storage in these reservoirs. The technology is referred to as CCS. Large point sources of CO_2 (e.g., coal-fired power plants) are particularly good candidates for capturing large volumes of CO_2. However, CO_2 capture from power plants is currently expensive. In addition to high costs of CO_2 capture, the low pressure of the flue gas (1 atm) and its low CO_2 content (typically 10–15 [percent]) contribute to the high cost of CO_2 capture from power plants and the subsequent compression. This makes conventional CO_2 flooding (which requires large volumes of CO_2) uneconomical in many oil reservoirs around the world which would otherwise be suitable candidates for CO_2 injection. Alternative strategies are therefore needed to utilize smaller sources of CO_2 that are usually available around oil and gas fields and can be captured at lower costs (due to their higher pressure and higher CO_2 concentration). [The authors] investigate the potential of carbonated (CO_2-enriched) water injection (CWI) as an injection strategy for improving recovery from oil reservoirs with the added benefit of safe storage of CO_2. The performance of CWI was investigated by conducting high-pressure flow visualization as well as coreflood experiments at reservoir conditions. The results show that CWI significantly improves oil recovery from water flooded porous media. A relatively large fraction of the injected CO_2 was retained (stored) in the porous medium in the form of dissolved CO_2 in water and oil. The results clearly demonstrate the huge potential of CWI as a productive way of utilizing CO_2 for improving oil recovery and safe storage of potentially large cumulative quantities of CO_2." **Mehran Sohrabi, Nor Idah Kechut, Masoud Riazi, Mahmoud Jamiolahmady, Shaun Ireland, and Graeme Robertson**, *Chemical Engineering Research and Design*, Available online February 5, 2011, doi:10.1016/j.cherd.2011.01.027, http://www.sciencedirect.com/science/article/B8JGF-523V3NP-3/2/908ab65aa70abf2068a0192a95725056. (Subscription may be required.)

"Brine flow up a well caused by pressure perturbation from geologic carbon sequestration: Static and dynamic evaluations." The following is the Abstract of this article: ―Industrial-scale storage of CO_2 in saline sedimentary basins will cause zones of elevated pressure, larger than the CO_2 plume itself. If permeable conduits exist between the injection reservoir and overlying shallow [formations], brine could be pushed upwards along these conduits and mix with groundwater resources. This paper discusses the potential for such brine [release] to occur in temperature- and salinity-stratified systems. Using static mass-balance calculations as well as dynamic well flow simulations, [the authors] evaluate the minimum reservoir pressure that would generate continuous migration of brine up a wellbore into a freshwater [formation]. Since the brine invading the well is denser than the initial fluid in the wellbore, continuous flow only occurs if the pressure perturbation in the reservoir is large enough to overcome the increased fluid column weight after full invasion of brine into the well. If the threshold pressure is exceeded, brine flow rates are dependent on various hydraulic (and other) properties, in particular the effective permeability of the wellbore and the magnitude of pressure increase. If brine flow occurs outside of the well casing, e.g., in a permeable fracture zone between the well cement and the formation, the fluid/solute transfer between the migrating fluid and the surrounding rock units can strongly retard brine flow. At the same time, the threshold pressure for continuous flow to occur decreases compared to a case with no fluid/solute transfer." **Jens T. Birkholzer, Jean Philippe Nicot, Curtis M. Oldenburg, Quanlin Zhou, Stephen Kraemer, and Karl Bandilla**, *International Journal of Greenhouse Gas Control*, Available online February 17, 2011, doi:10.1016/j.ijggc.2011.01.003, http://www.sciencedirect.com/science/article/B83WP-526CXS6-1/2/e26214df56490818f3f6dfdf22dc92cf. (Subscription may be required.)

May 2011

"Techno-economic evaluation of coal-to-liquids (CTL) plants with carbon capture and sequestration." The following is the Abstract of this article: ―Coal-to-liquids (CTL) processes that generate synthetic liquid fuels from coal are of increasing interest in light of the substantial rise in world oil prices in recent years. A major concern, however, is the large emissions of CO_2 from the process,

which would add to the burden of atmospheric [GHGs]. To assess the options, impacts and costs of controlling CO_2 emissions from a CTL plant, a comprehensive techno-economic assessment model of CTL plants has been developed, capable of incorporating technology options for CCS. The model was used to study the performance and cost of a liquids-only plant as well as a co-production plant, which produces both liquids and electricity. The effect of uncertainty and variability of key parameters on the cost of liquids production was quantified, as were the effects of alternative carbon constraints such as choice of CCS technology and the effective price (or tax) on CO_2 emissions imposed by a climate regulatory policy. The efficiency and CO_2 emissions from a co-production plant also were compared to the separate production of liquid fuels and electricity. The results for a 50,000 barrels/day case study plant are presented." **Hari Chandan Mantripragada and Edward S. Rubin**, *Energy Policy*, Available online March 5, 2011, doi:10.1016/j.enpol.2011.02.053, http://www.sciencedirect.com/science/article/B6V2W-529Y854-2/2/cee1a6b7e2efe77ba24d1d760d0a362e. (Subscription may be required.)

"Investigation of gridding effects for numerical simulations of CO_2 geologic sequestration." The following is the Abstract of this article: "Potential errors caused by grid shape and resolution are investigated for numerical simulations of CO_2 geologic sequestration. The spatial orientation of finite difference grids can strongly influence the calculated shapes of CO_2 fronts due to so-called 'grid orientation effect'. A coarse vertical discretization of a reservoir can impede gravity override (i.e., less-dense CO_2 flows over denser groundwater) of CO_2 plumes, resulting in underestimation of the maximum plume size. It is known that injection of CO_2 into a saline [formation] may cause formation dry-out and precipitation of solid salt near the injection well, which may reduce porosity and permeability of the [formation]. Numerical simulation of salt precipitation may require very fine grid size near the injection well, because dry-out would be greatly underestimated in a large grid block containing a large amount of water. In this study, these gridding effects are demonstrated using one-dimensional and two-dimensional idealized models as well as a three-dimensional field-scale simulation model of a large-volume CO_2 injection in a saline formation in California's Central Valley. For the field-scale modeling, [the authors] generated a high-resolution grid model utilizing Voronoi tessellation. To solve the high-resolution model efficiently TOUGH-MP, a parallelized version of general purpose multi-phase flow simulator TOUGH2, was used. [The authors'] results indicate that (1) the use of higher-order Voronoi tessellation significantly reduces the 'grid-orientation effects'; (2) coarse grids considerably underestimate gravity override, and thus the maximum lateral extent of a CO_2 plume is also underestimated to a few tens of percent; (3) a fine gridding in the vicinity of the injection well may be needed to simulate near-well phenomena accurately, especially when the capillary-driven backflow to the well is significant." **Hajime Yamamoto and Christine Doughty**, *International Journal of Greenhouse Gas Control*, Available online March 16, 2011, doi:10.1016/j.ijggc.2011.02.007, http://www.sciencedirect.com/science/article/B83WP-52D4JW2-2/2/de4f8ccec13b3e9df4229bfb7f25ab04. (Subscription may be required.)

"Feasibility of Distributed Carbon Capture and Storage (DCCS)." The following is the Abstract of this article: "The concept of Distributed Carbon Capture and Storage (DCCS) for small scale CO_2 sources, such as Distributed Energy Systems (DES), is proposed, and Carbon Storage in a Shallow Aquifer (CSSA), in which CO_2 is stored in shallow [formations] as aqueous solution, is also studied as a technique for the DCCS. A conceptual design for the CSSA have been performed and the fundamental calculations in this study show that the dissolution capacity, that is, the amount of CO_2 which can be dissolved into unit volume of water in a shallow [formation] is 10-35 kg-CO_2/m^3 in the range of the storage depth of 100-500 m. The dissolution capacity of the CSSA is less than 10 [percent] of the possible amount of CO_2 stored by the ordinary CCS technique in which CO_2 is stored in the supercritical condition. However, the CSSA is estimated to allow the CO_2 storage at less than ¥3000/t-CO_2 of the storage cost and more than 20 years of the injection period for CO_2 sources of 1800-39,000 t-CO_2/year, which correspond to the CO_2 emissions from 0.1 to 10 MW DES. The required energy for the CSSA is estimated to be less than 10 [percent] of the energy generated by the CO_2 sources." **Tatsuki Tokoro, Tohru Kato, Yohei Tanaka, Ken Kato, Akira Negishi, and Ken Nozaki**, *Energy Conversion and Management*, Available online March 23, 2011, doi:10.1016/j.enconman.2011.01.016,

http://www.sciencedirect.com/science/article/B6V2P-52FKTJ9-6/2/89fe9cda9a15903bfc3d70dc75272ba8. (Subscription may be required.)

June 2011

"U.S. DOE methodology for the development of geologic storage potential for carbon dioxide at the national and regional scale." The following is the Abstract of this article: ~~"~~A detailed description of the U.S.-DOE methodology for estimating CO_2 storage potential for oil and gas reservoirs, saline formations, and unmineable coal seams is provided. The oil and gas reservoirs are assessed at the field level, while saline formations and unmineable coal seams are assessed at the basin level. The U.S.-DOE methodology is intended for external users such as RCSPs, future project developers, and governmental entities to produce high-level CO_2 resource assessments of potential CO_2 storage reservoirs in the United States and Canada at the regional and national scale; however, this methodology is general enough that it could be applied globally. The purpose of the U.S.-DOE CO_2 storage methodology, definitions of storage terms, and a CO_2 storage classification are provided. Methodology for CO_2 storage resource estimate calculation is outlined. The Log Odds Method when applied with Monte Carlo Sampling is presented in detail for estimation of CO_2 storage efficiency needed for CO_2 storage resource estimates at the regional and national scale. [Carbon dioxide] storage potential reported in the U.S.-DOE's assessment are intended to be distributed online by a geographic information system in [National Carbon Sequestration Database and Geographic Information System (NATCARB)] and made available as hard-copy in the *Carbon Sequestration Atlas of the United States and Canada*. U.S.-DOE's methodology will be continuously refined, incorporating results of the Development Phase projects conducted by the RCSPs from 2008 to 2018. Estimates will be formally updated every two years in subsequent versions of the *Carbon Sequestration Atlas of the United States and Canada*." **Angela Goodman, Alexandra Hakala, Grant Bromhal, Dawn Deel, Traci Rodosta, Scott Frailey, Mitchell Small, Doug Allen, Vyacheslav Romanov, Jim Fazio, Nicolas Huerta, Dustin McIntyre, Barbara Kutchko, and George Guthrie**, *International Journal of Greenhouse Gas Control*, Available online April 19, 2011, doi:10.1016/j.ijggc.2011.03.010, http://www.sciencedirect.com/science/article/pii/S1750583611000405. (Subscription may be required.)

"Combining power plant water needs and carbon dioxide storage using saline formations: Implications for carbon dioxide and water management policies." The following is the Abstract of this article: ~~"~~Research involving management of [CO_2] has increased markedly over the last decade as it relates to concerns over climate change. Capturing and storing CO_2 in geological formations is one of many proposed methods to manage, and likely reduce, CO_2 emissions from burning fossil fuels in the electricity sector. Saline formations represent a vast storage resource, and the waters they contain could be managed for beneficial use. To address this issue, a methodology was developed to test the feasibility of linking coal-fired power plants, deep saline formations for CO_2 storage, and extracting and treating saline waters for use as power plant cooling water. An illustrative hypothetical case study examines a representative power plant and saline formation in the southwestern United States. A regional assessment methodology includes analysis of injection-induced changes in subsurface groundwater chemistry and fate and transport of supercritical CO_2. Initial water-CO_2-formation reactions include dissolution of carbonate minerals as expected, and suggest that very little CO_2 will be stored in mineral form within the first few centuries. Reservoir simulations provide direct input into a systems-level economic model, and demonstrate how water extraction can help manage injection-induced overpressure. Options for treatment of extracted water vary depending upon site specific chemistry. A high efficiency reverse osmosis system (HERO™) shows promise for economical desalination at the volumes of recovered water under consideration. Results indicate a coupled use CO_2 storage and water extraction and treatment system may be feasible for tens to hundreds of years." **Peter H. Kobos, Malynda A. Cappelle, Jim L. Krumhansl, Thomas A. Dewers, Andrea McNemar, and David J. Borns**, *International Journal of Greenhouse Gas Control*, Available online May 2, 1011, doi:10.1016/j.ijggc.2011.03.015, http://www.sciencedirect.com/science/article/pii/S1750583611000466. (Subscription may be required.)

"A new triaxial apparatus to study the mechanical and fluid flow aspects of carbon dioxide sequestration in geological formations." The following is from the Abstract of this article: ~~"~~Climate scientists are practically unanimous in the belief that anthropogenic [greenhouse gas (GHG)] contributions have added to the thickness and thus the effectiveness of the [GHG] layer, leading to a warming of the planet. Engineers and scientists around the globe are researching and developing measures to reduce [GHG] emissions. These measures have included proposals to sequester CO_2 in deep geological formations. For CO_2 sequestration in deep geological reservoirs to become a feasible strategy to reduce [GHG] emissions, a sound understanding of the manner by which mechanical properties and permeability changes with the introduction of CO_2 to the geological reservoir will influence the stability of that reservoir is required. Thus there is a need to develop laboratory equipment capable of simulating the CO_2 injection and storage process for deep geological CO_2 sequestration under the expected in situ pressure (confinement and fluid) and temperature conditions. Triaxial experiment has been identified as the best method for this purpose. Therefore, [the authors] present a new high-pressure triaxial apparatus which can provide the high confining and fluid injection pressures and elevated temperatures expected for deep geological CO_2 sequestration. The new setup can be used to conduct mechanical and permeability testing on intact or fractured natural rock samples or synthetic rock samples subjected to high-pressure injection of up to three fluid phases (gas and/or liquid) at high pressures and temperatures corresponding to field conditions. The equipment is capable of delivering fluids to the sample at injection pressures of up to 50 MPa, confining pressures of up to 70 MPa and temperature up to 50°C and will continuously record fluid injection and confining pressures, axial load and displacement, radial displacement and independent outflow rates for liquid and gas fluid phases (under drained conditions). Leakage tests have confirmed the effectiveness of the device at pressures up to its maximum capacities. Additionally the temperature-pressure relationship for the hydraulic oil used to apply confining pressure to the sample has been calibrated to account for the influence of changes in temperature on confining pressure. Several permeability tests (using [nitrogen (N_2)] and CO_2 as the injection fluid and 10 MPa confining pressure) and one strength test are reported for black coal samples from the Sydney Basin, New South Wales. According to the results of the permeability tests, coal mass permeability decreases with increasing effective stress for both gases. However, the permeability for N_2 gas is much higher than CO_2. Moreover, test results are consistent with matrix swelling due to the adsorption of CO_2 in coal. The strength testing results are in agreement with the results of testing carried on similar black coal samples from literature, certifying the ability for the new device to accurately measure strength and deformation properties of rock under deep ground conditions." **P.G. Ranjith and M.S.A. Perera**, *Fuel*, Available online April 16, 2011, doi:10.1016/j.fuel.2011.04.004, http://www.sciencedirect.com/science/article/pii/S0016236111001967. (Subscription may be required.)

July 2011

"Probabilistic Design of a Near-Surface CO_2 Leak Detection System." The following is the Abstract of this article: ~~"~~A methodology is developed for predicting the performance of near-surface CO_2 leak detection systems at geologic sequestration sites. The methodology integrates site characterization and modeling to predict the statistical properties of natural CO_2 fluxes, the transport of CO_2 from potential subsurface leakage points, and the detection of CO_2 surface fluxes by the monitoring network. The probability of leak detection is computed as the probability that the leakage signal is sufficient to increase the total flux beyond a statistically determined threshold. The methodology is illustrated for a highly idealized site monitored with CO_2 accumulation chamber measurements taken on a uniform grid. The TOUGH2 code is used to predict the spatial profile of surface CO_2 fluxes resulting from different leakage rates and different soil permeabilities. A response surface is fit to the TOUGH2 results to allow interpolation across a continuous range of values of permeability and leakage rate. The spatial distribution of leakage probability is assumed uniform in this application. Nonlinear, nonmonotonic relationships of network performance to soil permeability and network density are evident. In general, dense networks (with 10-20 m between monitors) are required to ensure a moderate to high probability

of leak detection." **Ya-Mei Yang, Mitchell J. Small, Egemen O. Ogretim, Donald D. Gray, Grant S. Bromhal, Brian R. Strazisar, and Arthur W. Wells**, *Environ. Sci. Technol.*, Available online July 6, 2011, DOI:10.1021/es104379m, http://pubs.acs.org/doi/abs/10.1021/es104379m. (Subscription may be required.)

"Techno-economical and environmental evaluations of IGCC power generation process with carbon capture and storage (CCS)." The following is the Abstract of this article: IGCC is a power generation technology in which the solid feedstock (coal, lignite, biomass etc.) is partially oxidized with oxygen and steam to produce syngas. In a conventional IGCC design for power generation without carbon capture, the syngas is purified for dust and hydrogen sulphide removal and then sent to a Combined Cycle Gas Turbine (CCGT) for power production. CCS technologies are expected to play a significant role in the coming decades for reducing the [GHG] emissions. IGCC is one of the power generation technologies having the highest potential to capture [CO_2] with low penalties in term of plant energy efficiency, capital and operational costs. This paper investigates the most important techno-economical and environmental indicators (e.g. net and gross power output, ancillary power consumption, plant efficiency, specific capital cost investment, operational costs, specific [CO_2] emissions etc.) for power generation with CCS applied to an IGCC scheme. The coal-based IGCC case study investigated in the paper produces around 400 MW net electricity with 90 [percent] carbon capture rate. Similar power plant schemes without carbon capture step were used as references for comparison." **Calin-Cristian Cormos, Ana-Maria Cormos, and Paul Serban Agachi**, *Computer Aided Chemical Engineering*, Available online June 12, 2011, doi:10.1016/B978-0-444-54298-4.50114-8, http://www.sciencedirect.com/science/article/pii/B9780444542984501148. (Subscription may be required.)

"CO_2 Sustainable Recovery Network Cluster for Carbon Capture and Sequestration." The following is the Abstract of this article: Sustainable CCS is becoming a transnational goal aiming at reducing global warming effects. Several large European projects focus on developing capture and geological sequestration technologies and sustainable transport networks of dedicated pipelines. This work proposes a model to collect the CO_2 captured in a sustainable cluster of medium range facilities, at close distance from the future input site for the transnational transport networks. The model considers a hyper-structure that involves all viable alternative transport modes as well as all associated CO_2 capture processes. The Eco-indicator 99 methodology is included to perform a life cycle impact assessment (LCIA) allowing the model to achieve individual optimization of economic and environmental objectives or, instead, to optimize both objectives simultaneously by using a weighted sum approach. An illustrative example considers a given input location to gather the CO_2 produced by neighboring medium size facilities, with capture technology selection focused on the producer's economic /environmental interests. A combination of all possible alternative transports modes (water, train, road and pipeline) is considered for establishing cluster's routes. Results give the optimized network design and the corresponding environmental damages/impacts. This model can be used either as a decision making tool to test strategies for raising CO_2 capture without aggravating pollution or operational costs, or to perform sensitivity studies on several network parameters." **J. Duque, A.P.F.D. Barbosa-Póvoa, and A.Q. Novais**, *Computer Aided Chemical Engineering*, Available online June 12, 2011, doi:10.1016/B978-0-444-54298-4.50017-9, http://www.sciencedirect.com/science/article/pii/B9780444542984500179. (Subscription may be required.)

August 2011

"A study of methodologies for CO_2 storage capacity estimation of coal." The following is the Abstract of this article: [CCS] in unmineable coal seams is regarded as one of the possible approaches to mitigate the ever increasing CO_2 concentration in the atmosphere resulting from human activities since the Industrial Revolution. Injection of CO_2 into unmineable coal seams not only provides a solution for long term storage of CO_2 but it also provides the added advantage of enhancing coalbed methane

recovery. Adsorption is the main trapping mechanism for CO_2 storage in coal seams where it constitutes to about 95–98 [percent] of total storage. Other trapping mechanisms include gas trapped within the matrix structure, free gas and CO_2 trapped as a solute in the pore water. Coal is usually highly heterogeneous and contains pores of different sizes: micropores, mesopores, and macropores. The physical properties such as permeability, which usually changes with depth and the degree of cleating, complicates the storage capacity estimation process. Injection of highly dense phase CO_2 may offer higher storage capacity because of its higher density compared to gaseous CO_2. However, there is a lack of verified CO_2 storage capacity estimation methodology for coalbeds. Computing storage potential of CO_2 is not straightforward due to the highly variable coal properties even in the same coal seam. Therefore, in this paper a statistical framework for estimating the CO_2 storage capacity in coal seams is presented with the emphasis on highly dense CO_2 conditions. The approach is based on earlier studies, which utilize important in situ parameters to estimate storage capacity in coal seams. These parameters include volatile matter content, moisture, ash, pressure and temperature. Furthermore, several widely used adsorption models for single- and multi-component gas are reviewed. The ability of the various models in predicting the adsorption capacity for different coal types and under various in situ conditions was examined. Dataset consists of adsorption data representing 69 coal types having vitrinite reflectance ranging from 0.25 [percent] to 3.86 [percent]. Results of analyses of this dataset showed that better estimation can be obtained by expressing adsorption capacity as a power function of pressure rather than assuming a linear relationship between adsorption capacity and pressure while keeping other important parameters unchanged." **P.N.K. De Silva, P.G. Ranjith and S.K. Choi**, *Fuel*, Available online July 20, 2011, doi:10.1016/j.fuel.2011.07.010, http://www.sciencedirect.com/science/article/pii/S0016236111004078. (Subscription may be required.)

"Estimating the probability of CO_2 plumes encountering faults." The following is the Abstract of this article: ~~O~~ne of the main concerns of CO_2 storage in saline aquifers is leakage via faults. In the early stages of site selection, site-specific fault (map) coverages are often not available for these saline aquifers. This lack of site-specific data motivates development of a method that makes use of available regional fault data to estimate the probability of injected CO_2 or the resulting pressure front encountering a fault, which is a necessary condition for leakage of CO_2 or brine to occur via these pathways. The probability of encounter can be calculated from areal fault density statistics generated from available data, and CO_2 plume or elevated pressure area dimensions generated by numerical simulation. Given a number of assumptions, the length of the plume or elevated pressure area perpendicular to a fault times the areal density of faults with offsets greater than some threshold of interest provides the probability of the plume or a pressure front of concern encountering such a fault. Application of this result to a previously planned, large-scale pilot injection in the southern portion of the San Joaquin Basin yielded a [three percent] and [seven percent] chance of the bulk phase CO_2 plume encountering a fully and half-seal offsetting fault, respectively. Subsequently available data provided a first test of this approach as a half-seal offsetting fault was discovered at a distance from the injection well that implied a 20 [percent] probability of encounter for a plume sufficiently large to reach it." **Preston D. Jordan, Curtis M. Oldenburg, and Jean-Philippe Nicot**, *Greenhouse Gases: Science and Technology*, Available online May 25, 2011, doi:10.1002/ghg.17, http://onlinelibrary.wiley.com/doi/10.1002/ghg.17/abstract. (Subscription may be required.)

Terrestrial

September 2010

"Permanent shallow subsoil CO_2 flux chambers for monitoring of onshore CO_2 geological storage sites." The following is from the Abstract of this article: ~~P~~ublic concern over the possibility of migration of stored CO_2 to the surface with resulting damage to vegetation or hazard to humans and animals is a matter which will need to be addressed to be able to satisfy likely regulatory requirements for onshore CO_2 storage in a number of jurisdictions. While soil CO_2 concentration is readily measured continuously

and in situ with current technology, the measurement of CO_2 flux at depths below the soil A horizon may be a more sensitive and meaningful technique for early detection of a near surface CO_2 plume. [The authors] describe a system for the continuous measurement of soil CO_2 flux at a depth of approximately 1.3 m and present results from three instruments deployed at the Otway Basin Pilot Project in Victoria, Australia and one development system deployed at Sutton, near the Australian Capital Canberra." **C. Bernado and D.F.de Vries**, *International Journal of Greenhouse Gas Control*, Available online July 1, 2010, doi:10.1016/j.ijggc.2010.05.011, http://www.sciencedirect.com/science/article/B83WP-50F36PP-1/2/da85c8678bfe96c710dbcfbc2edd8b57. (Subscription may be required.)

October 2010

"Designing policies to mitigate the agricultural contribution to climate change: an assessment of soil based carbon sequestration its ancillary effects." The following is the Abstract of this article: "Soil carbon sequestration has been regarded as a cheap and cost-effective way to sequester carbon until other technologies to tackle climate change become available or more cost-effective. An assessment of the social desirability of a soil carbon sequestration policy requires the consideration of all associated social costs and benefits. Measures to re-accumulate carbon in soils have ancillary or co-effects on the environment that can be beneficial or detrimental to social welfare and few of which are traded in markets. This paper discusses issues related to the development of soil carbon sequestration policies into agri-environmental schemes and reports findings from an application of a choice experiment to elicit preferences and estimate benefits of a soil carbon program in Scotland under consideration of co-effects on biodiversity and rural viability. Preferences for soil carbon based mitigation are found to be heterogeneous and related to beliefs about climate change and attitudes towards its mitigation. Benefit estimates suggest that including co-effects can significantly change the outcome of cost–benefit tests. Implications for the development of climate change policies are discussed." **Klaus Glenk and Sergio Colombo**, *Climatic Change*, Available online August 20, 2010, doi:10.1007/s10584-010-9885-7, http://www.springerlink.com/content/7h0k45m445061643/. (Subscription required.)

November 2010

"Effects of carbon sequestration rewards on forest management – An empirical application of adjusted Faustmann Formulae." The following is the Abstract of this article: "This paper assesses the effects that different economic instruments to reward carbon sequestration services might have on forest management, especially on the optimal rotation period. Three different carbon crediting schemes are considered, which are based on different accounting rules. The schemes are different with respect to the question whether and how to account for carbon emissions. The forest valuation method used for calculation is based on the land expectation value (LEV), which was adjusted for the value of carbon sequestration services. Changes in the LEV and optimal rotation are expected to be induced by the amount and interactions of carbon and timber prices, harvesting and regeneration costs, and interest rates. The optimal economic rotation period is calculated for single stands as well as for whole forest enterprises (fully regulated 'normal' forests). Crediting the carbon sequestration of single stands – starting from the time of regeneration – is comparable to rewarding afforestation projects. When crediting forest enterprises with existing timber and carbon stocks, additional carbon sequestration compared to a reference is rewarded. The findings reveal that, depending on the carbon price level, the optimal rotation period is increased in all considered crediting schemes, but with different intensity. If wood removals have to be accounted as carbon emissions this has the most significant effect on the optimal rotation period for forest stands and enterprises. In this case the increase of the optimal rotation period by rising carbon prices is boosted additionally by rising interest rates. Different thinning regimes, however, have only little impact on the time of maximum LEV under carbon crediting schemes." **Margret Köthke and Matthias Dieter**, *Forest Policy and Economics*, Available online September 6, 2010, doi:10.1016/j.forpol.2010.08.001, http://www.sciencedirect.com/science/article/B6VT4-50YFH45-1/2/67c70cb2188db7cc6722d47daf1e547b. (Subscription may be required.)

December 2010

"Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments." The following is from the Abstract of this article: "Adopting no-tillage in agro-ecosystems has been widely recommended as a means of enhancing carbon sequestration in soils. However, study results are inconsistent and varying from significant increase to significant decrease. It is unclear whether this variability is caused by environmental, or management factors or by sampling errors and analysis methodology. Using meta-analysis, [the authors] assessed the response of soil organic carbon (SOC) to conversion of management practice from conventional tillage (CT) to no-tillage (NT) based on global data from 69 paired-experiments, where soil sampling extended deeper than 40 cm. [The authors] found that cultivation of natural soils for more than [five] years, on average, resulted in soil carbon loss of more than 20 t ha^{-1}, with no significant difference between CT and NT. Conversion from CT to NT changed distribution of carbon in the soil profile significantly, but did not increase the total SOC except in double cropping systems. After adopting NT, soil carbon increased by 3.15 ± 2.42 t ha^{-1} (mean ± 95 [percent] confidence interval) in the surface 10 cm of soil, but declined by 3.30 ± 1.61 t ha^{-1} in the 20–40 cm soil layer. Overall, adopting NT did not enhance soil total carbon stock down to 40 cm. Increased number of crop species in rotation resulted in less carbon accumulation in the surface soil and greater carbon loss in deeper layer. Increased crop frequency seemed to have the opposite effect and significantly increased soil carbon by 11 [percent] in the 0–60 cm soil. Neither mean annual temperature and mean annual rainfall nor nitrogen fertilization and duration of adopting NT affected the response of soil carbon stock to the adoption of NT. [The authors'] results highlight that the role of adopting NT in sequestrating carbon is greatly regulated by cropping systems. Increasing cropping frequency might be a more efficient strategy to sequester carbon in agro-ecosystems. More information on the effects of increasing crop species and frequency on soil carbon input and decomposition processes is needed to further [the authors'] understanding on the potential ability of carbon sequestration in agricultural soils." **Zhongkui Luo, Enli Wang, and Osbert J. Sun**, *Agriculture, Ecosystems & Environment*, Available online September 9, 2010, doi:10.1016/j.agee.2010.08.006, http://www.sciencedirect.com/science/article/B6T3Y-510244F-1/2/affdf8a7e6edd8d7f14e53d12403d762. (Subscription may be required.)

January 2011

"Soil carbon storage and stratification under different tillage systems in a semi-arid region." The following is the abstract of this article: "Changes in the agricultural management can potentially increase the accumulation rate of soil organic carbon (SOC), thereby sequestering CO_2 from the atmosphere. In a long-term experiment (1992-2008) we examined the effects of various tillage intensities: no-tillage (NT), minimum tillage with chisel plow (MT), and conventional tillage with mouldboard plow (CT), on the topsoil profile distribution (0-30 cm) of SOC, on a semi-arid loamy soil from Central Spain. The crop sequence established was cheap pea (*Cicer arietinun* L.) cv. Inmaculada/barley (*Hordeum vulgare* L.) cv. Volley. Soil organic carbon in the various tillage treatments was expressed on a content bases and the equivalent soil mass approach. Measurements made at the end of 17 years showed that in the 0-30 cm depth, stocks of SOC had increased under NT compared with MT and CT. Most dramatic changes occurred within the 0-5 cm layer where plots under NT had 5.8 and 7.6 Mg ha^{-1} more SOC than under MT or CT respectively. No-tillage plots, however, exhibited strong vertical gradients of SOC with concentrations decreasing from 0-5 to 20-30 cm. Stratification ratios of SOC in 1992 showed no significant differences between tillage systems. On the contrary, from 1993 onwards all stratification ratios were significantly higher in NT than in the other two tillage systems. In addition, since 2003 stratification ratios of SOC obtained under NT were systematically >2 and more than 2-fold those obtained under MT and CT. Stratification ratios >2 are uncommon under degraded conditions and could suggest that NT management system may have the most benefits to soil quality in semi arid regions with low native soil organic matter." **C. López-Fando and M.T. Pardo**, *Soil and Tillage Research*, Available online December 4, 2010, doi:10.1016/j.still.2010.10.011,

http://www.sciencedirect.com/science/article/B6TC6-51MCG1B1/2/f3e17f4f8a30d8154966efc83b56b1d7. (Subscription may be required.)

February 2011

"A comparison of carbon assessment methods for optimizing timber production and carbon sequestration in Scots pine stands." The following is the Abstract of this article: "Projected changes in forest carbon stocks and carbon balance differ according to the choice of estimation methods and the carbon pools considered. Here, [the authors] compared three carbon assessment methods for optimizing timber production and carbon sequestration in six example Scots pine (*Pinus sylvestris* L.) stands in Finland. The forest carbon stock was assessed, with three methods: stem carbon, biomass expansion factors (BEFs), and a process-based model. Given a carbon price of [$54] t^{-1} and a [three percent] discount rate, the highest average carbon stock and mean annual increment (MAI) were obtained with the BEF method. Increasing the carbon price from [$0 to $272] t^{-1} resulted in longer optimal rotations and higher MAI, and increased the average carbon stock, especially when carbon was assessed by the BEF method. Comparison of these carbon assessment methods, using economic sensitivity analyses, indicated that optimal thinning regimes and average carbon stocks are strongly dependent on the assessment method. The process-based method led to less frequent thinnings and shorter rotations than the BEF method, due to different predictions of biomass production. As a cost-effective option, optimal thinning regimes play a very important role in timber production and carbon sequestration." **Tianjian Cao, Lauri Valsta, and Annikki Mäkelä**, *Forest Ecology and Management*, Available online September 21, 2010, doi:10.1016/j.foreco.2010.07.053, http://www.sciencedirect.com/science/article/B6T6X-512KGJT-1/2/28768cd40eec9c7f6ebcd59bad67aa35. (Subscription may be required.)

March 2011

"Bayesian hierarchical models for soil CO_2 flux and leak detection at geologic sequestration sites." The following is the Abstract of this article: "Proper characterizations of background soil CO_2 respiration rates are critical for interpreting CO_2 leakage monitoring results at geologic sequestration sites. In this paper, a method is developed for determining temperature-dependent critical values of soil CO_2 flux for preliminary leak detection inference. The method is illustrated using surface CO_2 flux measurements obtained from the AmeriFlux network fit with alternative models for the soil CO_2 flux versus soil temperature relationship. The models are fit first to determine pooled parameter estimates across the sites, then using a Bayesian hierarchical method to obtain both global and site-specific parameter estimates. Model comparisons are made using the deviance information criterion (DIC), which considers both goodness of fit and model complexity. The hierarchical models consistently outperform the corresponding pooled models, demonstrating the need for site-specific data and estimates when determining relationships for background soil respiration. A hierarchical model that relates the square root of the CO_2 flux to a quadratic function of soil temperature is found to provide the best fit for the AmeriFlux sites among the models tested. This model also yields effective prediction intervals, consistent with the upper envelope of the flux data across the modeled sites and temperature ranges. Calculation of upper prediction intervals using the proposed method can provide a basis for setting critical values in CO_2 leak detection monitoring at sequestration sites." **Ya-Mei Yang, Mitchell J. Small, Brian Junker, Grant S. Bromhal, Brian Strazisar and Arthur Wells**, *Environmental Earth Sciences*, Available online January 21, 2011, doi:10.1007/s12665-011-0903-5, http://www.springerlink.com/content/y06q3364p4611x09/. (Subscription required.)

April 2011

"Standing biomass and carbon storage of above-ground structures in dominant mangrove trees in the Sundarbans." The following is the Abstract of this article: "The authors] evaluated carbon stocks in the above-ground biomass (AGB) of three dominant mangrove species (*Sonneratia apetala*, *Avicennia*

alba and *Excoecaria agallocha*) in the Indian Sundarbans. [The authors] examined whether these carbon stocks vary with spatial locations (western region vs. central region) and with seasons (pre-monsoon, monsoon and post-monsoon). Among the three studied species, *S. apetala* showed the maximum above-ground carbon storage (t ha^{-1}) followed by *A. alba* (t ha^{-1}) and *E. agallocha* (t ha^{-1}). The AGB varied significantly with spatial locations ($p < 0.05$) but not with seasons ($p < 0.05$). The variation may be attributed to different environmental conditions to which these areas are exposed to such as higher siltation and salinity in central region compared to western region. The relatively higher salinity in central region caused subsequent lowering of biomass and stored carbon of the selected species." **Abhijit Mitra, Kasturi Sengupta, and Kakoli Banerjee**, *Forest Ecology and Management*, Available online February 4, 2011, doi: 10.1016/j.foreco.2011.01.012, http://www.sciencedirect.com/science/article/B6T6X-523KH7F-4/2/0203418bf1f6d107cab9bbd9269ff343. (Subscription may be required.)

May 2011

"Sensitivity to information upscaling of agro-ecological assessments: Application to soil organic carbon management." The following is the Abstract of this article: "Upscaling of agro-ecological indicators applied in regional analyses is sensitive to scale issues of the input data. This study develops a methodology to quantify this sensitivity for an indicator of soil organic carbon (SOC) dynamics at the farming system level. A reference case consists of seven fully described farms in northern Italy. Both upscaling in complexity by substituting measured input with estimated input and upscaling in space by extending the methods to farms not included in the reference case are addressed. The indicator increased with 3-107 [percent] at four farms after substituting measured management input with that estimated by an expert, whereas it remained unchanged or decreased at the other three farms. Taking the modal value from a cluster of pedological input did not lead to additional uncertainty in most cases, and only slightly increased it in others. [The authors] evaluated spatial upscaling by including 733 farms divided in 18 clusters that were described with less information as compared to the reference farms. Within each cluster, [the authors] observed relevant variability of the indicator (coefficients of variation of 12-43 [percent]), as a consequence of the heterogeneity of farms comprised in each cluster. In each cluster [the authors] calculated the indicator for one virtual farm, defined by using modal values for basic farm inputs. In this case the indicator was highly correlated ($R^2 = 0.98$) with the average of the values obtained using measured basic farm inputs. [The authors] conclude that upscaling in complexity and space introduces uncertainty in the values of the indicator compared to the reference case. The extent of such differences depends on the variability of the systems under analysis and on indicator sensitivity." **Luca Bechini, Nicola Castoldi, and Alfred Stein**, *Agricultural Systems*, Available online April 20, 2011, doi:10.1016/j.agsy.2011.03.005, http://www.sciencedirect.com/science/article/B6T3W-52NKD6M-1/2/8a065dc226505fedbb39d608ae03c786. (Subscription may be required.)

June 2011

"Long-term management impacts on carbon storage in Lake States forests." The following is the Abstract of this article: "[The authors] examined carbon storage following 50+ years of forest management in two long-term silvicultural studies in red pine and northern hardwood ecosystems of North America's Great Lakes region. The studies contrasted various thinning intensities (red pine) or selection cuttings, shelterwoods, and diameter-limit cuttings (northern hardwoods) to unmanaged controls of similar ages, providing a unique opportunity to evaluate long-term management impacts on carbon pools in two major North American forest types. Management resulted in total ecosystem carbon pools of 130–137 Mg ha^{-1} in thinned red pine and 96–177 Mg ha^{-1} in managed northern hardwoods compared to 195 Mg ha^{-1} in unmanaged red pine and 224 Mg ha^{-1} in unmanaged northern hardwoods. Managed stands had smaller tree and deadwood pools than unmanaged stands in both ecosystems, but management had limited impacts on understory, forest floor, and soil carbon pools. Total carbon storage and storage in individual pools varied little across thinning intensities in red pine. In northern hardwoods,

selection cuttings stored more carbon than the diameter-limit treatment, and selection cuttings generally had larger tree carbon pools than the shelterwood or diameter-limit treatments. The proportion of total ecosystem carbon stored in mineral soil tended to increase with increasing treatment intensity in both ecosystems, while the proportion of total ecosystem carbon stored in the tree layer typically decreased with increasing treatment intensity. When carbon storage in harvested wood products was added to total ecosystem carbon, selection cuttings and unmanaged stands stored similar levels of carbon in northern hardwoods, but carbon storage in unmanaged stands was higher than that of thinned stands for red pine even after adding harvested wood product carbon to total ecosystem carbon. [The authors'] results indicate long-term management decreased on-site carbon storage in red pine and northern hardwood ecosystems, but thinning intensity had little impact on carbon storage in red pine while increasing management intensity greatly reduced carbon storage in northern hardwoods. These findings suggest thinning to produce different stand structures would have limited impacts on carbon storage in red pine, but selection cuttings likely offer the best carbon management options in northern hardwoods." **Matthew Powers, Randall Kolka, Brian Palik, Rachel McDonald, and Martin Jurgensen**, *Forest Ecology and Management*, Available online May 7, 2011, doi:10.1016/j.foreco.2011.04.008, http://www.sciencedirect.com/science/article/pii/S0378112711002234. (Subscription may be required.)

"Phytolith occluded carbon and silica variability in wheat cultivars." The following is the Abstract of this article: ~~"~~Phytolith Occluded Carbon (PhytOC) has recently been demonstrated to be an important long-term terrestrial carbon fraction. The aim of this study was to examine the rates of silica accumulation and carbon bio-sequestered within the silica phytoliths of the leaf and stem material of wheat (Triticum sp.) cultivars. The phytolith content of 53 wheat cultivars sourced from 25 countries around the world and grown on a single trial site was first isolated and the PhytOC content then determined. The data shows that the phytolith occluded carbon content of the wheat cultivars ranged from 0.06 [percent] to 0.60 [percent] of dry leaf and stem biomass: a range of 1,000 [percent]. The data also demonstrates that it is the efficiency by which carbon is encapsulated within silica rather than the quantity of silica accumulated by the plant that is the most important factor in determining the relative PhytOC yields. The potential phytolith carbon bio-sequestration rates in the leaf and stem components of these wheat cultivars ranged up to 0.246 t-e-CO_2 $ha^{-1}y^{-1}$. These phytolith carbon bio-sequestration rates indicate a substantial potential (~50 million t-e-CO_2 y^{-1}) exists for increasing the rate of secure carbon bio-sequestration in wheat crops using existing cultivars." **Jeffrey F. Parr and Leigh A. Sullivan**, *Plant and Soil*, doi: 10.1007/s11104-010-0680-z, http://www.springerlink.com/content/y9846747n88h6h36/. (Subscription required.)

"Carbon bio-sequestration within the phytoliths of economic bamboo species." The following is the Abstract of this article: ~~"~~The rates of carbon bio-sequestration within silica phytoliths of the leaf litter of 10 economically important bamboo species indicates that (a) there is considerable variation in the content of carbon occluded within the phytoliths (PhytOC) of the leaves between different bamboo species, (b) this variation does not appear to be directly related to the quantity of silica in the plant but rather the efficiency of carbon encapsulation by the silica. The PhytOC content of the species under the experimental conditions ranged from 1.6 [percent] to 4 [percent] of the leaf silica weight. The potential phytolith carbon bio-sequestration rates in the leaf-litter component for the bamboos ranged up to 0.7 tonnes of CO_2 equivalents (t-e-CO_2) ha^{-1} yr^{-1} for these species. Assuming a median phytolith carbon bio-sequestration yield of 0.36 t-e-CO_2 ha^{-1} yr^{-1}, the global potential for bio-sequestration via phytolith carbon (from bamboo and/or other similar grass crops) is estimated to be ~1.5 billion t-e-CO_2 yr^{-1}, equivalent to 11 [percent] of the current increase in atmospheric CO_2. The data indicate that the management of vegetation such as bamboo forests to maximize the production of PhytOC has the potential to result in considerable quantities of securely bio-sequestered carbon." **Jeffrey Parr, Leigh Sullivan, Bihua Chen, Gongfu Ye, and Weipeng Zheng**, *Global Change Biology*, doi: 10.1111/j.1365-2486.2009.02118.x, http://dx.doi.org/10.1111/j.1365-2486.2009.02118.x. (Subscription may be required.)

July 2011

"Carbon Sequestration in Soil by in Situ Catalyzed Photo-Oxidative Polymerization of Soil Organic Matter." The following is the Abstract of this article: ~~"~~Here [the authors] describe an innovative mechanism for carbon sequestration in soil by in situ photopolymerization of soil organic matter under biomimetic catalysis. Three different Mediterranean soils were added with a synthetic water-soluble iron-porphyrin, irradiated by solar light, and subjected first to 5 days incubation and, then, 15, and 30 wetting and drying (w/d) cycles. The *in situ* catalyst-assisted photopolymerization of soil organic carbon (SOC) increased water stability of soil aggregates both after 5 days incubation and 15 w/d cycles, but not after 30 w/d cycles. Particle-size distribution of all treated soils confirmed the induced soil physical improvement, by showing a concomitant lower yield of the clay-sized fraction and larger yields of either coarse sand- or fine sand-size fractions, depending on soil texture, though only after [five] days incubation. The gain in soil physical quality was reflected by the shift of OC content from small to large soil aggregates, thereby suggesting that photopolymerization stabilized OC by both chemical and physical processes. A further evidence of the carbon sequestration capacity of the photocatalytic treatment was provided by the significant reduction of CO_2 respired by all soils after both incubation and w/d cycles. [The authors'] findings suggest that 'green' catalytic technologies may potentially be the bases for future practices to increase soil carbon stabilization and mitigate CO_2 emissions from arable soils." **Alessandro Piccolo, Riccardo Spaccini, Antonio Nebbioso, and Pierluigi Mazzei**, *Environ. Sci. Technol.*, Available online June 29, 2011, DOI:10.1021/es201572f, http://pubs.acs.org/doi/abs/10.1021/es201572f. (Subscription may be required.)

August 2011

"Modeling long-term soil carbon dynamics and sequestration potential in semi-arid agro-ecosystems." The following is the Abstract of this article: ~~"~~Long-term soil carbon (C) dynamics in agro-ecosystems is controlled by interactions of climate, soil and agronomic management. A modeling approach is a useful tool to understand the interactions, especially over long climatic sequences. In this paper, [the authors] examine the performance of the Agricultural Production Systems sIMulator (APSIM) to predict the long-term soil C dynamics under various agricultural practices at four semi-arid sites across the wheat-belt of eastern Australia. [The authors] further assessed the underlying factors that regulate soil C dynamics in the top 30 cm of soil through scenario analysis using the validated model. The results show that APSIM is able to predict aboveground biomass production and soil C dynamics at the study sites. Scenario analyses indicate that nitrogen (N) fertilization combined with residue retention (SR) has the potential to significantly slow or reverse the loss of C from agricultural soils. Optimal N fertilization (N_{opt}) and 100 [percent] SR, increased soil C by 13 [percent], 46 [percent], and 45 [percent] at Warra, Wagga Wagga and Tarelee, respectively. Continuous lucerne pasture was the most efficient strategy to accumulate soil C, resulting in increases of 49 [percent], 57 [percent] and 50 [percent] at Warra, Wagga Wagga and Tarlee, respectively. In contrast, soil C decreases regardless of agricultural practices as a result of cultivation of natural soils at the Brigalow site. Soil C input, proportional to the amount of retained residue, is a significant predictor of soil C change. At each site, water and nitrogen availability and their interaction, explain more than 59 [percent] of the variation in soil C. Across the four sites, mean air temperature has significant ($P < 0.05$) effects on soil C change. There was greater soil C loss at sites with higher temperature. [The authors'] simulations suggest that detailed information on agricultural practices, land use history and local environmental conditions must be explicitly specified to be able to make plausible predictions of the soil C balance in agro-ecosystems at different agro-ecological scales." **Zhongkui Luo, Enli Wang, Osbert J. Sun, Chris J. Smith, and Mervyn E. Probert**, *Agricultural and Forest Meteorology*, Available online July 15, 2011, doi:10.1013/jagrformet.2011.06.011, http://www.sciencedirect.com/science/article/pii/S0168192311002048. (Subscription may be required.)

Trading

September 2010

***The Province*, "B.C. to Adopt Cap-and-Trade Program for Greenhouse Gas Emissions in 2012,"** and ***The Vancouver Sun*, "B.C. to Unveil New Greenhouse Gas Emissions Rules."** British Columbia will set its own limits on GHG emissions and allow industries to store or trade their carbon credits in a new cap-and-trade program outlined by the Western Climate Initiative (WCI). The program, due to come into effect in 2012, is part of the plan to reduce CO_2 emissions to 15 percent below 2005 levels by 2020. The regulations in British Columbia will lead to limits on 40 large industrial operations; those who emit above those limits will have to buy carbon credits, which project to cost $33 a tonne by 2020. In addition, other emissions sources, including transportation, residential, and commercial, will be included in the program by 2015. British Columbia joined WCI in 2007 and introduced the Greenhouse Gas (Cap-and-Trade) Act in April 2008. For more information on GHG emissions in British Columbia, visit: http://www.livesmartbc.ca/learn/emissions.html. July 27, 2010, http://www.theprovince.com/technology/adopt+trade+program+greenhouse+emissions+2012/3329676/story.html, and July 28, 2010, http://www.vancouversun.com/technology/unveil+greenhouse+emissions+rules/3334656/story.html.

"Integration of CCS, emissions trading and volatilities of fuel prices into sustainable energy planning, and its robust optimization." The following is the Abstract of this document: ~~"~~In this paper, a new approach has been proposed that allows a robust optimization of sustainable energy planning over a period of years. It is based on the modified energy flow optimization model (EFOM) and minimizes total costs in planning capacities of power plants and CCS to be added, stripped or retrofitted. In the process, it reduces risks due to a high volatility in fuel prices; it also provides robustness against infeasibility with respect to meeting the required emission level by adopting a penalty constant that corresponds to the price level of emission allowances. In this manner, the proposed methodology enables decision makers to determine the optimal capacities of power plants and/or CCS, as well as volumes of emissions trading in the future that will meet the required emission level and satisfy energy demand from various user-sections with minimum costs and maximum robustness. They can also gain valuable insights on the effects that the price of emission allowances has on the competitiveness of RES and CCS technologies; it may be used in, for example, setting appropriate subsidies and tax policies for promoting greater use of these technologies. The proposed methodology is applied to a case based on directions and volumes of energy flows in South Korea during the year 2008." **Jamin Koo, Kyusang Han, and En Sup Yoon**, *Renewable and Sustainable Energy Reviews*, Available online August 2, 2010, doi:10.1016/j.rser.2010.07.050, http://www.sciencedirect.com/science/article/B6VMY-50P0DM2-8/2/e07be401f98e1438d2623016776ddeb0. (Subscription may be required.)

October 2010

***RGGI News Release*, "Ten States Mark Second Anniversary of Regional Program to Reduce Greenhouse Gas Emissions."** The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) conducted their 9th regional CO_2 allowance auction on September 8, 2010, marking the auction's two-year anniversary. The current control period CO_2 allowances (2009-2011) offered in the auction yielded a total of $63,997,020 from the sale of 34,407,000 allowances; the auction clearing price was $1.86 per allowance. A small amount of CO_2 allowances for a future control period (2012-2014) were also offered, yielding a total of $2,440,320 from the sale of 1,312,000 allowances; the auction clearing price was $1.86 per allowance. In all, more than 75 percent of the current control period CO_2 allowances offered were sold, and more than 61 percent of future control period allowances offered were sold. Since September 2008, RGGI auctions have generated $729,281,959 in proceeds; more than 80 percent of the proceeds are being invested in strategic energy

programs to benefit consumers and build a clean energy economy. September 10, 2010, http://www.rggi.org/docs/Auction_9_News_Release_MM_Report.pdf.

***Reuters*, "First Tokyo Carbon Credits Trade for $142/Tonne."** According to Point Carbon News, the first carbon credits traded in Tokyo's new cap-and-trade scheme traded for $142.20 per tonne; UN-backed carbon offset credits currently trade in the Japanese market at a rate of $17.78 per tonne. Tokyo's first mandatory cap-and-trade program launched in April 2010. Under the new plan, large-scale businesses must cut their emissions by an average of seven percent from 2010 to 2014. Tokyo is responsible for approximately five percent of Japan's total carbon emissions; Japan has pledged to cut its national emissions by 25 percent below 1990 levels by 2020. The online marketplace is expected to handle approximately 800,000 tonnes of CO_2 in 2015, rising to 1.3 million tonnes by 2020. August 24, 2010, http://www.reuters.com/article/idUSTRE67N3M520100824.

November 2010

***RGGI News Release*, "RGGI States Issue Notice for December 2010 CO_2 Allowance Auction."** The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice and application materials for the 2010 fourth quarter CO_2 allowance auction. A total of 43,173,648 CO_2 allowances for the current control period (2009 to 2012) and 2,137,991 CO_2 allowances for the future control period (2012 to 2014) will be offered for sale in CO_2 Allowance Auction 10; states will continue to use the reserve price of $1.86. The released application materials provide potential auction participants with the information needed to submit a Qualification Application and indicate their intent to bid on the allowances. Since the debut of the RGGI auctions on September 25, 2008, more than 290 million CO_2 allowances have been auctioned by the participating states in nine total auctions. To download auction materials, as well as a recorded version of a webinar reviewing the auction format and qualification process, visit: http://www.rggi.org/market/co2_auctions/information. October 5, 2010, http://www.rggi.org/docs/Auction_10_Notice_NR.pdf.

December 2010

***Yahoo! News*, "California Unveils Greenhouse Gas Trading Plan."** On October 29, Californian officials announced the intention to give away permits (rather than sell the majority of the necessary permits) to factories and power plants when the state's GHG trading program starts in 2012. On average, emitters will be given approximately 97 to 98 percent of the permits they will require in the first year. In addition, up to eight percent of permit needs could be met with offset credits that avoid emissions for storing GHGs. California will create as many permits as expected emissions in the first year of the plan, and will set aside an average of four percent of permits from 2012 to 2020 to be sold if trading prices increase higher than expected; the reserve will be approximately one percent in 2012. Permits auctioned by the state will cost at least $10 per tonne in the first year and $15 per tonne in 2020. California is part of WCI, a consortium of seven western states and four Canadian provinces aiming to start a joint trading scheme in 2012. October 29, 2010, http://news.yahoo.com/s/nm/20101029/us_nm/us_carbon_california.

***BBC News*, "Kenya to Launch Africa's First Carbon Exchange."** Kenyan officials announced plans to launch a climate exchange platform to facilitate the trading of carbon credits. The first of its kind in Africa, the market will enable all African countries to sell their carbon credits to help prevent potential climate change. According to Kenyan officials, the trade in carbon credits has the potential to spur investment in the generation of renewable energy and forestry projects. Kenya's government estimates that the Mau, the country's largest forest, has the potential to earn the country nearly $2 billion a year over the next 15 years – a value that would have to be certified by the United Nations Framework Convention on Climate Change (UNFCCC). November 11, 2010, http://www.bbc.co.uk/news/science-environment-11733765.

January 2011

***RGGI News Release*, "RGGI Auction Yields $48.2 Million for Investment in Energy Savings and Clean Energy."** The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) released the results of their 10th regional auction of CO_2 allowances, held December 1, 2010. The auction saw 57 percent (24,755,000) of the current control period CO_2 allowances (2009-2011) offered sold at a clearing price of $1.86 per allowance, yielding a total of $46,044,300; 55 percent (1,172,000) of allowances offered for a future control period (2012-2014) were sold at the same clearing price, yielding a total of $2,179,920. For the current control period, 38 entities submitted winning bids ranging from $1.86 to $10.02; for the future control period, four bidders submitted winning bids ranging from $1.86 to $2.01. Proceeds from the 10 RGGI auctions now total more than $777.5 million, of which more than 80 percent is being reinvested by states in strategic energy programs. The next RGGI auction is scheduled for March 9, 2011. December 3, 2010, http://www.rggi.org/docs/Auction_10_Release_Report.pdf.

"How carbon pricing changes the relative competitiveness of low-carbon baseload generating technologies." The following is the Abstract of this article: "There is wide public debate about which electricity generating technologies will best be suited to reduce [GHG] emissions. Sometimes this debate ignores real-world practicalities and leads to over-optimistic conclusions. Here [the authors] define and apply a set of fit-for-service criteria to identify technologies capable of supplying baseload electricity and reducing GHGs by amounts and within the timescale set by the Intergovernmental Panel on Climate Change (IPCC). Only five current technologies meet these criteria: coal (both pulverized fuel and integrated gasification combined cycle) with CCS; combined cycle gas turbine with CCS; Generation III nuclear fission; and solar thermal backed by heat storage and gas turbines. To compare costs and performance, [the authors] undertook a meta-review of authoritative peer-reviewed studies of levelized cost of electricity (LCOE) and life-cycle GHG emissions for these technologies. Future baseload electricity technology selection will be influenced by the total cost of technology substitution, including carbon pricing, which is synergistically related to both LCOE and emissions. Nuclear energy is the cheapest option and best able to meet the IPCC timetable for GHG abatement. Solar thermal is the most expensive, while CCS will require rapid major advances in technology to meet that timetable." **Martin Nicholson, Tom Biegler, and Barry W. Brook**, *Energy*, Available online November 18, 2010, doi:10.1016/j.energy.2010.10.039, http://www.sciencedirect.com/science/article/B6V2S-51H0085-6/2/68f10707d6938ad8d447a023c8efe7ca. (Subscription may be required.)

February 2011

***RGGI News Release*, "RGGI States Issue Notice for March 2011 CO_2 Allowance Auction."** The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice and application materials for the first quarterly CO_2 allowance auction of 2011. A total of 41,995,813 CO_2 allowances for the current control period (2009 to 2011) and 2,144,710 CO_2 allowances for the future control period (2012 to 2014) will be offered for sale in CO_2 Allowance Auction 11; states will use the reserve price of $1.89 (the reserve price is adjusted at the beginning of each calendar year for the U.S. Department of Labor, Bureau of Labor Statistics Consumer Price Index). The released application materials provide potential auction participants with the information needed to submit a Qualification Application and indicate their intent to bid on the allowances. Since the debut of the RGGI auctions on September 25, 2008, more than 318 million CO_2 allowances have been auctioned by the states participating in nine total auctions. For more information on the application process, visit: http://www.rggi.org/market/co2_auctions/information. January 11, 2011, http://www.rggi.org/docs/Auction_11_Notice_News_Release.pdf.

"Deployment of CCS Technologies across the Load Curve for a Competitive Electricity Market as a Function of CO_2 Emissions Permit Prices." The following is the Abstract of this article: "Consistent

with other published studies, the modelling presented here reveals that baseload power plants are the first aspects of the electricity sector to decarbonize and are essentially decarbonized once CO_2 permit prices exceed a certain threshold ($90/ton CO_2 in this study). The decarbonization of baseload electricity is met by significant expansions of nuclear power and renewable energy generation technologies as well as the application of CCS technologies applied to both coal and natural gas fired power plants. Relatively little attention has been paid thus far to whether intermediate and peaking units would respond the same way to a climate policy given the very different operational and economic context that these kinds of electricity generation units operate under. In this paper, the authors discuss key aspects of the load segmentation methodology used to imbed a varying electricity demand within the GCAM (a state-of-the-art Integrated Assessment Model) energy and economic modelling framework and present key results on the role CCS technologies could play in decarbonizing subpeak and peak generation (encompassing only the top 10 [percent] of the load) and under what conditions. To do this, the authors have modelled two hypothetical climate policies that require 50 [percent] and 80 [percent] reductions in U.S. emissions from business as usual by the middle of this century. Intermediate electricity generation is virtually decarbonized once carbon prices exceed approximately $150/ton$CO_2$. When CO_2 permit prices exceed $160/ton$CO_2$, natural gas power plants with CCS have roughly the same market share as conventional gas plants in serving subpeak loads. The penetration of CCS into peak load (upper [six percent] here) is minimal under the scenarios modeled here suggesting that CO_2 emissions from this aspect of the U.S. electricity sector would persist well into the future even with stringent CO_2 emission control policies in place." **P Luckow, MA Wise, and JJ Dooley**. Presented at GHGT-10, held September 19-23, at RAI in Amsterdam, The Netherlands, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00515%2Epdf.

March 2011

***Reuters*, "UK CO_2 Auction Income Seen Over [~$90 Bln] by 2020."** According to a report by carbon offsetting firm Carbon Retirement, United Kingdom revenues from auctioning European Union (EU) carbon permits could rise to more than $88 billion from 2013 to 2020. The current EU Emissions Trading Scheme (EU ETS) caps emissions of heavy industries and allows them to either buy EU Allowances (EUAs) to cover excess emissions, or sell them when they reduce their emissions. Rules allow member states to auction up to 10 percent of their EUAs from 2008 to 2012. Starting in 2013, the EU ETS will make emitters pay for the majority of their allowances, which is expected to result in the auction of at least 50 percent of permits every year (currently, seven percent of permits are auctioned off). The price of EUAs is also expected to jump from the current rate of approximately $19.50/tonne. Since the UK government began carbon auctions in November 2008, more than $1.3 billion has been raised for the UK Treasury. February 10, 2011, http://af.reuters.com/article/energyOilNews/idAFLDE7190KL20110210?sp=true.

April 2011

***RGGI News Release*, "RGGI Auction Yields $83.4 Million for Investment in Energy Efficiency, Job Creation."** The Regional Greenhouse Gas Initiative's (RGGI) 11th quarterly auction of CO_2 allowances, held March 9, 2011, yielded $83,425,588 for states to invest in programs that enable energy consumers to control their energy budgets. All of the 41,995,813 current control period CO_2 allowances (2009-2011) offered in the auction, as well as all of the 2,144,710 CO_2 allowances for a future control period (2012-2014) offered, sold at a price of $1.89 per allowance. A total of 36 entities submitted bids to purchase 1.1 times the available supply of current control period allowances, with electric generators and their corporate affiliates purchasing 85 percent. Seven entities submitted bids to purchase 1.4 times the available supply of future control period allowances, with electric generators and their corporate affiliates purchasing 56 percent. The 10 Northeast and Mid-Atlantic states that participate in RGGI invest proceeds from the auctions, which now totals more than $860.9 million, in programs aimed at saving

energy consumers money, creating jobs, and making business more competitive. The next RGGI auction is scheduled for June 8, 2011. March 11, 2011, http://www.rggi.org/docs/Auction_11_Release_Report.pdf.

***Reuters*, "EU to Auction 120 Million CO_2 Permits in 2012."** The European Commission has added to its auctioning regulation by proposing that 120 million Phase 3 EU carbon permits be auctioned in early 2012. Under the EU Emissions Trading Scheme (EU ETS), emissions from approximately 11,000 factories and power plants are capped. A corresponding number of permits (EU Allowances [EUAs]) are distributed accordingly; if more CO_2 is emitted than EUAs allocated, more can be purchased. In Phase 3 of EU ETS, which runs from 2013 to 2020, most EUAs will be allocated through auctions as opposed to being distributed for free. The 120 million EUAs to be auctioned in 2012 will be in addition to 300 million EUAs that the European Investment Bank intends to monetize by the end of 2012 to raise low-carbon technology funds. March 15, 2011, http://www.reuters.com/article/2011/03/15/us-eu-carbon-auctions-idUSTRE72E2I220110315.

"Carbon capture and storage as a corporate technology strategy challenge." The following is the Abstract of this article: ~~L~~atest estimates suggest that widespread deployment of CCS could account for up to one-fifth of the needed global reduction in CO_2 emissions by 2050. Governments are attempting to stimulate investments in CCS technology both directly through subsidizing demonstration projects, and indirectly through developing price incentives in carbon markets. Yet, corporate decision-makers are finding CCS investments challenging. Common explanations for delay in corporate CCS investments include operational concerns such as the high cost of capture technologies, technological uncertainties in integrated CCS systems and underdeveloped regulatory and liability regimes. In this paper, [the authors] place corporate CCS adoption decisions within a technology strategy perspective. [The authors] diagnose four underlying characteristics of the strategic CCS technology adoption decision that present unusual challenges for decision-makers: such investments are precautionary, sustaining, cumulative and situated. Understanding CCS as a corporate technology strategy challenge can help move beyond the usual list of operational barriers to CCS and make public policy recommendations to help overcome them." **Frances Bowen**, *Energy Policy*, Available online March 3, 2011, doi:10.1016/j.enpol.2011.01.016, http://www.sciencedirect.com/science/article/B6V2W-529C3TM-2/2/06f31d2e212f48e3fc10d80a978016fb. (Subscription may be required.)

May 2011

***RGGI News Release*, "RGGI States Issue Notice for June 2011 CO_2 Allowance Auction."** The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice and application materials for CO_2 Allowance Auction 12, providing potential auction participants the information needed to submit a Qualification Application and indicate their intent to bid. To be held June 8, 2011, CO_2 Allowance Auction 12 will offer 42,034,184 CO_2 allowances for sale for the current control period (2009-2011) and 2,144,710 CO_2 allowances for the future control period (2012-2014); a reserve price of $1.89 will be used for all allowances in the June auction. Since the debut of the RGGI auctions on September 25, 2008, the participating states have auctioned more than 360 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. April 8, 2011, http://www.rggi.org/docs/Auction_12_Notice_News_Release.pdf.

***Industrial Fuels and Power*, "China to Launch Emissions Trading in Six Regions."** According to government officials, China will launch pilot emissions trading schemes in six areas before 2013 to prepare for a nationwide trading platform by 2015. The pilot schemes will be launched in the cities of Beijing, Chongqing, Shanghai, and Tianjin, as well as the provinces of Hubei and Guangdong. Over the 2011 through 2015 period, the Chinese government plans to cut energy intensity by 16 percent and carbon intensity by 17 percent to meet their target of reducing carbon intensity by 40 to 45 percent based

on 2005 levels by the end of 2020. Local targets have been issued to provinces and regions, but have yet to be made public. April 14, 2011, http://www.ifandp.com/article/0010690.html.

June 2011

***RGGI News Release*, "Regional Clean Energy Economy Boosted with $25.5 Million in RGGI Auction Proceeds."** The states participating in the Regional Greenhouse Gas Initiative (RGGI) announced the results of their 12th quarterly auction of CO_2 allowances and published a report prepared by the independent market monitor Potomac Economics containing auction data and a list of the qualified participants. Of the 42,034,184 CO_2 allowances offered for sale for the current control period (2009-2011), 12,537,000 were sold (approximately 30 percent); the 25 winning bids ranged from $1.89 (the auction clearing price) to $7.40. Of the 1,864,952 CO_2 allowances offered for the future control period (2012-2014), 943,000 were sold (approximately 51 percent); the five winning bids ranged from $1.89 to $2.07. Electric generators and their corporate affiliates purchased 91 percent of the current control period allowances sold and 100 percent of the future control period allowances sold. To date, more than $886.4 million has been generated from the auctions, with a vast majority of the proceeds invested to promote clean energy sources and lower energy costs for consumers across the region. June 10, 2011, http://www.rggi.org/docs/Auction_12_Release_Report.pdf.

"Optimal pricing instruments for emission reduction certificates." The following is the Abstract of this article: "The clean development mechanism (CDM), launched under the Kyoto Protocol is intended to internalize environmental externalities and to help developing countries achieve their developmental objectives employing cleaner, albeit possibly more expensive, technologies, inter alia creating markets for trading of emission reduction certificates (certified emission reduction [CER]). Statistical analyses reveal trends in pricing of Euro denominated CERs, which is interpreted as market inefficiency. Since the exporting countries are required to 'liquidate,' 'package' and 'export' a natural asset, and in real terms, surrender the option to employ certain technologies or to undertake certain initiatives, they should be recompensed through an asset of comparable quality, and more importantly, one on whose valuation the sellers have sufficient control. A currency-basket consisting of major CER exporting country currencies is considered. A specially constructed synthetic currency named the CERO, a weighted average of the CER exporting countries' import partners' currencies is proposed as a second alternative. It is strongly recommended that policy makers negotiating a successor to the Kyoto Protocol actively consider the basket approach to valuation proposed herein." **Srinivasan Sunderasan**, *Environmental Science & Policy*, Available online April 17, 2011, doi:10.1016/j.envsci.2011.03.013, http://www.sciencedirect.com/science/article/pii/S1462901111000475. (Subscription may be required.)

July 2011

***RGGI News Release*, "RGGI States Initiate Bidding Process for September 2011 CO_2 Allowance Auction."** The states participating in the Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice and application materials for their 13th quarterly CO_2 allowance auction, providing potential participants with information needed to submit a Qualification Application and indicate their intent to bid. A total of 42,189,685 CO_2 allowances will be offered for sale for the current control period (2009-2011), and 1,864,951 will be offered for the future control period (2012-2014). A reserve price of $1.89 will be used for all allowances in the auction, which is scheduled for September 7, 2011, three years since the debut of RGGI auctions. RGGI, the Nation's first market-based regulatory program to reduce GHG emissions, has auctioned more than 375 million CO_2 allowances to date. For information on previous auction results, visit: http://www.rggi.org/market/co2_auctions/results. July 12, 2011, http://www.rggi.org/docs/Auction_13%20Notice_News_Release.pdf.

***ABC Central West NSW*, "Australia's First Carbon Trading Pilot Set for Lachlan Valley."** Approximately 300 farmers in the Canowindra, Cudal, and Manildra areas will be eligible to participate in

Australia's first soil carbon trading pilot scheme at Lachlan Valley. Farmers who best demonstrate increases in the amount of CO_2 stored in their soil will be able to bid for funding under the five-year scheme from the Lachlan Catchment Management Authority. The trial is expected to provide a better understanding of how farmers can store CO_2 while still keeping their properties profitable. June 23, 2011, http://www.abc.net.au/news/stories/2011/06/23/3251073.htm?site=centralwest&section=news.

August 2011

***Huffington Post*, "Australia Carbon Tax Plan Introduced By Julia Gillard,"** and ***Energy Daily*, "Australian Cabinet to Vote on Carbon Tax."** The Australian Government plans to introduce a carbon price in Parliament next month, which would require Australia's 500 highest emitters to pay approximately $24 per ton of carbon emissions emitted beginning on July 1, 2012. The largest emitters would pay the fixed price per tonne of CO_2, which would allow emitters to buy offsetting shares from companies producing emissions less than target levels, until 2015, when a market-based trading scheme is expected to be introduced. The Australian Government would then designate a floor price and an upper limit for at least the first three years to avoid price fluctuations. Under the scheme scheduled to begin on July 1, 2012, the Australian Government plans to include any company that produces at least 25,000 tonnes of CO_2 per year. According to Australia's Prime Minister, the carbon tax plan would reduce emissions by five percent over 2000 levels by 2020 and would cut 159 million tons of carbon emissions. July 10, 2011, http://www.huffingtonpost.com/2011/07/10/australia-carbon-tax-plan_n_894016.html, and August 17, 2011, http://www.energy-daily.com/reports/Australian_Cabinet_to_vote_on_carbon_tax_999.html.

"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 August 4, 2011, doi:10.1016/j.enpol.2011.07.003, http://www.sciencedirect.com/science/article/pii/S030142151100526X. (Subscription may be required.)

Recent Publications

September 2010

"Report of the Interagency Task Force on Carbon Capture and Storage." The following is from the Executive Summary of this document: "CCS refers to a set of technologies that can greatly reduce CO_2 emissions from new and existing coal- and gas-fired power plants, industrial processes, and other stationary sources of CO_2. In its application to electricity generation, CCS could play an important role in achieving national and global GHG reduction goals. However, widespread cost-effective deployment of CCS will occur only if the technology is commercially available and a supportive national policy framework is in place. In keeping with that objective, on February 3, 2010, President Obama established an Interagency Task Force on Carbon Capture and Storage composed of 14 Executive Departments and

Federal Agencies. The Task Force, co-chaired by DOE and EPA, was charged with proposing a plan to overcome the barriers to the widespread, cost-effective deployment of CCS within [10] years, with a goal of bringing five to [10] commercial demonstration projects online by 2016. Composed of more than 100 Federal employees, the Task Force examined challenges facing early CCS projects as well as factors that could inhibit widespread commercial deployment of CCS. In developing the findings and recommendations outlined in this report, the Task Force relied on published literature and individual input from more than 100 experts and stakeholders, as well as public comments submitted to the Task Force. The Task Force also held a large public meeting and several targeted stakeholder briefings. While CCS can be applied to a variety of stationary sources of CO_2, its application to coal-fired power plant emissions offers the greatest potential for GHG reductions. Coal has served as an important domestic source of reliable, affordable energy for decades, and the coal industry has provided stable and quality high-paying jobs for American workers. At the same time, coal-fired power plants are the largest contributor to U.S. GHG emissions, and coal combustion accounts for 40 percent of global CO_2 emissions from the consumption of energy. EPA and Energy Information Administration (EIA) assessments of recent climate and energy legislative proposals show that, if available on a cost-effective basis, CCS can over time play a large role in reducing the overall cost of meeting domestic emissions reduction targets. By playing a leadership role in efforts to develop and deploy CCS technologies to reduce GHG emissions, the United States can preserve the option of using an affordable, abundant, and domestic energy resource, help improve national security, help to maximize production from existing oil fields through enhanced oil recovery (EOR), and assist in the creation of new technologies for export." The complete report is available at: http://www.fossil.energy.gov/programs/sequestration/ccstf/CCSTaskForceReport2010.pdf.

"Impact of the Marcellus Shale Gas Play on Current and Future CCS Activities." The following is from the Introduction of this document: "The Marcellus Shale is a major geologic formation underlying significant portions of New York, Ohio, Pennsylvania, and West Virginia. Although it is a very tight formation, it contains a massive quantity of natural gas, thus making it of great economic importance. This paper covers the geology of the Marcellus Shale (extent, depth, gas producing potential, properties, etc.), the techniques used to produce the gas, and the potential for CCS in the Marcellus Shale or adjacent formations. Because of the low permeability of shale units, hydraulic fracturing and horizontal drilling were developed in the Barnett Shale of Texas during the 1990s; these were the key enabling technologies that made recovery of shale gas economically viable. These technologies have been applied to the Marcellus Shale and other shale gas basins. In addition to gas production from the Marcellus Shale and other gas shale basins in the [United States], this paper discusses the impact of shale gas exploration and production on the potential for CCS in the Marcellus and other units in the Appalachian Basin." The complete report is available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/Marcellus_CCS.pdf.

"Development and innovation in carbon dioxide (CO_2) capture and storage technology." The following is from a summary of this two-volume document: "The fossil-fuel power sector and energy-intensive industries are major producers of CO_2 emissions, contributing to rising global CO_2 levels that have been linked to climate change. CCS technology is therefore being developed for application to power plants and in CO_2-intensive industries to reduce the carbon footprint of these activities, in order to mitigate the potentially harmful effects of climate change. CO_2 capture options range from post- and pre-combustion separation to advanced combustion-based options, which are applicable to both new-build power plant or as a retrofit to existing plant, and can also be adopted in other industries. CO_2 storage options range from geological sequestration in deep saline aquifers and [utilization] of CO_2 for enhanced oil and gas recovery, to mineral carbonation and biofixation. Developments and innovations in this field are aimed at increasing the effectiveness and lowering the cost of capture, and at verifying the safety and efficacy of storage/sequestration. *Developments and innovation in [CO_2] capture and storage technology, Volumes 1 and 2,* provide a comprehensive reference on the state of the art of research, development and demonstration of CCS technology in the power sector and in industry. With its distinguished international team of contributors, *Developments and innovation in [CO_2] capture and*

storage technology, Volumes 1 and 2, will be a standard reference for professional and manager in the power sector and related industries, as well as to academics and researchers in this important field." To view Volume 1, titled, "Carbon dioxide (CO_2) capture, transport and industrial applications," click: http://www.woodheadpublishing.com/en/book.aspx?bookID=1552. To view Volume 2, titled, "Carbon dioxide (CO_2) storage and utilization," go to: http://www.woodheadpublishing.com/en/book.aspx?bookID=2047.

October 2010

"Government Response to the Consultation on the Proposed Offshore Carbon Dioxide Storage Licensing Regime." The following is from the Executive Summary of this document: "The Energy Act 2008 established a legislative basis in the UK for permitting the offshore storage of [CO_2]. A consultation document published on September 25, 2009 set out proposals for an appropriate licensing system, together with draft licensing regulations, which will also implement much of the EU Directive on geological storage of [CO_2]. This document sets out the Government's response to the comments received. In general, respondents were supportive of the broad structure of the proposed licensing system, including the proposal for a license which would cover all phases of such developments (exploration/appraisal, operation, post-closure) and would convey an exclusive but time-limited right to apply for the storage permit required by the Directive. A number of issues prompted particular interest or comment. These included the scope of the license and its relationship to the lease. Broadly speaking, [the Department of Energy and Climate Change (DECC)] envisages that the license will refer to an essentially two dimensional plan, authorizing the relevant activities within that area and its downward projection, in the same way as the established petroleum licenses. But the storage permit when issued will contain three-dimensional definitions of the storage site and the storage complex, and the authorization conveyed will relate to these areas. The initial agreement for lease issued by The Crown Estate will relate to the same area as the license, and the subsequent lease will incorporate the same definition of the site as that in the permit…There was also particular interest in the relationship between carbon storage projects and existing petroleum developments. The Government is not persuaded by a number of proposals made for new powers to regulate such situations, but is giving further consideration to the possibility of giving priority, in certain limited circumstances, to operators of producing hydrocarbon fields for redeveloping these fields for carbon storage." To view the DECC document, click: http://www.decc.gov.uk/assets/decc/Consultations/carbondioxidestorage%20licensing/422-govt-response-offshore-co2-storage.pdf.

"Oil & gas reservoirs in U.S. like the producing formation." The following is from the Introduction of this document: "[The Rocky Mountain Oilfield Testing Center's (RMOTC)] operations at the Teapot Dome Oil Field (NPR-3) in Wyoming provide an excellent natural laboratory in which to conduct research in EOR and carbon sequestration in geologic reservoirs. In addition, RMOTC provides a testing center environment ideal for testing and/or demonstrating new technologies for EOR and sequestration. Several oil-producing formations at NPR-3 have characteristics similar and analogous to nationwide CO_2-EOR and sequestration target reservoirs, including: Tensleep Sandstone, Second Wall Creek Sandstone, Muddy Sandstone, [and] Dakota Sandstone. The Shannon Sandstone is also productive at NPR-3, but it is too shallow and has too low a reservoir pressure to be a candidate for CO_2-EOR, so it isn't included in this review. However, it may still be useful for sequestration research for evaluation of leakage, containment, and monitoring technologies. NETL categorizes geologic sequestration into these classes: (1) oil and gas reservoirs; (2) unmineable coal seams; (3) deep saline formations; (4) basalt formations; [and] (5) organic-rich shales. This summary will only address #1 and #3 for the NPR-3 site. Two other identified geologic sequestration targets, #2 coals and #4 basalts, are out of scope for this summary, as those are not present at Teapot Dome. Fractured organic-rich shales (#5), including the Niobrara Formation, are productive at NPR-3, and although these are seen as future potential sequestration targets, the sequestration science for these targets is immature and they exhibit very low permeabilities, so they are also not included. NPR-3 does have two key deep saline formations (#3 in above list), conducive to research as sequestration targets, which are also analogous to similar saline reservoirs

nationwide: Crow Mountain Sandstone [and] Madison Limestone. These are not EOR targets at NPR-3, but they do relate to nationwide sequestration capacity numbers discussed in a later section." To view DOE's RMOTC white paper, click: http://www.rmotc.doe.gov/PDFs/CO2_white_paper.pdf.

November 2010

"Geologic Storage Formation Classification: Understanding Its Importance and Impacts on CCS Opportunities in the United States." The following is from the Executive Summary of this manual: "A need exists for further research on carbon storage technologies to capture and store CO_2 from stationary sources that would otherwise be emitted to the atmosphere. CCS technologies have the potential to be a key technology for reducing CO_2 emissions and mitigating global climate change. Deploying these technologies on a commercial-scale will require geologic storage formations capable of: (1) storing large volumes of CO_2; (2) receiving CO_2 at an efficient and economic rate of injection; and (3) safely retaining CO_2 over extended periods. Eleven major types of depositional environments, each having their own unique opportunities and challenges, are being considered by DOE for CO_2 storage. The different classes of reservoirs reviewed in this study include: deltaic, coal/shale, fluvial, alluvial, strandplain, turbidite, eolian, lacustrine, clastic shelf, carbonate shallow shelf, and reef. Basaltic interflow zones are also being considered as potential reservoirs. DOE has recently completed this study which investigated the geology, geologic reservoir properties and confining units, and geologic depositional systems of potential reservoirs and how EOR and CBM are currently utilizing CO_2. The study looked at the classes of geologic formations, and their potential to serve as CO_2 reservoirs, distribution, and potential volumes. This study discussed the efforts that DOE is supporting to characterize and test small- and large-scale CO_2 injection into these different classes for reservoirs. These tests are important to better understand the directional tendencies imposed by the depositional environment that may influence how fluids flow within these systems today, and how CO_2 in geologic storage would be anticipated to flow in the future. Although diagenesis has modified fluid flow paths during the intervening millions of years since they were deposited, the basic architectural framework created during deposition remains. Geologic processes that are working today also existed when the sediments were initially deposited. Analysis of modern day depositional analogs and evaluation of core, outcrops, and well logs from ancient subsurface formations give an indication of how formations were deposited and how fluid flow within the formation is anticipated to flow." To view the NETL-developed manual, click: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/Geologic_Storage.pdf.

"Carbon Capture and Storage: Mobilizing Private Sector Finance." The following is from the Executive Summary of this document: "The Climate Group and the Ecofin Research Foundation are working on a joint initiative to assess, and possibly stimulate, private sector financing for first generation industrial scale CCS projects. This brief report provides an overview of initial findings from a European perspective. [The authors] canvassed over 30 private sector capital providers about the risks and returns of a post-combustion, new build, coal-fired power station. The following messages are emerging: (1) *Debt… not yet*. Ample debt may be available but only if three prerequisites can be addressed: (a) An indicator of performance across the whole capture and generation chain must be provided by a well-regarded equipment supplier or contractor; (b) Major sponsors who have successfully managed sizeable and complicated construction projects must be involved; (c) Economics of CCS must have a route to being competitive with other forms of generation, without public funding; (2) *Not for specialist equity*. Specialist equity, such as private equity or infrastructure funds, will not be mobilized to finance demonstration projects. Private equity sees demonstration of CCS, like technology funding – requiring high returns across a spread of projects. Infrastructure funds don't take the construction and integration risk inherent in demonstration CCS projects; (3) *On the balance sheet… but limited in scale*. Bond holders or equity holders from the big pension funds or insurance companies are comfortable with corporates using their balance sheets to finance CCS, but only as long as the scale is limited to just a couple of percent of group assets. Across the European utilities, though, this would enable a maximum of [$6.97 billion] of funds to be available, and even then it is questionable if those utilities would be prepared to invest that much in CCS demonstrations whilst balance sheets are being delivered and

capital budgets are being cut; (4) *Demonstrations helped by the private sector… but for two not eight projects*. Limited private sector funding means that a multitude of CCS demonstration projects cannot be pursued. It is generally agreed that government sources will provide part of the funding for CCS demonstration projects and that will be topped up by private sector sources. However, the initial findings of [the authors'] initiative indicate that private sector funds will be adequate to support maybe just two CCS demonstrations – and that's across the whole of Europe. This is clearly a long way short of the UK's plans to have up to four demonstration projects, let alone Europe's ambition to see eight and hopefully [12] demonstration projects; and (5) *Government funding needs to focus on fewer CCS demonstration projects*. Public sector financial support for CCS from European sources needs to be focused on far fewer projects instead of being spread over numerous CCS technologies. This will ensure some of the challenges are faced – and hopefully overcome – rather than attempting to initiate CCS in a variety of settings which may simply result in none of the challenges being properly addressed. Once the concerns of private sector debt market participants are addressed, the need for government funds would be sharply reduced." To view the full document, click: http://www.theclimategroup.org/_assets/files/CCS-report.pdf.

"Report on the Secondary Market for RGGI CO_2 Allowances: First Quarter 2010." The following is from the Introduction of this document: "The primary market for RGGI CO_2 allowances consists mainly of the auctions where allowances are initially sold. Once an allowance is purchased in the primary market, it can then be resold in the secondary market. The secondary market for RGGI CO_2 allowances comprises the trading of physical allowances and financial derivatives, such as futures and options contracts. The secondary market is important for several reasons. First, it gives firms an ability to obtain CO_2 allowances at any time during the three months between the RGGI auctions. Second, it provides firms a way to protect themselves against the potential volatility of future auction clearing prices. Third, it provides price signals that assist firms in making investment decisions in markets affected by the cost of RGGI compliance. This report provides a summary of activity in the secondary market in the first quarter of 2010 and discusses the results of [the] market power screens. Several patterns have emerged in this period in the secondary market: (1) CO_2 allowance prices remained stable in the first quarter as the price of 2009 vintage futures contracts averaged $2.15. The quarter began with 2009 vintage futures contracts trading at a small (up to [three] percent) premium over 2010 vintage futures contracts, but the premium fell to [zero] percent by late February; (2) the volume of futures trading decreased 83 percent from 127 million allowances in the fourth quarter of 2009 to 22 million allowances in the first quarter of 2010. Although most of the trading volume was for 2009 vintage contracts, the share associated with 2010 vintage contracts increased to 31 percent in the first quarter; (3) 27.6 million allowances were exchanged between unaffiliated firms in the first quarter of 2010. [Eighty-two] percent of the allowances were exchanged in the first week of January, likely as a result of the final settlement of futures and forward contracts with December 2009 delivery; and (4) the number of participants in the market for RGGI CO_2 allowance derivatives was relatively constant as approximately 20 firms maintained significant positions in contracts related to 2009 vintage allowances during the first quarter of 2010. Participation in the market for 2010 vintage allowance derivatives increased following the March auction as up to 20 firms held significant positions." The complete document is available at: http://www.rggi.org/docs/MM_Secondary_Market_Report_2010_Q1.pdf.

December 2010

"Carbon Sequestration Atlas of the United States and Canada – Third Edition (Atlas III)" The following is from the Foreword of the document: "The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) is proud to release the third edition of the *Carbon Sequestration Atlas of the United States and Canada (Atlas III)*. Production of *Atlas III* is the result of collaboration among carbon storage experts from local, State, and Federal agencies, as well as industry and academia. *Atlas III* provides a coordinated update of CCS potential across most of the United States and portions of Canada. The primary purpose of *Atlas III* is to update the CO_2 storage potential for the United States and Canada, and to provide updated information on the Regional Carbon Sequestration

Partnerships' (RCSPs) field activities. In addition, *Atlas III* outlines DOE's Carbon Sequestration Program, DOE's international CCS collaborations, worldwide CCS projects, and CCS regulatory issues; presents updated information on the location of CO_2 stationary source emissions and the locations and storage potential of various geologic storage sites; and further provides information about the commercialization opportunities for CCS technologies from each RCSP." The complete Atlas III is available for download at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIII/.

"Carbon Capture and Storage Model Regulatory Framework." The following is from the Executive Summary of this document: ~~"~~According to the IEA publication *Energy Technology Perspectives 2010* (*ETP 2010*), in the absence of new energy policies or supply constraints, energy-related CO_2 emissions in 2050 will be twice 2007 levels…This publication, the IEA *Carbon Capture and Storage Model Regulatory Framework* (*Model Framework*), seeks to deal with the reality that such rapid expansion and scale-up of CCS technology raises a number of regulatory issues that need to be addressed in parallel with ongoing efforts to demonstrate the technical, safety and environmental viability of industrial scale CCS projects. Regulatory frameworks are required to ensure the effective stewardship of CO_2 storage sites over the long term, the protection of public health and the environment, and the security of CCS activities. Appropriate regulatory frameworks are also required to clarify the rights and responsibilities of CCS stakeholders, including relevant authorities, operators and the public. Additionally, regulations are needed to underpin performance and associated incentive schemes, commercial transactions relating to CCS operations, and also to build public confidence in, and acceptance of, the technology." To view the entire document, visit: http://www.iea.org/ccs/legal/model_framework.pdf.

"CCS Ready." The following is from the Summary of this document: ~~"~~Recent efforts by the Global CCS Institute, in collaboration with the IEA, and Carbon Sequestration Leadership Forum (CSLF) to establish a definition for Carbon Capture and Storage Ready (CCSR), highlights increasing recognition of its potential to facilitate CO_2 mitigation in the future. In addition, many governments around the world are now considering how CCSR can play a role in broader climate change policies. The introduction of CCSR policy anticipates a future transition to broader CCS deployment. It acts as a signaling mechanism by indicating that governments are willing to mandate a technology still in development if there is perceived to be an environmental benefit. CCSR is an option for governments seeking to facilitate any future transition to CCS deployment." To view the complete Issues Brief, visit: http://new.globalccsinstitute.com/sites/default/files/GCCSI%20Issues%20Paper%2010.01%20-%20CCS%20Ready_1.pdf.

"CCS and Community Engagement: Guidelines for Community Engagement in Carbon Dioxide Capture, Transport, and Storage Projects." The following is from the Introduction of this document: ~~"~~Globally, nearly 70 percent of anthropogenic (human-caused) CO_2 emissions are related to energy consumption. The IEA projects these energy-related CO_2 emissions will nearly double between 2007 and 2050 if the world follows a business-as-usual path. Therefore, achieving significant cuts in these energy-related emissions is critical to avoiding more than a 2.7°F rise in global temperatures by 2050 and the irreversible and damaging impacts such a temperature rise would have on people and ecosystems…In July 2008, the [Group of Eight (G8)] set a goal of launching 20 CCS demonstration projects globally by 2010, with wide-scale deployment beginning in 2020. However, this goal is far from being met, and local opposition is often cited as one of the reasons for CCS project delays and cancellations. Past experience suggests that CCS will not be widely deployed at the pace needed without local community support. Such support can evolve from active participation in an engagement process by regulatory policy designers and regulatory authorities, project developers, local opinion leaders, national and local policy-makers, and community members." The complete World Resources Institute (WRI) report is available at: http://pdf.wri.org/ccs_and_community_engagement.pdf.

"PSD and Title V Permitting Guidance For Greenhouse Gases." The following is the Introduction of this document: ~~"~~EPA is issuing this guidance document to assist permit writers and permit applicants in addressing the prevention of significant deterioration (PSD) and title V permitting requirements for GHGs

that begin to apply on January 2, 2011. This document: (1) describes, in general terms and through examples, the requirements of the PSD and title V permit regulations; (2) reiterates and emphasizes relevant past EPA guidance on the PSD and title V review processes for other regulated air pollutants; and (3) provides additional recommendations and suggested methods for meeting the permitting requirements for GHGs, which are illustrated in many cases by examples. We believe this guidance is necessary to respond to inquiries from permitting authorities and other stakeholders regarding how these permitting programs will apply to GHG emissions." The complete permitting guidance document is available at: http://www.eenews.net/assets/2010/11/10/document_gw_04.pdf.

January 2011

"Carbon Sequestration Program FY2008-2009 Accomplishments." The following is from the document: ~~"~~The mission of DOE's NETL-managed Carbon Sequestration Program is to create a public benefit by discovering and developing methods to economically separate and permanently store GHG emissions from the combustion of fossil fuels. The technologies developed through the program will be used to maintain fossil fuel power plants as viable, clean sources of electric power. This goal will be accomplished by reducing the cost of these technologies and conducting demonstrations based on sound science to ensure that commercial applications can reliably and safely capture, transport, store, and monitor CO_2 injected into geologic formations… The Carbon Sequestration Program has achieved numerous accomplishments through the growth, expansion, and introduction of new concepts and opportunities as a result of an adapting effort that incorporates novel activities to resolve issues uncovered by R&D activities and social demands. In the remainder of the document, significant accomplishments are reported for each aspect of the Carbon Sequestration Program. These accomplishments are identified for the last three FYs (2007-2009) and organized in reverse chronological order by Carbon Sequestration Program element (Core R&D, Infrastructure, and Global Collaborations). A section containing Carbon Sequestration Program Recovery Act-related Accomplishments follows." The complete document is available on NETL's Carbon Sequestration Reference Shelf at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/CS_AR2008-2009.pdf.

"CSLF's 2010 Technology Roadmap." The following is from the Introduction of this document: ~~"~~CCS can play a critical role in tackling global climate change. In order for it to be an effective part of the solution, CCS must be demonstrated as soon as possible with wide deployment before the target date of CCS commercialization by 2020. A prerequisite to this achievement is the establishment of the technical foundation for affordable capture, transport, and safe and effective long-term geologic storage of CO_2 as quickly as possible. This Technology Roadmap (TRM) has identified the current status of CCS technologies around the world; the increasing level of activity in the industry; the major technology needs and gaps; and the key milestones for a wide development of improved cost-effective technologies for the separation, capture, transport, and long-term storage of CO_2. Implementation of national and international pilot and demonstration projects is seen as a critical component in the development of lower-cost, improved capture technologies and safe long-term storage. The demonstration projects have to be built in parallel with R&D efforts in order to close the technological gaps as cost effectively as possible. The CSLF will continue to catalyze the deployment of CCS technologies by actively working with member countries, governments, industry, and all sectors of the international research community on the strategic priorities outlined in this TRM. The CSLF will also continue to work with existing and new support organizations, such as the Global Carbon Capture and Storage Institute, in order to efficiently utilize scarce world resources and effort and to ensure that key technology gaps are addressed and closed." The complete technology roadmap is available at: http://www.cslforum.org/publications/documents/CSLF_Technology_Roadmap_2010.pdf.

"A Cleaner Future for Power Stations." The following is from the Introduction of this document: ~~"~~On [July 23, 2010] the [Australian] Government released the *Cleaner Future for Power Stations* election commitment which includes the establishment of new emissions standards and reporting requirements for power stations, and in particular that all new coal-fired power stations will be required to meet best

practice emissions standards and be built CCS-Ready. Specifically, the [Australian] Government announced: (1) *Best practice emissions standards for new coal-fired power stations:* [a] all new coal-fired power stations will be required to meet an emission standard set with reference to best practice coal-fired generation technology; [b] the standard for best practice will be determined in consultation with stakeholders; [c] the starting point for consultation will be below the level (0.86 tCO_2-e/MWh) at which transitional assistance was proposed under the Carbon Pollution Reduction Scheme (CPRS); and [d] the standards are to commence in 2011. (2) *CCS-Ready standards:* [a] approval will only be granted to new coal-fired generators which meet the emissions standard and are capable of retrofitting CCS technologies; [b] all new coal-fired generators will be required to retrofit CCS technologies within an appropriate time after they become commercially available; and [c] the standard for CCS-Ready, tailored for Australian conditions, will be determined by the Government in consultation with stakeholders. The National CCS Council (formerly the National Low Emissions Coal Council) will play a key role in assisting with the work on the CCS-Ready standard. (3) *Expansion of Energy Efficiency Opportunities (EEO) program to cover* all existing generators, including coal-fired power stations. (4.) *Publication of National Energy and Greenhouse Reporting (NGER) data:* [a] The Government will publish annual facility-level greenhouse gas emissions and electricity production data by electricity generation facility. The Government has established an Interdepartmental Task Group (ITG) to develop these measures, in consultation with energy market institutions, State and Territory Governments, industry, and environmental stakeholders. This discussion paper is intended to facilitate initial consultation with stakeholders on the *Cleaner Future for Power Stations* measures. It outlines the Government's commitment in relation to each of these elements, discusses the context of these measures, and proposes a way forward to defining and implementing measures. It also raises a series of important questions, for which stakeholder feedback is sought." The entire document is available at: http://www.ret.gov.au/energy/Documents/sustainbility%20and%20climate%20change/MO%20Final%20InterDepartmental%20Discussion%20Paper%20Cleaner%20Future%20Power%20Station%2026%20November%202010%20EMBARGO%20til%2030%20November%20(2).pdf.

February 2011

"Site Screening, Site Selection, and Initial Characterization for Storage of CO_2 in Deep Geologic Formations." The following is from the Executive Summary of this document: "The contribution of [GHGs] to global warming continues to be a growing concern. One of the most common [GHGs] is CO_2. A number of methods to lower CO_2 emissions are under investigation. One of the promising technologies for near- to medium-term CO_2 emissions reduction is geologic storage of CO_2 (CO_2 GS) in deep geologic formations. It is estimated that the storage potential for assessed U.S. and Canadian geologic formations is sufficient to store CO_2 equivalent in the amount that would be emitted to the atmosphere from large stationary sources in these two countries for several hundred years. The purpose of this document is to establish a framework and methodology for Site Screening, Site Selection, and Initial Characterization of CO_2 GS sites that: [(1)] Provide stakeholders with a compilation of best practices for Site Screening, Site Selection, and Initial Characterization; [(2)] Communicate the experience gained through RCSP Initiative through the Characterization and Validation Phases; [and (3)] Develop a consistent industry-standard framework, terminology, and set of guidelines for communicating project related storage resources and risk estimates associated with the project. The primary audience for this manual is future storage project developers, CO_2 producers, and transporters. It will also be of use in informing local, regional, state, and national governmental agencies regarding best practices in exploration for CO_2 GS sites. Furthermore, it will inform the general public on the rigorous analyses conducted for potential CO_2 GS sites." To read the full BPM, visit: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-SiteScreening.pdf.

"DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap." The following is from the Overview of this document: "The combustion of fossil fuels for electricity generation plays an integral role in the energy security and global economic competitiveness of the United States. According to Energy Information Administration (EIA) estimates, fossil fuels accounted for approximately 71 percent of total U.S. electricity generation in 2008. However, fossil fuel combustion results in the emission of large

quantities of CO_2 such that the U.S. power generation sector produced more than 40 percent of total U.S. anthropogenic CO_2 emissions in 2008. It now appears likely that Federal legislation and/or regulation could soon be enacted that would limit CO_2 emissions from the U.S. power generation sector in order to stabilize atmospheric concentrations of CO_2 and address concerns that anthropogenic emission of GHG, including CO_2, is contributing to global climate change. While it is not clear what specific rules, regulations, or targets may be put in place, it is highly probable that emissions of CO_2 from these power plants will be targeted for reduction. The majority of current U.S. power generation sector CO_2 emissions result from the combustion of coal. According to EIA estimates, more than 1 billion tons of coal were consumed by the U.S. power generation sector in 2008 and accounted for almost 50 percent of total U.S. electricity generation. The resulting 1.9 billion metric tons of CO_2 emissions comprised more than 80 percent from the power generation sector and almost 34 percent of the 5.8 billion metric tons of total U.S. anthropogenic CO_2 emissions in 2008. Moreover, EIA estimates that almost 95 percent of the coal-based CO_2 emissions projected to be released from today through 2030 will originate from existing coal-based power plants. Therefore, both existing and new coal-based power plants would likely be targeted for reduction should Federal legislation and/or regulation be enacted to reduce CO_2 emissions from the power sector." To view the 2010 CCS Roadmap, go to: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/CCSRoadmap.pdf.

"Best Practices for Terrestrial Sequestration of Carbon Dioxide." The following is from the Introduction of this document: ~~"~~Carbon (C) is an essential element for sustaining life. It can be found naturally in organic and inorganic forms with a small exchange rate between them. At about 18 percent (about 50 percent on a dry basis), the concentration of C in living matter is almost 100 times greater than the average concentration in the earth (0.19 percent). Thus, for life to continue, carbon must be recycled. This is accomplished primarily by photoautotrophs that use light energy from the sun to convert CO_2 in the atmosphere to organic matter by photosynthesis. This carbon is returned to the atmosphere as CO_2 by respiration, combustion, and decay. For thousands of years, this cycle remained in balance, and the CO_2 concentration in the atmosphere remained fairly constant. However, in the last 100 years or so, combustion of fossil fuels, deforestation, changes is tillage practices, and other factors have perturbed this balance, resulting in an increase in atmospheric CO_2. There is growing concern that increasing levels of GHGs in the atmosphere, particularly CO_2, are contributing to global climate change. Atmospheric levels of CO_2 have risen significantly from preindustrial levels of 280 parts per million (ppm) to present levels of 384 ppm. Evidence suggests that elevated atmospheric CO_2 concentrations are the result of a combination expanded use of fossil fuels for energy production and transportation, land use conversion (deforestation), and soil cultivation. Predictions of increased global fossil energy use imply a continued increase in carbon emissions and a corresponding rise in the CO_2 level in the atmosphere unless a major change is made in the way energy is produced and used – in particular, how carbon is managed." The full BPM is available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM_Terrestrial.pdf.

"CO_2 Storage – Is it safe? Towards large-scale implementation of CCS." The following is from the Summary of this document: "[Carbon dioxide] geologic storage (CGS) technology is by no means fail-proof or risk-free, but carefully selected and qualified storage sites that are operated according to effective regulatory supervision should be safe. The key will be to apply fit-for-purpose risk management throughout the lifecycle of the storage sites, starting from screening, and continuing through site selection, qualification, injection operations, and, finally, closure. CGS is a mature technology that has been used at industrial scale at several large sites both onshore and offshore. CGS technology can be applied immediately, at a much larger scale, at tens to hundreds of sites globally. The main evidence for this is empirical, collected through relevant analogue subsurface industrial experiences and at large-scale demonstrations of CGS at several sites. This includes almost 100 years of natural gas storage at hundreds of sites in North America and Europe, 35+ years of experience with CO_2 enhanced oil recovery (EOR) in North America, 15+ years experience with acid gas (mixtures of [hydrogen sulfide (H_2S)] and CO_2) injection in western Canada, and 14+ years experience at dedicated CGS projects in the North Sea and Algeria. Moreover, there are currently a handful of research-focused pilot CGS projects on [five]

continents. The current state of CO_2 injection technology can best be summarized by the conclusions reached by the Massachusetts Institute of Technology in their Environmental Assessment of Geological Storage of CO_2, namely that: *'The technologies and practices associated with geological CO_2 storage are all in current commercial operation, and have been so for a decade to several decades... No major "breakthrough" technological innovations appear to be required for large scale CO_2 transportation and storage.'*" To view this document, click: http://www.dnv.com/binaries/Position%20paper%20-%20Is%20CO2%20storage%20safe_tcm4-442340.pdf.

March 2011

"A Policy, Legal, and Regulatory Evaluation of the Feasibility of a National Pipeline Infrastructure for the Transport and Storage of Carbon Dioxide." The following is the Abstract of this document: "The report focuses on the transportation of CO_2 through pipelines from a 'source' to a geologic '[formation],' the possibility of a Federal mandate requiring capture and storage of CO_2. An overview of carbon capture drivers and the geologic means of storing CO_2 is provided. The report also describes the nature, size, and location of the significant CO_2 pipeline system that currently exists in the United States, and the state and Federal regulatory regime, under which it operates. An analysis of the regulatory status of CO_2 pipeline systems under the Interstate Commerce Act and the Natural Gas Act is included as well as a discussion of other prospective regulatory models. Potential business models and economic issues for future CO_2 pipeline build-out are also discussed. Conclusions and recommendations suggest that the market is responding to current CO_2 pipeline construction demand and that future build-out of CO_2 pipelines should occur with limited Federal regulatory intervention." The full report is available at: http://www.sseb.org/downloads/pipeline.pdf.

"Integrated Management of Carbon Sequestration and Biomass Utilization Opportunities in a Changing Climate." The following is from the Abstract of this document: "Forests can play a role in carbon sequestration and mitigating CO_2 emissions. However, what course of action needed to meet issues concerning carbon management and other ecosystem services for specific situations is not always clear. The National Silviculture Workshop, held in Boise, Idaho on June 15-18, 2009, focused on scientific information and management opportunities and strategies applicable for meeting a variety of objectives, while simultaneously addressing carbon sequestration and biomass utilization. The symposium and subsequent proceedings covered four general areas of interest: the role of climate change in science and management; silvicultural methods to address carbon sequestration and biomass utilization; alternative silvicultural strategies to address the growth and development of forests; and current applications of computer simulation models or modeling techniques designed to provide decision support." The Proceedings of the 2009 National Silviculture Workshop is available at: http://www.fs.fed.us/rm/pubs/rmrs_p061.pdf.

"Investment of Proceeds from RGGI CO_2 Allowances." The following is from the Executive Summary of this document: "In 2008, [10] states – Connecticut, Delaware, Maine, Massachusetts, Maryland, New Hampshire, New Jersey, New York, Rhode Island, and Vermont – launched the first market-based regulatory program to reduce GHG emissions in the United States. Through the Regional Greenhouse Gas Initiative (RGGI), each participating state caps CO_2 emissions from power plants, auctions CO_2 emission allowances, and invests the proceeds in strategic energy programs that further reduce emissions, save consumers money, create jobs, and build a clean energy economy. Each RGGI participating state has developed its own plan for investment of CO_2 allowance proceeds. This analysis translates the investment plans of the ten RGGI participating states into common, comparable terms to identify regional trends and demonstrate the benefits of RGGI participating state investments." For the entire report, visit: http://www.rggi.org/docs/Investment_of_RGGI_Allowance_Proceeds.pdf.

April 2011

"The Global Status of CCS: 2010." The following is from the Executive Summary of this document: "The concentration of CO_2 in the atmosphere continues to increase, rising to 390 [ppm] by the end of 2010. At the same time, 2010 was the warmest year on record, ranking equally with 2005 and 1998. Efficiently and effectively managing the risks of climate change requires reducing greenhouse gas [(GHG)] emissions, particularly CO_2…In response, governments have increased research, development and demonstration efforts for a range of renewable and low emission energy technologies, including CCS. Carbon capture technologies have been deployed commercially in the gas processing and chemical industries for some time. However, the same capture technologies are considered to be immature and in need of demonstration when applied to the power generation, iron and steel or cement industries. In terms of storage applications, while CO_2 use in EOR has a long history, it requires enhancements in the measurement, monitoring and verification of CO_2 injected. The use of deep saline formations is much more recent and is only in operation at large-scale in a few projects. This report, an annual global review of project developments and the drivers behind them, serves as a reference point for the broader CCS community in understanding the 'state of play' in the development of CCS activities and projects globally." This Global CCS Institute (GCCSI) report is available at: http://www.globalccsinstitute.com/sites/default/files/global-status-css-final_0.pdf.

"Progressing Scotland's CO_2 storage opportunities." The following is from the Executive Summary of this document: "CCS is a rapidly growing industry that offers both environmental benefits and substantial business, employment and research opportunities for Scotland and the UK. In 2009 the report *Opportunities for CO_2 storage around Scotland* identified the size of these opportunities and key initiatives that need to be acted upon to move CCS forward in Scotland. Government, industry and stakeholder organizations joined with SCCS researchers in this *Scottish Carbon Capture and Storage Development Study* to progress some of the actions needed to inform the deployment of the entire CCS chain in Scotland and the UK. The study presents new insights on: a path to CCS, defining the activities and timescales to meet national and international ambitions for deployment of CCS and reduction of [GHG] emissions; Scotland's CO_2 storage assets, refining the estimated large-scale CO_2 storage capacity in North Sea sandstones; skills and capacity needs for the future global CCS industry and how to realize opportunities it presents for UK economic development; [and] public communication and engagement on CCS." The complete SCCS report is available at: http://www.sccs.org.uk/progress-to-co2-storage-scotland/ProgressingScotlandCO2Opps.pdf.

"Cost and Performance of Carbon Dioxide Capture from Power Generation." The following is from the Executive Summary of this document: "Energy scenarios developed by IEA suggest that CCS from power plants might contribute by 2050 to around 10 [percent] of the energy-related CO_2 emission reduction required to stabilize global warming. Since CO_2 capture from power generation is an emerging technology that has not been demonstrated on a commercial scale, related cost and performance information is based on feasibility studies and pilot projects and is still uncertain. This paper analyses techno-economic data for CO_2 capture from power generation, including CO_2 conditioning and compression, in order to support energy scenario modeling and policy making. Cost and performance trends are shown based on estimates published over the last five years in major engineering studies for about 50 CO_2 capture installations at power plants. Capital cost and levelized cost of electricity (LCOE) are re-evaluated and updated to 2010 cost levels to allow for a consistent comparison. Presented data account for CO_2 capture but not transportation and storage of CO_2. They are estimates for generic, early commercial plants based on feasibility studies, which have an accuracy of on average ±30 [percent]. The data do not reflect project-specific cost or cost for first large-scale demonstration plants, which are likely higher. For coal-fired power generation, no single CO_2 capture technology outperforms available alternative capture processes in terms of cost and performance. Average net efficiency penalties for post- and oxy-combustion capture are 10 percentage points relative to a pulverized coal plant without capture, and eight percentage points for pre-combustion capture compared to an [IGCC]. Overnight costs of power plants with CO_2 capture in regions of the OECD are about [$3,800/kW] across capture

routes, which is 74 [percent] higher than the reference costs without capture. Cost figures vary substantially depending on the type of power plant type and fuel used. The relative increase in overnight costs compared to a reference plant without CO_2 capture is a comparably stable metric across studies. It is thus recommended for estimating cost is limited data are available. Projected LCOE is on average [$105 per megawatt hour]. Average costs of CO_2 avoided are [$55 per tonne of CO_2] if a pulverized coal power plant without CO_2 capture is used as a reference." To read the IEA paper, click: http://www.iea.org/papers/2011/costperf_ccs_powergen.pdf.

"A Roadmap for moving to a competitive low carbon economy in 2050." The following is from the document: "The EU provides its Member States with a long-term framework for dealing with the issue of sustainability and the cross-border effects of phenomena that cannot be dealt with at the national level alone. Climate change has long been recognized as one such long-term shaping factor where coherent EU action is needed, both inside the EU and internationally. The Commission recently proposed the Europe 2020 flagship initiative for a resource-efficient Europe and within this framework it is now putting forward a series of long-term policy plans in areas such as transport, energy and climate change. This Communication sets out key elements that should shape the EU's climate action helping the EU become a competitive low carbon economy by 2050. The approach is based on the view that innovative solutions are required to mobilize investments in energy, transport, industry and information and communication technologies, and that more focus is needed on energy efficiency policies." This European Commission-adopted Roadmap is available at: http://ec.europa.eu/clima/documentation/roadmap/docs/com_2011_112_en.pdf.

May 2011

"The East Irish Sea CCS Cluster: A Conceptual Design – Technical Report." The following is from the Introduction of this document: "The Intergovernmental Panel on Climate Change (IPCC) states that there is now a high confidence (>90 [percent]) that the net effect of human activities has contributed to climate change. As such, it is important that overall levels of GHG emissions from human activities are reduced. In the United Kingdom (UK), GHG emission reduction targets are encapsulated within the Climate Change Act 2008, where a legally binding target of at least an 80 percent cut in GHG emissions by 2050 (compared to levels in 1990) is required. Carbon Dioxide accounts for around 85 percent of total UK GHGs (574.6 million tonnes of CO_2e in 2009). The largest contributor to the UK's portfolio of emissions is the energy sector, which is responsible for approximately 40 [percent] of UK's CO_2 emissions. It is therefore vital, that this sector is able to decarbonize and reduce its overall level of emissions in order to achieve the targets. One method of decarbonization will undoubtedly be the use of renewable energy sources. Whilst these will continue to be an increasing feature of the energy mix in the UK and beyond, the intermittent nature and practical limitations of renewable energies such as wind, wave and solar mean that 'base-load' and flexible power generation will remain essential to any modern economy for the foreseeable future. Both the age of the existing UK fleet of power stations and EU environmental regulations are such that significant new such generating capacity is needed. Whilst the UK Coalition Government has indicated an intention that nuclear energy should continue to have a role to play, in the interests of energy security (through diversity of supply) it has also stated its belief that fossil fuels, including coal, will need to continue to play a vital role in energy generation for decades to come." To view the document in its entirety, visit: http://www.eunomia.co.uk/shopimages/The%20East%20Irish%20Sea%20CCS%20Cluster%20-%20A%20conceptual%20Design%20-%20Technical%20Report.pdf.

"Annual Report on the Market for RGGI CO_2 Allowances: 2010." The following is the Executive Summary of this document: "RGGI began full operation on January 1, 2009, becoming the first mandatory cap-and-trade program to limit CO_2 emissions in the United States. Currently, approximately 95 percent of the CO_2 emissions from the electric power generation sector in ten states in the northeast and mid-Atlantic regions are regulated under the program. RGGI distributes CO_2 emissions allowances

to the market primarily through auctions, making it distinctive among existing cap-and-trade programs. [Ninety-four] percent of the CO_2 allowances in circulation at the end of 2010 initially entered the market through one of the auctions. By the end of 2010, the RGGI participating states conducted ten successful auctions, selling a total of 319 million CO_2 allowances for $777 million. This report evaluates activity in the market for RGGI CO_2 allowances in 2010, focusing on the following areas: allowance prices, trading and acquisition of allowances in the auctions and the secondary market, participation in the market by individual firms, and market monitoring." The complete marketing report, prepared by independent market monitor Potomac Economics, is available at: http://www.rggi.org/docs/MM_2010_Annual_Report.pdf.

"The UK Carbon Plan." The following is from the Foreword of this document: ~~"~~This Carbon Plan sets out a vision of a changed Britain, powered by cleaner energy used more efficiently in [the UK's] homes and businesses, with more secure energy supplies and more stable energy prices, and benefiting from the jobs and growth that a low carbon economy will bring…Doing this means change across the whole economy, but most critically and fundamentally in three areas, namely: (1) in the way [they] generate [their] electricity, where [they] must see a dramatic shift away from fossil fuels and towards low carbon alternatives – renewable energy, new unsubsidized nuclear power and fossil fuel power stations fitted with [CCS]; (2) in the way [they] heat [their] homes and businesses, where a step change is needed in how well [their] homes are insulated and in the use of low carbon energy alternatives, such as heat pumps; (3) and in the way [they] travel. This means better public transport, reducing emissions from petrol and diesel engines and moving towards alternative technologies such as electric vehicles." The full Carbon Plan is available at: http://www.decc.gov.uk/assets/decc/What%20we%20do/A%20low%20carbon%20UK/1358-the-carbon-plan.pdf.

June 2011

"CCS Demonstration in Developing Countries: Priorities for a Financing Mechanism for Carbon Dioxide Capture and Storage." The following is from the Executive Summary of this document: ~~"~~Despite often-aggressive programs to promote energy efficiency and deploy nuclear, renewable, and other low-carbon energy sources, many developing countries will still rely heavily on fossil fuel energy to power their development for decades to come. There is therefore a need for developing countries to create strategies that address fossil fuel emissions in a way that minimizes the costs of doing so, and consequently minimizes impacts to their national development goals. CCS is currently the only near-commercial technology proven to directly disassociate CO_2 emissions from fossil fuel use at scale. Its deployment could potentially allow developing countries to gradually shift away from fossil fuels for energy and industrial needs with relatively little disruption to their long-term development strategies. If deployed as an interim measure, it could allow time for other alternative low-carbon technologies to be developed and deployed, permitting fossil fuels to be gradually phased out. This strategy could assist developing countries to transition to a low-carbon economy in the next 15 [to] 50 years. While CCS is potentially attractive to some developing countries, there has been limited development of demonstration projects in Africa, Asia, or Latin America due mainly to their high cost in the absence of expected profits or significant carbon financing. The International Energy Agency (IEA) CCS Roadmap proposes 50 CCS projects in developing countries in the next 10 to 20 years. As well as reducing the developing world's [GHG] emissions, accelerating CCS demonstration efforts in non-OECD countries can likely also improve technologies, increase efficiency, reduce uncertainty and risk, and initiate learning-by-doing at a lower cost than would be possible in OECD countries. The captured benefits from doing so will be more significant the sooner acceleration in CCS development in developing countries begins." The full World Resources Institute (WRI) Working Paper is available at: http://pdf.wri.org/working_papers/ccs_demonstration_in_developing_countries.pdf.

"Carbon Capture and Storage Legal and Regulatory Review – Edition 2." The following is a summary of this document: "The IEA considers CCS a crucial part of worldwide efforts to limit [climate change] by reducing GHGs. The IEA has estimated that the broad deployment of low-carbon energy technologies could reduce projected 2050 emissions to half 2005 levels – and that CCS could contribute about one-fifth of those reductions in a least-cost emissions reduction portfolio. Reaching that goal, however, would require around 100 CCS projects to be implemented by 2020 and over 3 000 by 2050. Such rapid expansion raises many regulatory issues, so in 2008 the IEA established the IEA International CCS Regulatory Network (Network). 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 (Paris, January 2010) that the IEA produce a regular review of CCS regulatory progress worldwide. The CCS Review aims to help countries develop their own CCS regulatory frameworks by providing a forum for sharing knowledge on CCS legal and regulatory issues. 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 every six months, to provide an up-to-date snapshot of CCS regulatory developments in contributing jurisdictions…The theme for this second edition of the CCS Review is long-term liability for stored CO_2. This is discussed in the second part of each contribution. Where a jurisdiction or [organization] has limited potential to discuss long-term liability, broader challenges to CCS regulatory development are addressed. For this edition, contributions were received from 28 governments and 9 international CCS [organizations]." The full publication is available for download at: http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2407.

"Climate and Electricity Annual 2011: Data and Analyses." The following is the Summary of this document: "Electricity use is growing worldwide, providing a range of energy services: lighting, heating and cooling, specific industrial uses, entertainment, information technologies, and mobility. Because its generation remains largely based on fossil fuels, electricity is also the largest and the fastest-growing source of energy-related CO_2 emissions, the primary cause of human-induced climate change. Forecasts from the IEA and others show that 'decarbonizing' electricity and enhancing end-use efficiency can make major contributions to the fight against climate change…The IEA *Climate and Electricity Annual 2011* provides an authoritative resource on progress to date in this area, with statistics related to CO_2 and the electricity sector across ten regions of the world. It also presents topical analyses on meeting the challenge of rapidly curbing CO_2 emissions from electricity, from both a policy and technology perspective." To view the rest of the IEA report, visit: http://www.iea.org/w/bookshop/add.aspx?id=410. (Purchase required.)

July 2011

"DOE/NETL Advanced Carbon Dioxide Capture R&D Program: Technology Update." The following is from the Introduction of this document: "The purpose of this report is to provide an update on the R&D of advanced CO_2 capture technologies for coal-based power systems being conducted by DOE/NETL. While efforts are focused on capturing CO_2 from the flue gas or synthesis gas (syngas) of coal-based power plants, these capture technologies should be applicable to natural-gas and oil-fired power plants and other industrial CO_2 sources. Intended to be updated annually, the report tracks the progress of DOE/NETL's CO_2 capture related technology developments. DOE/NETL's CO_2 capture R&D program currently funds a broad portfolio of research projects in three primary technology pathways—pre-, post-, and oxy-combustion. Although the majority of the technology options being considered are still in the laboratory- and bench-scale stages of development, a limited number of small pilot-scale field tests have been initiated." For more information, as well as a link to the full Technology Update, visit: http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/CO2Handbook/.

"IEAGHG Storage Research Networks." The following is from the Introduction of this document: "The IEA Greenhouse Gas R&D Programme (IEAGHG) published a series of small booklets for GHGT-9 in

Washington D.C. in 2008, outlining the activities of its storage based research networks on Wellbore Integrity (WBI), Risk Assessment (RA) and Monitoring. Since then, the range of networks coordinated by IEAGHG has grown to incorporate Modeling of Geological Storage and Social Research as well as the [three] pre-existing networks. The storage based networks that IEAGHG coordinate aim to address various aspects of CO_2 geological storage. The broad aims of the research networks are to provide a platform for the expertise and experience of those [organizations] in the forefront of research, development and demonstration of [GHG] mitigation technologies to come together and share experiences and knowledge, to determine a way forward from research to reality. This brochure will provide a short introduction to each of these storage based research networks, and outline the main achievements of each network over its existence, and the aims for the future." To view the complete IEAGHG report, go to: http://www.ieaghg.org/docs/General_Docs/Publications/IEAGHG_Storage_Research_Networks_LR.pdf.

"The Social Cost of Carbon in U.S. Climate Policy." The following is from the Introduction of this document: ~~"~~As the U.S. federal government uses its rulemaking authority to address [GHG] emissions, it is important to understand the social cost of carbon (SCC) and its role within the process. When the federal government considers regulation, many values are at play, and the process engages various expertise including law, climate science, engineering, economics, and public policy as well as reaching out to consider the views of stakeholders. SCC provides a dollar figure, or range of dollar figures, that estimate the value of social benefits accrued by acting to reduce climate change. Because of the internal government process for evaluating proposed regulations, the SCC dollar figure, which is a tool devised by economists, can have significant impacts on decision makers if they approach regulation from the point of view that the *cost* per tonne to curb CO_2 should not be greater than its presumed *effectiveness* in achieving the result. The SCC value can also be misused if the limitations and caveats inherent in its estimation are not considered." The complete World Resources Institute (WRI) Policy Brief is available at: http://pdf.wri.org/more_than_meets_the_eye_social_cost_of_carbon.pdf.

August 2011

"The Costs of CO_2 Capture, Transport, and Storage." The following is from the Executive Summary of this document: ~~"~~Costs for different CO_2 capture, transport and storage options were first determined using data for the three main capture technologies (post-combustion, pre-combustion and oxyfuel) applied to hard coal, lignite and natural gas-fired power plants; the two main transport options (pipelines and ships); and the two main storage options (depleted oil and gas fields, and deep saline aquifers), both on- and offshore. The results were then combined in order to identify: (1) total costs for full-scale, commercial CCS projects in the [European Union (EU)] post 2020; (2) key trends and issues for various deployment scenarios; and (3) the impact of fuel prices, economies of scale and other factors (e.g. economic). Publicly available cost data on CCS are scarce. In order to obtain a reliable base for the estimations, it was therefore decided to use new, in-house data provided exclusively by [Zero Emission Fossil Fuel Power Plants (ZEP)] member organizations – 15 in total. This included five independent power companies and manufacturers of power plant equipment for CO_2 capture. In order to access the data, all basic cost information was kept confidential, regarding both source and individual numbers. To this end, one person per area was assigned to collect the information, align it, create mean values and render it anonymous. However, all contributors to the study, including those who provided detailed economic data, are named in Annex II. The ZEP cost study presents best current estimates for full-scale commercial CCS in the power sector in Europe post 2020, based on new, in-house data provided by member organizations. The final results assume that all elements of the value chain have been successfully demonstrated in the EU CCS demonstration program and other demonstration initiatives worldwide." The complete ZEP report is available for download at: http://www.zeroemissionsplatform.eu/library/publication/165-zep-cost-report-summary.html.

"Improving Domestic Energy Security and Lowering CO_2 Emissions with „Next Generation' CO_2-Enhanced Oil Recovery (CO_2-EOR)." The following is from the Executive Summary of this document: "This analysis, sponsored by U.S. DOE/NETL and prepared by Advanced Resources International (ARI), builds a national CO_2 EOR resource assessment from reservoir-to-reservoir simulations of CO_2 floods. ARI used a proprietary database that contains oil properties and geologic characteristics of 1,800 onshore reservoirs and over 4,000 off shore sands. The simulations were conducted using the PROPHET model. PROPHET, originally developed by Texaco for DOE in the 1980s, models stream tubes of fluid flow between injection wells and producing wells. PROPHET is a screening tool and estimates the magnitude and timing of oil production based on a user-defined CO_2 injection protocol and the porosity of the host rock, the thickness of the oil, the degree of fracturing and discontinuity within the target formation and other inputs. NETL published a similar resource assessment in February 2010; this report supersedes the earlier assessment. For this analysis, the simulation methodology was peer reviewed by industry practitioners and important refinements were made based on their input. Aggregated results indicate that CO_2-EOR can provide high value benefits to the domestic economy and the environment, as discussed below." This NETL published document is available at: http://www.netl.doe.gov/energy-analyses/pubs/NextGen_CO2_EOR_06142011.pdf.

"Underground Storage of CO_2: Extensive Research and Operating Experience Show It Can Be Done Safely." The following is an excerpt from this document: "Storing CO_2 in deep underground rock formations is not a new idea. Large underground reservoirs of CO_2 occur naturally, and have existed for millions of years. Permanently storing CO_2 that has been captured from above-ground industrial projects returns the CO_2 to deep, secure, underground rock formations. The CO_2 is stored at geological depths of 1 to 5 kilometers whereas drinking water is found only a couple of hundred meters below the surface, thus ensuring the safety of groundwater. Proper storage site selection, a barrier of impermeable caprock above the CO_2, and natural trapping mechanisms ensure that CO_2 will remain permanently stored." This Integrated CO_2 Network (ICO_2N) publication can be viewed at: http://www.ico2n.com/wp-content/uploads/2010/07/Carbon-Storage-Backgrounder2.pdf.

Legislative

September 2010

***Reuters*, "New Climate and Energy Policies Could Create 2.5 Million Jobs, Hold Down Energy Costs."** According to a new report from the Center for Climate Strategies, new Federal GHG emissions and energy policies could generate up to 2.5 million new jobs and create $134 billion in economic activity in the United States. Based on economic impacts of climate policies developed by 16 states, the report calls for the implementation of 23 policy approaches that aim to reduce emissions; be cost-effective; and improve energy, health, environment, and economic development. More specifically, the report suggested policies focus on the creation of new clean energy sources for heat and power, improved energy efficiency and industrial processes, transportation and land use improvements, agriculture and forestry conservation, and expanded recycling and waste energy recovery under a national framework. According to the report, and assuming all 23 actions are implemented, the resulting GHG reductions would surpass proposed national targets, reducing U.S. emissions to 27 percent below 1990 levels by 2020. The full report is available at: http://advanced.jhu.edu/academic/government/energy-policy-report/. July 22, 2010, http://www.reuters.com/article/idUS153522+22-Jul-2010+PRN20100722.

October 2010

***Reuters*, "Australia's Capital Sets 40 Percent Carbon Cut Law."** The government of the Australian Capital Territory (ACT) will enact carbon cutting laws that would set a target of cutting CO_2 emissions by 40 percent by 2010 from 1990 levels. The cut would rise to 80 percent by 2050, with an aim of the territory to become carbon neutral by 2060. The ACT's Climate Change and Greenhouse Gas Reduction

Bill 2010's goal is to cut carbon emissions by boosting renewable energy and increasing energy efficiency in homes and businesses. In addition, the bill would establish an independent climate change council and encourage the private sector to undertake voluntary agreements with the government. August 26, 2010, http://www.reuters.com/article/idUSTRE67P0TQ20100826.

November 2010

***ABC News*, "ACT Sets Ambitious Emissions Target," and *ACT News Release*, "Greenhouse Gas Emissions Targets Adopted."** The Australian Capital Territory (ACT) government has set a target to reduce CO_2 emissions by 40 percent by 2020, based on 1990 levels, and by 80 percent by 2050. The legislation will also mandate periodic reporting to the Legislative Assembly on ACT GHG emissions trends, establish a Climate Change Council to provide independent advice, and encourage private organizations and industries to take action through voluntary sector agreements. ACT plans to meet the emissions reduction target by making buildings more energy efficient, encouraging public transportation, and increasing renewable energy use. The legislation provides framework for helping the territory realize the government's goal for the ACT region of zero net emissions by 2060. October 17, 2010, http://www.abc.net.au/news/stories/2010/10/27/3049154.htm, and October 17, 2010, http://www.environment.act.gov.au/__data/assets/pdf_file/0020/207335/Greenhouse_Gas_Legislation_Passes_Media_Release.pdf.

December 2010

***New Mexico Environment Department Press Release*, "Environmental Improvement Board Approves First-in-the-Nation Rules to Reduce Global Warming Pollutants from Multiple Sectors,"** and ***Reuters*, "New Mexico Quietly Adopts Country's Most Comprehensive Greenhouse Gas Rules."** The New Mexico Environmental Improvement Board (EIB) has approved two sets of proposed GHG emission reduction regulations. The first set of potential climate change regulations establishes rules for GHG reporting and verification; the second set deals with more specific GHG cap-and-trade regulations. The rules, proposed by the New Mexico Environment Department, will enable the state to participate in WCI, a consortium of seven western states and four Canadian provinces focused on developing strategies to address potential climate change. The cap-and-trade program will affect approximately 63 facilities, primarily fossil fuel-fired power plants and oil and gas operations, which emit more than 25,000 metric tons of GHGs annually. Beginning in 2012, each facility will be required to begin reducing emissions by two percent per year below 2010 levels. November 2, 2010, http://www.nmenv.state.nm.us/OOTS/documents/PR-EIBDecision-11-2-10_3_.pdf, and November 3, 2010, http://www.reuters.com/article/idUS323795324720101103.

***The Vancouver Sun*, "Alberta Gov't Moves to Assume Carbon-Capture Liability."** The Alberta Government introduced legislation that would have the province assume long-term liability for CO_2 injected underground. A fund would be created that is financed by CCS operators for monitoring costs and any required remediation. The Alberta Government has promised $2 billion for CCS projects, the focus of their 2008 Climate Change Strategy, which commits to reducing projected emissions by 200 megatonnes by 2050. The projects are still in early stages and CO_2 will not be injected until 2015 at the earliest. November 2, 2010, http://www.vancouversun.com/business/Alberta+moves+assume+carbon+capture+liability/3761219/story.html.

January 2011

***Wall Street Journal*, "California Adopts Cap and Trade,"** and ***Reuters*, "California Approves Cap and Trade."** The California Air Resources Board (CARB) voted on December 16, 2010, to cap the state's major industries' GHG emissions and establish the first large-scale cap-and-trade program in the

United States. The cap-and-trade plan would require 600 industrial plants in the state to cap their GHG emissions in 2012, and reduce those levels over the next eight years. Companies that are unable to cut their emissions by the required amount would be able to obtain emission allowances from the state, or buy them from other emitters with excess allowances. In addition, companies could also comply with required emissions cuts by purchasing carbon offsets associated with emission-reduction projects, such as forests that are managed to contain CO_2. Under the first few years of the proposed cap-and-trade rules, most allowances would be given away; in later years, the majority of the allowances would be sold in auctions with a floor price of $10 per metric ton of CO_2 on sold allowances. December 17, 2010, http://online.wsj.com/article/SB10001424052748703395204576024650186378260.html, and December 17, 2010, http://www.reuters.com/article/idUS382911868420101217.

February 2011

***New York Times*, "Massachusetts Sets Targets to Slash Carbon Emissions."** Massachusetts officials have announced a plan that will reduce statewide GHG emissions by 25 percent below 1990 levels in the next 10 years. The emissions targets are the highest allowed under Massachusetts state climate legislation and are believed to be the most stringent in the Nation. The plan, which will rely on existing programs to reach the reduced levels – such as renewable-energy mandates, energy-efficiency standards, and efforts in the electricity sector that are already in place under RGGI – is expected to result in a net increase in jobs across the state. Massachusetts is one of 10 states participating in RGGI, a cap-and-trade system for electric utilities. December 29, 2010, http://www.nytimes.com/2010/12/30/science/earth/30climate.html?_r=2.

March 2011

***BusinessWeek*, "Mississippi Considering Bills on Carbon Storage,"** and ***Mississippi Business Journal*, "Carbon Capture Bill."** The Mississippi State Senate passed a bill to set up a regulatory structure that gives the Mississippi Department of Environmental Quality (MDEQ) the authority to oversee the process of considering bills to allow and regulate long-term underground CO_2 storage. The ~~"M~~ississippi Geologic Sequestration of Carbon Dioxide Act" outlines duties of the state Oil and Gas Board, which currently oversees the use of CO_2 in oil wells. Under the bills, MDEQ and the Oil and Gas Board would work out an agreement to store the CO_2 in oil and gas fields for EOR. Companies could apply for permits from MDEQ and the Oil and Gas Board to build storage facilities in the state. Mississippi Power Company, which is building a $2.4 billion coal-fired plant in Kemper County that is expected to capture 65 percent of its CO_2 emissions and store them underground, will also monitor the legislation. To view Senate Bill No. 2723, click: http://index.ls.state.ms.us/isysnative/UzpcRG9jdW1lbnRzXDIwMTFccGRmXHNiXDI3MDAtMjc5OVxzYjI3MjNpbi5wZGY=/sb2723in.pdf#xml=http://10.240.72.35/isysquery/irl8748/1/hilite. February 4, 2011, http://www.businessweek.com/ap/financialnews/D9L67GEO0.htm, and February 6, 2011, http://msbusiness.com/blog/2011/02/carbon-capture-bill/.

***Bloomberg*, "Kentucky Senate Panel Advances Carbon Storage Bill."** Legislation was sent to the Kentucky Senate on February 23, 2011, calling for the state Energy and Environment Cabinet to seek one to five demonstration projects to store CO_2 emissions from power plants. The bill was approved by the Senate Natural Resources and Energy Committee. The projects would require approval from environmental regulators, and landowners would receive royalties as a result of having CO_2 stored beneath their property. After completion, the CO_2 injection sites would be monitored by storage operators. Ownership of a storage facility could eventually be transferred to the Federal or state government. February 23, 2011, http://www.bloomberg.com/news/2011-02-23/ky-senate-panel-advances-carbon-storage-bill.html.

April 2011

***WDAQ.com*, "Gov. Barbour Signs Energy Bill."** Governor Haley Barbour signed a bill that sets up a regulatory structure that grants the Mississippi Department of Environmental Quality (MDEQ) and Mississippi Oil and Gas Board the authority to oversee and monitor long-term underground CO_2 storage. Under the "Mississippi Geologic Sequestration of Carbon Dioxide Act," MDEQ and the Oil and Gas Board will work out an agreement to store CO_2 in oil and gas fields for EOR. Companies will be able to apply for permits from MDEQ and the Oil and Gas Board to build storage facilities in the state. To view Senate Bill No. 2723, click: http://index.ls.state.ms.us/isysnative/UzpcRG9jdW1lbnRzXDIwMTFccGRmXHNiXDI3MDAtMjc5OVxzYjI3MjNpbi5wZGY=/sb2723in.pdf#xml=http://10.240.72.35/isysquery/irl8748/1/hilite. March 24, 2011, http://www.wdam.com/Global/story.asp?S=14313203.

***NASDAQ*, "Australia's Swan to Introduce Carbon Price Legislation in Spring."** Australian officials announced plans to introduce legislation for a carbon tax in the spring session of parliament, which begins August 16, 2011. In order for the legislation to pass, the Labor government needs to negotiate majorities in both the upper and lower houses. According to officials, the full details of the carbon price package will be announced prior to the introduction of the legislation. March 24, 2011, http://www.nasdaq.com/aspx/stock-market-news-story.aspx?storyid=201103222230dowjonesdjonline000448&title=australias-swan-to-introduce-carbon-price-legislation-in-spring.

May 2011

***Platts*, "CO_2 Pipeline Bill Passes Indiana House of Representatives."** A bill containing eminent domain language sought by the developer of a proposed CO_2 pipeline has been approved by the Indiana House of Representatives and sent to a conference committee. The bill, S.B. 251, was amended prior to being voted on by the House to authorize companies to condemn private property for a CO_2 pipeline that would move CO_2 from coal plants in the Midwest to the Gulf Coast for EOR use. The bill contains a provision for the law to expire in 10 years. To view S.B. 251, click: http://www.in.gov/legislative/bills/2011/SB/SB0251.3.html. April 21, 2011, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Coal/6023905.

June 2011

***U.S. Senator John Barrasso News Release*, "Barrasso CCS Bills Ensure Long-Term Future for Coal."** The U.S. Senate Energy and Natural Resources Committee held a hearing on two measures in May 2011. The committee discussed S.699, which would establish a program within DOE that would help the development of 10 commercial-scale CCS projects. The bill would also create an MVA system for the CO_2 stored at the project sites and provide a $10 million annual grant to educate state regulators. The second bill, S.757, would incentivize the development and implementation of new carbon capture technologies. S.699 is available at: http://www.gpo.gov/fdsys/pkg/BILLS-112s699is/pdf/BILLS-112s699is.pdf. S.757 is available at: http://www.gpo.gov/fdsys/pkg/BILLS-112s757is/pdf/BILLS-112s757is.pdf. A webcast and testimony from the hearing can be viewed at: http://energy.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=bc9e9485-df04-5fb0-8621-ac3afa2b26a6. May 12, 2011, http://barrasso.senate.gov/public/index.cfm?FuseAction=PressOffice.PressReleases&ContentRecord_id=e649575b-0a36-1cd0-9674-17f6c74ace58&Region_id=&Issue_id.

July 2011

***Reuters*, "German Parliament Set to Okay Clean Coal Bill."** As of July 7, 2011, Germany's lower house was considering the passage of legislation that would provide EU funding for clean coal technologies. The bill lays the foundation for testing and demonstration efforts only; broader funding opportunities would be subject to consultation with local residents. Vattenfall Europe applied for EU funding for a pilot plant in the Brandenburg region. Germany has committed to reducing its carbon footprint by 40 percent in 2020 compared to 1990 levels. July 7, 2011, http://www.reuters.com/article/2011/07/07/us-germany-coal-idUSTRE7663ZY20110707.

August 2011

***Illinois Governor Pat Quinn Press Release*, "Governor Quinn Signs Law to Advance Clean Energy Project in Southern Illinois."** On August 2, 2011, the Governor of Illinois signed Senate Bill 2169 to provide the framework for Power Holdings, LLC, to build a $2.3 billion facility that will convert coal to synthesis natural gas (SNG) in Jefferson County. The legislation, which immediately took effect, includes consumer protections like a rate cap and an account to pass savings back to consumers. Power Holdings will also be required to share its construction and carbon storage costs, as well as operating expenses, to state regulators through annual reports and plant reviews. Power Holdings has already obtained an active air quality permit from the Illinois Environmental Protection Agency for its gasification technology to capture emissions and safely store more than 90 percent of the plant's CO_2 emissions. Power Holdings expects to generate more than $10 billion in economic activity and create more than 1,650 jobs, including approximately 1,100 construction jobs, 300 permanent mining jobs, and 250 permanent plant jobs. Senate Bill 2169 can be viewed at: http://www.ilga.gov/legislation/97/SB/PDF/09700SB2169lv.pdf. August 2, 2011, http://www.illinois.gov/PressReleases/ShowPressRelease.cfm?SubjectID=3&RecNum=9595.

Announcements

September 2010

Geothermal Funding Opportunity Announcement Released. DOE has announced a new Funding Opportunity Announcement (FOA) focused on advancing geothermal systems research and development (R&D) throughout the United States. The FOA, which marks an investment of up to $15 million to spur the design and validation of innovative methods for geothermal heat recovery, is seeking to reach out beyond traditional geothermal communities, including the carbon sequestration community. The FOA closing date is Friday, October 1, 2010, and the solicitation is available at: http://www1.eere.energy.gov/geothermal/financial_opps_detail.html?sol_id=358.

2009 Annual Report on the Market for RGGI CO_2 Allowances Now Available. Potomac Economics, the independent market monitor for the Regional Greenhouse Gas Initiative (RGGI) CO_2 allowance market, released the "2009 Annual Report on the Market for RGGI CO_2 Allowances," which is based on data from RGGI CO_2 allowance auctions, the Commodity Futures Trading Commission (CFTC), the Chicago Climate Futures Exchange (CCFE), and the New York Mercantile Exchange (NYMEX). The complete report is available at: http://www.rggi.org/docs/MM_2009_Annual_Report.pdf.

October 2010

NETL Releases Annual Accomplishments Report. DOE's NETL released its 2009 Accomplishments Report, highlighting energy research and technology development achievements, including advances in clean, fossil-based systems with CCS. The report details NETL R&D projects and activities, as well

describes the laboratory's research over the past century. To read the report, visit: http://www.netl.doe.gov/publications/others/accomp_rpt/accomp09.pdf.

NETL Releases Carbon Sequestration Project Portfolio Available Online. DOE/NETL's 2010 Carbon Sequestration Project Portfolio contains selected carbon sequestration program papers and publications; NETL's Best Practices Manuals (BPMs); DOE's RCSP fact sheets (Validation and Development Phases); Carbon Sequestration Focus Area fact sheets (pre-combustion capture; geologic carbon storage; monitoring, verification, and accounting [MVA]; simulation and risk assessment; and CO_2 utilization); and Recovery Act fact sheets. The portfolio is available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/project%20portfolio/2010/index.html.

Website Launched to Track Climate Change Financing. The United Nations (UN) launched a website that tracks how countries provide aid to help fight potential climate change. According to the website, five countries have contributed financing to help implement new technologies that could reduce carbon emissions. To visit the website, which is titled, "Fast Start Finance," click: http://www.faststartfinance.org/home.

Atlas on Geological Storage of Carbon Dioxide Launched in Africa. On September 9, 2010, South Africa officially initiated efforts to develop Africa's first atlas to identify geologic CO_2 storage opportunities in the region with the help of government entities and the private industry. The atlas will be incorporated into the work program of the South African Centre for Carbon Capture and Storage, and will provide an overview of the country's energy economy, a roadmap on CCS, and progress made to date. To learn more, click: http://www.cef.org.za/index.php?option=com_content&view=article&id=138:atlas-on-geological-storage-of-carbon-dioxide-&catid=4:press-releases&Itemid=25.

November 2010

Carbon Management Advisory Service Launched. Pike Research has launched the Carbon Management Advisory Service – a subscription-based information suite that provides insights for companies seeking to manage their carbon emissions. To view the press release, click: http://www.pikeresearch.com/newsroom/pike-research-launches-carbon-management-advisory-service.

Canada Announces International Climate Change Investment. The Government of Canada released the details of the country's commitment to international climate change. Funding will support projects that build knowledge and focus on private sector investment in renewable energy and energy efficiency projects. The Environment Canada News Release is available at: http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=454E8F15-55C2-4A70-9FC0-249B35E5DD80. For a complete breakdown of the funding, go to: http://www.climatechange.gc.ca/default.asp?lang=En&n=5F50D3E9-1.

Protocol Released to Support U.S. GHG Accounting. On October 5, 2010, the World Resources Institute (WRI) and LMI released "The Greenhouse Gas Protocol for the U.S. Public Sector," which outlines how Federal, state, and local governments can account for their GHG emissions. The protocol serves as a reference for implementing Executive Order 13514, which requires Federal agencies to report and reduce their GHG emissions over time. The protocol is available at: http://pdf.wri.org/ghg_protocol_for_the_us_public_sector.pdf.

New Data Highlights the Role of Forests in Climate Change. The U.S. Department of Agriculture (USDA) Forest Service released new estimates of data highlighting U.S. forests' role in preventing potential climate change. According to the report, the Nation's forests currently store 41.4 billion metric tons of CO_2. An additional 192 million metric tons are stored annually, offsetting approximately 11

percent of the country's industrial GHG emissions. For more information, view the USDA News Release at: http://www.fs.fed.us/rmrs/docs/forest-carbon/news-release.pdf.

December 2010

IEA Launches CCS Model Regulatory Framework. The International Energy Agency (IEA) CCS Model Regulatory Framework provides an overview of 29 key issues associated with regulating CCS to assist both regional and national CSS regulatory framework development. For each issue, the model framework provides an explanation and examples of how each issue has been addressed in existing legislation. For more information, visit: http://www.iea.org/ccs/legal/modelframework.asp.

WCI Emissions Calculators Available. The Western Climate Initiative (WCI) has posted final default emissions factor calculators for 2006, 2007, and 2008. Both "light" and full versions of the calculators are available; the light versions contain the calculator worksheet and its data table, while the full versions also include the underlying plant and unit level data. The final calculators are available for download at: http://www.westernclimateinitiative.org/component/remository/Electricity-Team-Documents/Default-Emission-Factor-Calculators/.

DOE's World Gasification Database Now Available. The 2010 Worldwide Gasification Database was made available by DOE, documenting the worldwide growth of gasification technologies. The database is a comprehensive collection of gasification plant data, describes the current world gasification industry, and identifies near-term planned capacity additions. To link to the database, click: http://www.netl.doe.gov/technologies/coalpower/gasification/worlddatabase/index.html.

January 2011

NETL Releases Accomplishments Document. The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has released a new document, titled, "Carbon Sequestration Program FY2008-2009 Accomplishments," which highlights the accomplishments of the Carbon Sequestration Program during the 2008 and 2009 fiscal years (FY). The new publication shows that the program has achieved numerous accomplishments through the growth, expansion, and introduction of new concepts and opportunities as a result of an adapting effort that incorporates novel activities to resolve issues uncovered by research and development (R&D) activities and social demands. The document is available on the NETL website at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/CS_AR2008-2009.pdf.

DOE Technology Receives Prestigious Award. A DOE project demonstrating DryFining™ technology, a more affordable way to control emissions while improving fuel quality by simultaneously drying and refining coal, has been named the 2010 Coal-Fired Project of the Year by Power Engineering magazine. The award honors technologies that uncover breakthrough solutions in coal-fired, gas-fired, nuclear, and renewable sustainable energy categories. For more information, visit: http://www.fossil.energy.gov/news/techlines/2010/10059-DOE_Funded_Technology_Wins_Award.html.

Canada and British Columbia Sign Agreement on GHG Data Collection. With the support of the Canadian Council of Ministers of the Environment (CCME), Canada and British Columbia announced they will coordinate their GHG emission reporting under a national single window system. The Federal, provincial, and territorial governments will ensure that all jurisdictions are able to measure, track, and report progress on GHG reduction. To view the Environment Canada news release, click: http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=615F3B21-033F-4BD3-9A14-74098416EA04.

February 2011

First Issue of Fossil Energy Today Now Available. DOE's FE has launched a new digital newsletter, titled, "Fossil Energy Today." The quarterly newsletter will provide readers with updates on important activities, progress, and other developments within Fossil Energy in an easily accessible format. For more information, as well as a link to the first issue, go to: http://www.fossil.energy.gov/news/energytoday.html.

March 2011

Documents Now Available on the NETL Reference Shelf. The following documents are available for download on the NETL Carbon Sequestration Reference Shelf: the "Carbon Sequestration Atlas of the United States and Canada – Third Edition (Atlas III)"; the "DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap"; "Carbon Sequestration Program FY2008-2009 Accomplishments"; the "Site Screening, Site Selection, and Initial Characterization for Storage of CO_2 in Deep Geologic Formations" BPM; and "Best Practices for Terrestrial Sequestration of Carbon Dioxide." To view these documents, go to: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/refshelf.html.

NETL-Developed Process Wins National Award for Excellence in Technology Transfer. The NETL-developed Basic Immobilized Amine Sorbent (BIAS) Process, which improves the capture of CO_2 emissions from power plants while reducing costs, has received a 2011 Award for Excellence in Technology Transfer. The national award is presented annually by the Federal Laboratory Consortium for Technology Transfer (FLC) in recognition of outstanding work by researchers in the transfer of technology from Federal laboratory to the commercial marketplace. To learn more, visit: http://www.fossil.energy.gov/news/techlines/2011/11009-NETL_Process_Wins_Award.html.

April 2011

New Movie on CCS. BIGCCS, established by the Norwegian Research Center, has published a movie illustrating the basic elements of CCS technology and explaining how CCS can contribute to reaching global CO_2 emission reduction targets. For more information, visit: http://www.bellona.org/news/news_2011/1300716787.59; to view the movie, go to: http://www.youtube.com/watch?v=eTBnuU8BSew.

May 2011

Second Issue of Fossil Energy Today Released. The second issue of "Fossil Energy Today," a free quarterly newsletter published by DOE's FE, has been released, providing updates on important activities, progress, and other developments within FE. For more information, as well as links to the first two issues, visit: http://www.fossil.energy.gov/news/energytoday.html.

Global CCS Institute Launches CCS Regulatory Test Toolkit. The Global CCS Institute released a toolkit that provides a blueprint for nations to ensure they use best practice regulations and permitting processes for CCS projects. To access the toolkit, visit: http://globalccsinstitute.com/CCSRegToolkit. For more information, click: http://globalccsinstitute.com/institute/news/global-ccs-institute-launches-ccs-regulatory-test-toolkit.

Taiwan Unveils Carbon Capture, Storage Alliance. Taiwan's Environmental Protection Administration (EPA) has launched a CCS alliance as part of their government's efforts to reduce GHG emissions. According to officials, a key alliance pilot program involves the removal, capture, and storage of 10,000 tons of CO_2 in geologic formations. The alliance includes the Bureau of Energy, Council for Economic

Planning and Development, National Science Council, CPC Corp, and Taiwan Power Co. To learn more about the CCS alliance, click: http://www.taiwantoday.tw/ct.asp?xItem=158133&ctNode=445.

June 2011

NETL Releases Updated Version of the Carbon Sequestration Website. DOE's National Energy Technology Laboratory (NETL) released a new, user-friendly version of the Carbon Sequestration Program website in early May. The Carbon Sequestration Program website contains both introductory and in-depth information about sequestration fundamentals, supporting technologies, sequestration applications, environmental benefits, and the status of the latest research and development (R&D) activities. The updated website can be viewed at: http://www.netl.doe.gov/technologies/carbon_seq/index.html.

July 2011

DOE EERE Awards $11.3 Million for Geothermal Technology R&D. As part of DOE's recent Energy Efficiency & Renewable Energy (EERE) awards, Lawrence Berkeley National Laboratory (LBNL) will receive up to $4.99 million for "The Geothermal Energy Coupled with CCS: Heat Recovery Using an Innovative High Efficiency Supercritical CO_2 Turboexpansion Cycle" project to develop new ways to produce electricity from superheated and pressurized CO_2 in deep geothermal formations. In addition, Lawrence Livermore National Laboratory (LLNL) will receive up to $874,000 for "The Active Management of Integrated Geothermal—CO_2 Storage Reservoirs: An Approach to Improve Energy Recovery and Mitigate Risk" project to study the technical and economic feasibility of integrating geothermal energy production with CCS. For more details, visit: http://www1.eere.energy.gov/geothermal/news_detail.html?news_id=17493.

National Enhanced Oil Recovery Initiative Launched. On July 12, 2011, industry, government, and organizational leaders gathered to launch a national EOR initiative aimed at increasing the supply of domestic oil produced through EOR using CO_2. The group will develop recommendations for Federal and state policymakers on how to ramp up CO_2-EOR to improve U.S. energy security, create economic opportunities, support job creation, and reduce GHG emissions. The slate of recommendations is expected to be released in early 2012. More information is available at: http://www.pewclimate.org/press-center/press-releases/members-congress-support-eor-initiative.

Ground Set for Sequestration Degree. Richland Community College has broken ground for the National Education Center, which will award CCS degrees. Courses are currently being developed, and the program is expected to receive approval by the Illinois Community College Board in time for the 2012 fall semester. For more information, go to: http://www.herald-review.com/news/local/article_a5c8d63a-abb1-11e0-9ae0-001cc4c002e0.html.

August 2011

CCS Public Outreach and Education. The Wyoming Carbon Capture and Storage Technology Institute (WCTI), an organization that develops CCS education and training courses with the University of Wyoming, is offering a new, online class, titled, "CCS Public Outreach and Education." The primary objective of the course is to help professionals in the CCS industry understand and apply effective public education and outreach strategies in selecting, permitting, and operating a carbon storage site. For more information, as well as a list of all available WCTI courses, visit: http://www.wyomingcarbonstorage.com/courses.

Norway, Germany Establish Power, Carbon Capture Working Groups. Norway and Germany announced an agreement to establish energy working groups to explore cooperation on CCS and power

market trading balancing capacity. According to the joint statement released by the Norwegian Energy and Oil Ministry and the Germany Economics and Technology Ministry, the groups will share knowledge on CCS and promote cross-border electricity trade. To learn more, visit: http://www.bloomberg.com/news/2011-08-03/norway-germany-establish-power-carbon-capture-working-groups.html.

Contact Information:

National Energy Technology Laboratory

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

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

Contacts:

John Litynski
U.S. Department of Energy
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236
Phone: (412) 386-4922
Fax: (412) 386-4775
john.litynski@netl.doe.gov

Dawn Deel
U.S. Department of Energy
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
Phone: (304) 285-4133
Fax: (304) 285-4403
dawn.deel@netl.doe.gov

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