NETL's Carbon Storage Newsletter: Annual Index

(*FORMERLY THE CARBON SEQUESTRATION NEWSLETTER*)

September 2012 – August 2013

This is a compilation of the National Energy Technology Laboratory's (NETL) monthly Carbon Storage Newsletter published over the last year. The newsletter is produced by NETL to provide information on activities and publications related to carbon storage. It covers domestic, international, public sector, and private sector news. This compilation covers newsletters issued from September 2012 to August 2013. Outdated Information (e.g., conference dates, paper submittals, etc.) has been removed.

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For more information on DOE's Carbon Storage Program, click here.

HIGHLIGHTS

September 2012

***Fossil Energy Techline*, "DOE-Sponsored Project Begins Demonstrating CCUS Technology in Alabama."** A project sponsored by the U.S. Department of Energy (DOE) has begun demonstrating carbon dioxide (CO_2) injection with the goals of assessing integration of the technologies involved and laying the foundation for the future use of CO_2 for enhanced oil recovery (EOR). Conducted by the Southeast Regional Carbon Sequestration Partnership (SECARB), one of seven DOE Regional Carbon Sequestration Partnerships (RCSPs), the "Anthropogenic Test" uses CO_2 from the newly constructed post-combustion CO_2-capture facility at Alabama Power's 2,657-megawatt (MW) Barry Electric Generating Plant. Located in southwest Alabama, the project will help demonstrate the feasibility of carbon capture, utilization, and storage (CCUS) by diverting a small amount of flue gas from Plant Barry (equivalent to amount produced when generating 25 MW of electricity) and capturing it using Mitsubishi Heavy Industries' advanced amine process to produce a nearly pure stream of CO_2. The captured CO_2 is then transported approximately 12 miles to the Citronelle Dome, within the Paluxy saline formation. The CO_2 injection will span two years at a rate of up to 550 metric tons of CO_2 per day, and multiple monitoring technologies will be deployed to track the CO_2 plume, measure the pressure front, evaluate CO_2 trapping mechanisms, and ensure that the CO_2 remains in the formation. The Paluxy is an ideal site for injection because it is more than 9,000 feet underground and is overlain by multiple geologic confining units that serve as barriers to prevent CO_2 from escaping. Following three years of post-injection monitoring, the site will be closed in 2017 and the wells will either be plugged and abandoned according to state regulations, or re-permitted for CO_2-EOR and CO_2 storage operations. To learn more about DOE's RCSP Program, visit: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html. August 22, 2012, http://www.fossil.energy.gov/news/techlines/2012/12037-CO2_Injection_Begins_in_Alabama.html.

***Fossil Energy Techline*, "Novel Sorbent Achieves 90 Percent Carbon Capture in DOE-Sponsored Test."** The successful bench-scale test of BrightBlack™, a novel CO_2 capturing sorbent, promises to further advance the process as a possible technological option for reducing CO_2 emissions from coal-fired power plants. The new sorbent was originally developed for a different application by Advanced Technology Materials Inc. (ATMI). SRI developed a method, through partnering with the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL), to use the ATMI sorbent to capture CO_2. In the SRI process – which is less energy-intensive than amine-based CO_2-capture processes – CO_2 is absorbed in a bed of sorbent pellets and desorbed in a separate reactor that regenerates the sorbent, cycling it back to the absorber. The observed CO_2-capture efficiency was as high as 95 percent as the test run began, with the captured CO_2 purity at 95 to 100 percent. After 7,000 absorption-regeneration cycles and 130 hours of operation, the sorbent showed little-to-no mechanical or chemical degradation. The test results will be analyzed in detail by SRI and the total system performance and estimated economic benefits will be determined. Information gathered will be used for designing a larger, pilot-scale unit of 0.5 MW or more in preparation for potential future testing at an operating pulverized-coal boiler. August 21, 2012, http://www.fossil.energy.gov/news/techlines/2012/12036-Novel_Sorbent_Meets_Goal.html.

October 2012

***Fossil Energy Techline*, "First-Generation Risk Profiles Help Predict CO_2 Storage Site Obstacles."** A collaboration of five U.S. Department of Energy (DOE) national laboratories has completed first-generation risk profiles in support of large-scale carbon capture, utilization, and storage (CCUS) projects. The collaboration offers a means to predict the probability of complications that could potentially arise from carbon dioxide (CO_2) storage sites. The risk profiles have a detailed methodology for quantifying risk potential at underground carbon storage sites that will help support safe, large-scale CCUS projects.

The risk profiles are a product of the National Risk Assessment Partnership (NRAP), led by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL) and the NETL-Regional University Alliance (RUA). The five national laboratories that form the partnership include: Lawrence Berkeley National Laboratory (LBNL) and Los Alamos National Laboratory (LANL), both of which contributed expertise in monitoring for risk assessment; Pacific Northwest National Laboratory (PNNL), contributing expertise in risks to groundwater systems; Lawrence Livermore National Laboratory (LLNL), offering expertise in natural seal integrity; and NETL, contributing expertise in wellbore integrity. The first-generation risk profiles are part of NRAP's Phase I, during which three different generations of risk profiles will be developed, each improving the technical complexity and reducing uncertainty compared to the previous generation. In Phase II, NRAP researchers will identify and develop risk management approaches that include strategic monitoring to verify system performance and lower uncertainty. NRAP may also include a Phase III, which would involve gaining additional data from field tests. NRAP is one of several simulation and modeling efforts conducted under the Carbon Capture and Storage Simulation Initiative. September 18, 2012, http://fossil.energy.gov/news/techlines/2012/12043-Risk_Profiles_Aid_CO2_Storage.html.

***Fossil Energy Techline*, "Energy Department Announces Major Milestones for Decatur, Ill. Clean Coal Project."** DOE announced two major milestones in their first large-scale Industrial Carbon Capture and Storage (ICCS) project in Decatur, Illinois: progress made on construction of the project's storage facility was marked by the Archer Daniels Midland Company (ADM), and the National Sequestration Education Center was opened to the public. The Illinois project will be able to store 1 million tons of CO_2 per year once fully operational in 2013, and will also help demonstrate the feasibility and reduce the cost of clean coal and CCUS technologies. Funded in partnership with the Richland Community College, the Education Center contains classrooms, training, and laboratory facilities, and offers students associate degrees in [carbon storage] technology. The Illinois ICCS project is led by ADM, a member of the Midwest Geological Sequestration Consortium (MGSC), one of seven DOE Regional Carbon Sequestration Partnerships (RCSPs), and is designed to store approximately 2,500 metric tons of CO_2 per day in the Mount Simon Sandstone saline formation at approximate depths of 7,000 feet. According to researchers' estimates, the sandstone formation has the potential to store all of the more than 250 million tons of CO_2 produced each year by industry in the Illinois Basin region. The Illinois ICCS project includes the design, construction, and demonstration of a CO_2 compression and dehydration facility that will enable the high-pressure stream of CO_2 available to the pipeline and injection well. The operations phase of the project is expected to begin in late-summer 2013 and will create approximately 260 jobs and add to the understanding of long-term CO_2 storage in saline formations. September 19, 2012, http://www.fossil.energy.gov/news/techlines/2012/12044-Sequestration_Education_Center_Ope.html.

November 2012

***Fossil Energy Techline*, "International Carbon Storage Body Praises Department of Energy Projects."** The Carbon Sequestration Leadership Forum (CSLF) recognized three U.S. Department of Energy (DOE) projects as important advancements toward commercialization and large-scale deployment of carbon capture, utilization, and storage (CCUS) technologies. CSLF, an international climate change initiative focused on cost-effective CCUS technologies, officially recognized the projects at a recent meeting in Perth, Australia, for making contributions to the development of global carbon dioxide (CO_2) mitigation technologies. With the recognition, all three projects will appear on the CSLF website in a yearly project portfolio to keep the global community updated on progress, enhancing the projects' global visibility and widespread knowledge sharing opportunities. The three DOE projects, which are managed by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL), are: the Illinois Basin Decatur Project (Decatur, Illinois), a large-scale CCUS demonstration project being conducted by the Midwest Geological Sequestration Consortium (MGSC), one of seven DOE Regional Carbon Sequestration Partnerships (RCSPs); Air Products & Chemicals, Inc. (Allentown, Pennsylvania), a large-scale industrial CCUS project funded by the American Recovery and Reinvestment Act of 2009 (ARRA); and the Illinois Industrial Carbon Capture and Storage Project

(Decatur, Illinois), another ARRA-funded, large-scale industrial CCUS project. November 8, 2012, http://www.fossil.energy.gov/news/techlines/2012/12051-CSLF_Praises_DOE_Carbon_Storage_Pr.html.

***Fossil Energy Techline*, "Carbon Storage Partner Completes First Year of CO_2 Injection Operations in Illinois."** Led by the Illinois State Geological Survey (ISGS), the Illinois Basin-Decatur Project has completed the first year of injecting CO_2 from an industrial plant at a large-scale test site in Illinois. The project is the first demonstration-scale project in the United States to use CO_2 from an industrial source and inject it into a saline formation. The CO_2, which is being captured from an ethanol production facility operated by the Archer Daniels Midland Company, is being injected in a compressed "supercritical" (dense phase) state into the Mount Simon Sandstone reservoir approximately 7,000 feet below the surface. Injection operations began November 17, 2011, with an average injection rate of 1,000 metric tons (1,100 short tons) per day; after approximately one year, a total of 317,000 metric tons of CO_2 have been injected – about one-third of the planned 1 million metric ton injection volume. The technologies applied and lessons learned from this project will support industry in the region looking to develop CO_2 capture and transport infrastructure, whether it is for carbon storage or enhanced oil recovery (EOR) in the depleted oilfields in the Illinois Basin. November 19, 2012, http://www.fossil.energy.gov/news/techlines/2012/12056-Carbon_Storage_Partner_Completes_F.html.

***IPAC-CO_2 News Release*, "Announcing the World's First Standard for Geologic Storage of CO_2."** CSA Group and the International Performance Assessment Center for Geologic Storage of Carbon Dioxide (IPAC-CO_2) have announced the CSA Z741 Geologic Storage of Carbon Dioxide Standard, the world's first bi-national carbon capture and storage standard for the geologic CO_2 storage for Canada and the United States. The standard, developed with a technical committee of more than 30 professionals from industry, regulators, researchers, and non-government organizations (NGOs) from both sides of the border, is intended to also be used as a basis for the international carbon capture and storage standards through the International Organization for Standardization (ISO). The standard provides essential guidelines for regulators, industry, and others around the world involved with scientific and commercial carbon capture and storage projects, establishing requirements and recommendations for the environmentally safe and long-term geological storage of CO_2 in a way that minimizes risks to the environment and human health. November 15, 2012, http://ipac-co2.com/uploads/File/PDFs/CSA%20IPAC-CO2%20CCS%20Standard%202012%20Final%20News%20Release%20v1%20copy.pdf.

***Fossil Energy Techline*, "Ohio State Develops Game-Changing CO_2 Capture Membranes in DOE-Funded Project."** Researchers from Ohio State University have developed a new hybrid membrane that combines the separation performance of inorganic membranes with the cost-effectiveness of polymer membranes. The technology, which was developed in a project managed by DOE/FE's Carbon Capture Program, has commercial potential for use at coal-fired power plants with CCUS. Ohio State's new hybrid membrane consists of a thin, inorganic "zeolite Y" layer between an inorganic intermediate and a polymer cover. The three layers sit atop a polymer support, which in turn rests on a woven backing. A first prototype was realized by researchers as they combined new nanotechnology characterization and fabrication methods with state-of-the-art manufacturing techniques. They were then able to slash the growth rate of the "zeolite Y" from eight hours to less than 15 minutes, also reducing the ceramic processing time from 43 hours to 20 minutes. November 15, 2012, http://www.fossil.energy.gov/news/techlines/2012/12053-OSU_Develops_Novel_Composite_Membr.html.

December 2012

***Fossil Energy Techline*, "DOE Approves Field Test for Promising Carbon Capture Technology."** The U.S. Department of Energy (DOE) has approved a promising post-combustion membrane technology to advance to a larger-scale field test. The technology, with $18.75 million in funding from the American Recovery and Reinvestment Act of 2009 (ARRA), successfully demonstrated the separation

and capture of 90 percent of the carbon dioxide (CO_2) from a pulverized coal plant. In the ARRA-funded project, Membrane Technology and Research Inc. (MTR) and its partners tested the Polaris™ membrane system, which uses a CO_2-selective polymeric membrane material and module to capture CO_2 from a plant's flue gas. Since the Polaris™ membranes are 10 times more permeable to CO_2 than conventional materials and use a slipstream of combustion air as a sweep gas, the system has potential for reduced energy requirements, reasonable capture costs, and greater efficiencies for post-combustion capture – all of which are factors for retrofitting existing coal-based plants. MTR will next begin fabricating a 1-megawatt (MW) system capable of meeting DOE's program goals of capturing more than 90 percent of CO_2 from flue gas with a less than 35 percent increase in cost of electricity. The 1-MW system, capable of meeting DOE goals for a 20-ton/day slipstream of coal-fired flue gas, will be tested at DOE's National Carbon Capture Center (NCCC) in Wilsonville, Alabama, beginning in 2013. The data generated in a six-month field test will be used by MTR to develop a preliminary 20-MW full-scale commercial design in cooperation with their partners. November 20, 2012, http://www.fossil.energy.gov/news/techlines/2012/12057-DOE_Approves_Carbon_Capture_Field_.html.

January 2013

***Fossil Energy Techline*, "DOE's Carbon Utilization and Storage Atlas Estimates at Least 2,400 Billion Metric Tons of U.S. CO_2 Storage Resource."** According to the U.S. Department of Energy's (DOE) 2012 United States Carbon Utilization and Storage Atlas (Atlas IV), the United States has at least 2,400 billion metric tons of potential carbon dioxide (CO_2) storage resource in saline formations, oil and gas reservoirs, and unmineable coal. This CO_2 storage resource could potentially store hundreds of years' worth of greenhouse gas (GHG) emissions. Atlas IV states that more than 225 billion metric tons of storage resource has been identified in depleted oil and gas fields, which could accommodate storage of emissions from stationary sources while simultaneously improving the energy security of the United States by enhancing oil and gas recovery. Atlas IV was created by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL) with input from DOE's seven Regional Carbon Sequestration Partnerships (RCSPs) and American Recovery and Reinvestment Act (ARRA)-funded site characterization projects. The RCSPs are testing CO_2 storage potential and investigating best practices for CO_2 storage in a variety of geologic formations. The site characterization projects are furthering DOE efforts to assess the Nation's CO_2 storage resource by developing additional characterization data for possible storage reservoirs. The primary purpose of Atlas IV is to provide an update on the CO_2 storage potential in the United States and to showcase updated information about the RCSPs' field activities and new information from the site characterization projects. Atlas IV outlines DOE's Carbon Storage Program and its carbon capture, utilization, and storage (CCUS) collaborations, along with worldwide CCUS projects and CCUS regulatory issues. Atlas IV also presents updated information on the location of CO_2 stationary source emissions and the locations and storage potential of various geologic storage sites, and it provides information about the commercialization opportunities for CCUS technologies. The complete version of Atlas IV is available for download at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIV/Atlas-IV-2012.pdf. The NATCARB Viewer is accessible from: http://www.netl.doe.gov/technologies/carbon_seq/natcarb/index.html. December 19, 2012, http://www.fossil.energy.gov/news/techlines/2012/12061-DOE_Releases_Carbon_Storage_Atlas.html.

February 2013

"Breakthrough Large-Scale Industrial Project Begins Carbon Capture and Utilization." A carbon capture, utilization, and storage (CCUS) project at Air Products and Chemicals hydrogen production facility in Port Arthur, Texas, has begun capturing carbon dioxide (CO_2) and piping it to an oilfield for use in enhanced oil recovery (EOR). The project demonstrates both the effectiveness and commercial viability of CCUS technology as an option in helping mitigate atmospheric CO_2 emissions. In the project, CO_2 normally released to the atmosphere is separated from the gas stream of one of Air Products'

steam methane reformers using "vacuum swing adsorption." The CO_2 is then delivered through a pipeline to Denbury Onshore's West Hastings, Texas, oilfield for EOR operations. A monitoring, verification, and accounting (MVA) program will ensure that the injected CO_2 remains safely underground. The project is expected to capture approximately 1 million metric tons of CO_2 per year that would otherwise be released in the atmosphere, as well as recover 1.6 to 3.1 million additional barrels of domestic oil annually. This event also marks a milestone in the U.S. Department of Energy's (DOE) Industrial Carbon Capture and Storage (ICCS) Program by progressing beyond research and development (R&D) to a demonstration scale that can be replicated and deployed within the industry. The ICCS Program's goals are to mitigate potential climate change through CCUS, create jobs, and position the United States as a world leader in carbon capture technologies. The project is funded in part through the American Recovery and Reinvestment Act (ARRA) and managed by the DOE Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL). From *NETL News Release* on January 25, 2013.

"New Set of Computational Tools and Models Expected to Help Enable Rapid Development and Deployment of Carbon Capture Technologies." A new suite of 21 computational tools and models to help enable development and deployment of carbon capture technologies has been developed and made available by the Carbon Capture Simulation Initiative (CCSI), a public-private partnership led by NETL. The toolset, which aims to take carbon capture concepts from the laboratory to the power plant more quickly, at lower cost, and with reduced risk, is expected to make it easier for U.S. utilities to meet carbon capture requirements if/when they are enacted. In addition, the tools can also help technology companies doing business in countries where controls are already in place. The toolset includes tools to help identify promising concepts more quickly, reduce the time to design and troubleshoot new systems, and quantify the uncertainty of model predictions. It also includes tools with new capabilities, such as creating reduced-order models from reacting multi-phase flow simulations, and concurrently running thousands of process simulations for optimization and uncertainty quantification. From *NETL News Release* on January 28, 2013.

"DOE-Supported Project Advances Clean Coal, Carbon Capture Technology." Ohio State University (OSU) researchers have successfully completed more than 200 hours of continuous operation of their patented Coal-Direct Chemical Looping (CDCL) technology, which is a one-step process to produce both electric power and high-purity CO_2. The test was conducted at OSU's 25-kilowatt thermal (kWth) CDLC combustion sub-pilot unit under the auspices of DOE's NETL-managed Carbon Capture Program. According to OSU researchers, the CDCL plant's 200-plus hours of operation shows the robustness of its novel moving-bed design and non-mechanical valve operation. The combination resulted in nearly 100 percent solid fuel conversion and a CO_2 stream more than 99 percent pure, making it attractive to CO_2-EOR operations. From *NETL News Release* on January 29, 2013.

March 2013

"Research Experience in Carbon Sequestration 2013 Now Accepting Applications." Supported by the U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) and the National Energy Technology Laboratory (NETL), the Research Experience in Carbon Sequestration (RECS) Program is accepting applications for RECS 2013. Scheduled for June 2-12, 2013, in Birmingham, Alabama, RECS 2013 is an intensive science- and field-based program that combines background briefings with group exercises and field activities at an integrated carbon capture and storage (CCS) project. In addition, RECS 2013 includes visits to a power plant, core laboratory, and the National Carbon Capture Center (NCCC), and covers CCS deployment issue topics, with a particular focus on carbon dioxide (CO_2) enhanced oil recovery (EOR)/carbon storage. The graduate students and early career professionals who participate will gain hands-on experience modeling CO_2 injection and subsurface fluid flow, monitoring surface CO_2, and analyzing core and well logs, as well as capture technologies. Founded in 2004, RECS was the first program to offer an intensive program on CCS systems to young scientists and engineers. Applicants should be early career professionals, Ph.D., or Master's level students with backgrounds in

geology, chemistry, hydrology, physics, engineering, climate science, and related fields. For more information, as well as application instructions, visit the RECS website.

April 2013

"President Requests $638.0 Million for Fossil Energy Programs." The FY 2014 budget request seeks $638 million for the Office of Fossil Energy (FE) to advance technologies related to the reliable, efficient, affordable, and environmentally sound use of fossil fuels, as well as managing the Strategic Petroleum Reserve and Northeast Home Heating Oil Reserve. The request includes $420 million for the fossil energy research and development (R&D) portfolio. For the Carbon Capture and Storage (CCS) Demonstrations program, including the Clean Coal Power Initiative and Industrial CCS Demonstrations, the FY 2014 budget does not request any funds because these projects are already fully funded by prior year appropriations and the 2009 American Recovery and Reinvestment Act; the CCS and Power Systems program FY 2014 budget request is $276.6 million, including $35.0 million for National Energy Technology Laboratory (NETL) staff to conduct in-house coal R&D; the carbon capture R&D FY 2014 budget request is $112.0 million to develop post-combustion and pre-combustion CO_2 capture and compression technologies for new and existing power plants ($25.0 million is allocated to fund a solicitation to demonstrate a commercial natural gas combined cycle plant to capture and store 75 percent or more of the CO_2 emissions); and finally the carbon storage R&D FY 2014 budget request is $61.1 million to develop and validate technologies to ensure safe and permanent geologic storage of captured CO_2. The budget request allows FE to fulfill its mission of providing the Nation with the best opportunity to tap the full potential of its fossil energy resources in an environmentally sound and affordable manner, while ensuring America's readiness to respond to short-term energy supply disruptions. For more information, refer to the Fossil Energy Budget-in-Brief. From *Fossil Energy Techline* on April 10, 2013.

May 2013

"**Breakthrough Industrial Carbon Capture, Utilization and Storage Project Begins Full-Scale Operations.**" The Air Products and Chemicals hydrogen production facilities in Port Arthur, Texas, have successfully begun capturing carbon dioxide (CO_2) and using it for enhanced oil recovery (EOR). At full-scale operation, more than 90 percent of the CO_2 from the product stream of two methane steam reformers (approximately 1 million metric tons of CO_2 per year) will be delivered for storage and EOR, leading to an estimated annual increase in oil production of 1.6 to 3.1 million barrels from the West Hastings oil field. The approximately $431 million project, supported by $284 million from the U.S. Department of Energy (DOE), included retrofitting the plants with an innovative system that separates CO_2 from the steam reformer product gas during hydrogen production, followed by compression and drying processes. The DOE investment also helped construct a 13.1-mile-long feeder that connects the two plants to Denbury's 325-mile, 24-inch Green Pipeline, which begins in Louisiana and ends at the West Hastings field. Monitoring, verification, and accounting (MVA) activities are underway to ensure the injected CO_2 remains in the geologic formation. The first plant has been capturing CO_2 since December 2012, while the second plant completed construction in February and began carbon capture operations in March. Both units are now operating at full capacity. More than 222,000 tons of CO_2 have been captured and provided for storage as of early May. The two retrofitted Air Products and Chemicals plants produce commercial bulk hydrogen primarily for use at the nearby Valero refinery. To learn more about carbon capture and storage (CCS), watch this short video. From *NETL News Release* on May 10, 2013.

"**Carbon Storage Atlas, Employee Newsletter Earn International Communications Awards.**" DOE's Office of Fossil Energy (FE) and its National Energy Technology Laboratory (NETL) won two prestigious 2013 Blue Pencil & Gold Screen Awards presented by the National Association of Government Communicators (NAGC). NETL earned first place honors in the "Technical or Statistical Report" category for the United States 2012 Carbon Utilization and Storage Atlas (Atlas IV). NETL also won the top award

last year for the previous version of the Atlas. Since its first edition in 2007, NETL has updated the Atlas every two years to reflect the current state of CCS technology. Atlas IV highlights the potential of CCS and estimates hundreds of years' worth of CO_2 storage resource potential. Atlas IV is available for download via the Carbon Storage Reference Shelf. An interactive version of the data used in Atlas IV is available via the National Carbon Sequestration Database and Geographic Information System (NATCARB) Viewer. More about Atlas IV is available in an informational video on YouTube. FE's internal employee newsletter, inTouch, was also recognized for communications excellence. The NAGC Blue Pencil & Gold Screen Awards program is an international competition that recognizes exceptional government communication products across more than 40 categories. This year's competition drew more than 300 entries. From *NETL News Release* on May 7, 2013.

"Regional Partnership Documentary Wins 'Best of Show' Aurora Award." A documentary co-produced by Prairie Public Broadcasting and the Plains CO_2 Reduction (PCOR) Partnership, with support from DOE, won a 2012 Platinum Best of Show Aurora Award in the nature/environment documentary category. The documentary, titled, "Global Energy and Carbon: Tracking Our Footprint," demonstrates global energy use by average families in industrialized, emerging, and developing economies. In addition, it explores carbon management options that ensure adequate energy access for the world's growing population. The 30-minute documentary represents an important outreach tool for keeping the public informed of DOE's efforts to mitigate greenhouse gases (GHGs) in the atmosphere. The fifth in a series of documentaries produced by the PCOR Partnership and Prairie Public Broadcasting, the documentary premiered on Prairie Public Television in October 2010, and has since been broadcasted more than 100 times in 30 different states. The PCOR Partnership is one of seven partnerships in the NETL-managed Regional Carbon Sequestration Partnership Initiative. From *NETL Press Release* on April 30, 2013.

June 2013

"Livermore Develops the World's Deepest ERT Imaging System for CO_2 Sequestration." Lawrence Livermore National Laboratory (LLNL) researchers have broken the record for tracking the movement and concentration of carbon dioxide (CO_2) in a geologic formation using the Electrical Resistance Tomography (ERT) system. The team obtained time-lapse electrical resistivity images during the injection of more than 1 million tons of CO_2 more than 10,000 feet deep in an oil and gas field in Cranfield, Mississippi. This represents the deepest application of the imaging technique to date. ERT can track the movement and concentration of the injected CO_2 and the degree of geologic containment using time-lapse electrical resistivity changes. The installation of each ERT array in the storage reservoir required designing all cabling and electrodes, which were externally mounted on the borehole casing, some 10,000 feet underground. The team used the ERT array in an environment of high temperature (260 degrees Fahrenheit), high pressure (5,000 pounds per square inch [psi]) and high corrosive fluids to detect CO_2 breakthroughs and saturation changes over time. When converted to CO_2 concentration, the images provided information about the movement of the injected CO_2 within a complex geologic formation and how the storage of the CO_2 changed with time. An LLNL representative said that higher-resolution ERT may also have an application as a warning system for fracture pathways in caprock and another potential application involves monitoring the boundary of a storage lease to ensure that CO_2 does not migrate to an adjacent parcel. The ERT project is part the U.S. Department of Energy (DOE)-sponsored Southeast Regional Carbon Sequestration Partnership (SECARB) Cranfield project near Natchez, Mississippi, which has become the fifth ERT system worldwide and the first in the United States to inject more than 1 million tons of CO_2 into the subsurface. The Cranfield study was funded by DOE's National Energy Technology Laboratory (NETL) to the Southern States Energy Board. From *LLNL News Release* on June 6, 2013.

July 2013

"**MRCSP Begins Field Tests in Michigan**." The Midwest Regional Carbon Sequestration Partnership (MRCSP), led by Battelle, announced the beginning of a large-scale carbon dioxide (CO_2) injection in Michigan's Northern Reef Trend. The project is designed to inject and monitor at least 1 million metric tons of CO_2 into a series of oil fields that are in different stages of their production life cycles. The first test in the series will inject up to 500,000 metric tons of CO_2 into an oil field that has undergone primary production and enhanced oil recovery (EOR) for several years and is now near the end of its productive life. During the last year, MRCSP has conducted baseline geologic characterization and advanced monitoring to prepare the wells for the injection phase. These fields are already permitted as part of the EOR operations. In this first leg of the field test, MRCSP expects injection rates of approximately 1,000 metric tons of CO_2 per day. MRCSP will be using state-of-the-art techniques to track the CO_2 and quantify the amount that is retained in the formation after the oil is removed. The CO_2 will be injected into the geologic structures known as the northern Niagaran pinnacle reef trend. These oil fields are located approximately 6,000 feet below the surface. This milestone builds on the work completed by MRCSP during earlier phases of the program, including small-scale testing and mapping of geologic formations across the region. MRCSP is one of seven Regional Carbon Sequestration Partnerships (RCSPs) established by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL). From *Battelle News Release* on July 9, 2013.

"**Research Without Borders: NETL Pens MOU with Brazilian Coal Association**." On June 6, DOE's NETL and the Brazilian Coal Association (BCA) signed a Memorandum of Understanding (MOU) on carbon capture and storage (CCS) in Florianópolis, Brazil. Under the MOU, both parties will work together to assess the potential of CCS in fossil fuel-based systems over the next five years, as well as the development of clean coal technologies applicable to Brazilian coals. The MOU also covers the development of other technologies to reduce the environmental impact of fossil fuel production and use. The MOU follows an agreement signed by NETL and BCA in 2007, which resulted in scientific exchanges and several publications. From *NETL News Release* on July 18, 2013.

August 2013

"MSU and Partners Send Carbon Dioxide Deep Underground in Regional Experiment" and **"Ancient Lava Flows Trap CO_2 for Long-Term Storage in Big Sky Injection."** A Big Sky Carbon Sequestration Partnership-managed (BSCSP) project injected 1,000 tons of carbon dioxide (CO_2) into geological formations that consist of ancient basalt flows beneath Boise Inc. property. The Boise pulp and paper mill is located in the Columbia Basin between the Tri-Cities and Walla Walla, Washington. The site is located on top of dozens of volcanic lava flows, extending down 8,000 feet or more; these geologic layers were formed as volcanic lava flowed and cooled. According to a project official, laboratory tests have been conducted on basalts from the region for several years that demonstrate the unique geochemical nature of basalts to react with CO_2 and form carbonate minerals or solid rock. Over the next 14 months, scientists will examine fluid samples from the injection well to look for changes in chemical composition and compare results to predictions that were made using Pacific Northwest National Laboratory's (PNNL) supercomputer. At the end of the monitoring period, rock samples from the well are expected to show the formation of carbonate mineralization, or limestone crystals, as a result of CO_2 reacting with minerals in the basalt. In 2009, an injection well at the site confirmed that basalt flows located above and below the injection zone were nearly impermeable and additional research in late 2012 indicated that the location is well suited for the pilot test. BSCSP is one of seven Regional Carbon Sequestration Partnerships (RCSPs) funded by the U.S. Department of Energy (DOE) and managed by the National Energy Technology Laboratory (NETL). More information is available via YouTube and the BSCSP project website. From *Montana State University News Release* on July 26, 2013, and *Fossil Energy Techline* on August 13, 2013.

Carbon Storage in the News

September 2012

***CO2CRC Media Release*, "World Class Carbon Reduction Hub Opens in Victoria."** The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) will direct research at the newly launched Peter Cook Centre for Carbon Capture and Storage Research in Victoria, Australia. Rio Tinto will sponsor the Peter Cook Centre with $3 million in funding over three years. In addition, Rio Tinto will also provide another $3 million in funding over three years for the CO2CRC Otway Project, which is Australia's first demonstration of geologic storage. The Peter Cook Centre will incorporate extensive research already underway at the University of Melbourne, and will initially host more than 30 scientists currently working on carbon capture and storage (CCS). The center will link the researchers with the CO2CRC Otway Project Subsurface Storage Laboratory, which has been safely storing CO_2 deep underground since 2008. August 14, 2012, http://www.co2crc.com.au/dls/media/12/PeterCookCCS_Centre.pdf.

***Shell Media Release*, "Shell to Construct World's First Oil Sands Carbon Capture and Storage Project."** Shell officials announced plans to proceed with the Quest CCS project for an oil sands operation in Canada. The project will be built on behalf of the Athabasca Oil Sands Project joint venture owners. The Athabasca Oil Sands project produces bitumen, which is piped to Shell's Scotford Upgrader near Edmonton, Alberta. In late 2015, Quest will capture and store more than 1 million tonnes a year of CO_2 produced in bitumen processing. Quest will reduce emissions from the Scotford Upgrader by up to 35 percent. The CO_2 will be injected more than two kilometers underground into a porous rock formation called the Basal Cambrian Sands (BCS), which is located beneath layers of impermeable rock. Monitoring technologies will ensure that the CO_2 is safely and permanently stored. In 2011, Quest received the world's first certificate for its storage development plan from Det Norske Veritas (DNV), an international risk management firm. The Alberta government will invest $745 million in Quest from a $2-billion fund to support CCS, while the Government of Canada will invest $120 million through its Clean Energy Fund. Shell has received the necessary federal and provincial regulatory approvals for Quest. Construction has begun and will employ an average of approximately 400 workers over roughly 30 months. September 5, 2012, http://www.shell.com/home/content/media/news_and_media_releases/2012/quest_first_oil_sands_ccs_project_05092012.html.

***DNV Press Release*, "New Experimental Data to Support CCS Safety."** The DNV-led CO2PIPETRANS joint industry project (JIP) launched the 2nd release of data along with supporting material. The free experimental data will assist dense phase CO_2 computer model development and validation and further support global CCS implementation. The material released by the CO2PIPETRANS JIP in May was gathered by BP in 2006 as part of their Peterhead/Miller CO_2 capture and EOR project. The 2nd release (collected by Shell in 2010) provides datasets covering different initial conditions and a greater number of measurements. According to DNV officials, the combined material now released by the JIP provides a reference source for those involved with CCS, CO_2-EOR, or CO_2-rich hydrocarbon extraction. The material covers a number of experiments undertaken to investigate the behavior of releasing dense phase CO_2 up to 150 bar (2,175 pounds per square inch [psi]) and 150°C (300°F) through orifices up to 25 mm (1 inch) in diameter at constant or decaying inventory pressure. The data has been critically reviewed prior to being made available and the review reports are also being provided with the datasets to help interpretation. The data can be downloaded, along with the 1st datasets released, from DNV's website, at: www.dnv.com/ccs. September 6, 2012, http://www.dnv.com/press_area/press_releases/2012/new_experimental_data_to_support_ccs_safety.asp.

***Fossil Energy Techline*, "Energy Department Announces Awards to Projects Advancing Innovative Clean Coal Technology."** DOE has selected eight projects to advance the development of transformational oxy-combustion technologies capable of high-efficiency, low-cost CO_2 capture from coal-fired power plants. The selections are part of a two-phase effort to evaluate and develop advanced oxy-combustion projects that yield cost-competitive options for CCUS. The selected projects, each lasting one year, will aim to achieve at least 90 percent CO_2 removal while delivering CO_2 at a capture cost of less than $25 per ton. DOE will invest $7 million to support the development and deployment of CCUS by focusing on further improving the efficiency and reducing the costs associated with carbon capture. The projects will be managed by NETL. July 26, 2012, http://www.fossil.energy.gov/news/techlines/2012/12033-DOE_Announces_Oxycombustion_Projec.html.

October 2012

***Carbon Capture Journal*, "Imperial College London CO_2 Storage Labs Opened."** Four recently opened laboratories at Imperial College London will explore methods of storing CO_2 in carbonate rock. The labs offer Imperial researchers an outlet to develop a deeper understanding of what happens to CO_2 emissions at the microscopic level by carrying out experiments observing CO_2 within the rock under reservoir conditions and modeling how it flows through pores in the rock. By linking this to imaging experiments and models on a larger scale, researchers can then predict what happens to CO_2 when it is stored in carbonate rock reservoirs and provide detail on how to effectively and efficiently store CO_2 in carbonate rock. The research is part of the Qatar Carbonates and Carbon Storage Research Center (QCCSRC), which was established in 2008 as part of a 10-year, $70 million collaboration between Imperial, Qatar Petroleum, Shell, and the Qatar Science and Technology Park. Carbonate Rocks are the predominant reservoir type in the Middle East and store a large portion of the world's oil and gas reserves. September 13, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=1015&PHPSESSID=dth89mab1uh1mptrlhea1do0c3.

***Proactive Investors*, "Elk Petroleum's Grieve Enhanced Oil Recovery Project on Schedule and Within Budget."** Elk Petroleum is advancing the construction phase of the Grieve oil field enhanced oil recovery (EOR) project in Wyoming on schedule and within budget, according to the company. Operated by Denbury Resources, the Grieve Project is expected to produce up to 1,000 barrels of oil per day net within three years, with the potential to produce up to 5,000 barrels per day by five years. Site preparation work at the Grieve field is nearing completion, and the first of the concrete foundations for the new field facilities has been poured. Denbury has submitted an Application for Permit to Drill to the Wyoming Oil and Gas Conservation Commission for the Grieve #62 well, which will be the first of the wells to be drilled to the Madison formation. The well will be drilled to a target depth of 3,231 meters to source water for the injection and accelerated re-pressuring of the oil-bearing Muddy formation. The project is set to begin CO_2 injection in November 2012. The Elk Petroleum Grieve Project Update is available at: http://clients2.weblink.com.au/clients/elkpet/article.asp?asx=ELK&view=6604844. September 21, 2012, http://www.proactiveinvestors.com.au/companies/news/33677/elk-petroleums-grieve-enhanced-oil-recovery-project-on-schedule-and-within-budget--33677.html.

***Carbon Capture Journal*, "Aquistore Drills Deepest Well in Saskatchewan."** According to officials, the deepest well in Saskatchewan has been drilled to a total depth of 3,396 meters, becoming the new home of the Petroleum Technology Research Center's (PTRC) Aquistore project, a saline storage project located outside Estevan in southeastern Saskatchewan. Due to the lack of deep wells in the area, the Aquistore well is expected to become the primary data point for the Deadwood formation, the deepest sedimentary unit in the Williston Basin. In addition to CO_2 storage, the comprehensive suite of well logs, core samples, and other data that accompany this well are also useful for the area's oil companies with interest in oil-bearing formations. Information gathered from the well is expected to provide valuable knowledge for the [monitoring, verification, and accounting (MVA)] program undertaken by the project. A second observation well will also be drilled, at a comparable depth, to further track the CO_2. Together,

these two wells can provide valuable information and data to the project and other interested parties. September 25, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=1022&PHPSESSID=l8dkjsha7qaa6s815mlrslvtq4

***Australian Mining*, "Geosequestration Research Facility to be Developed,"** and ***Mining Weekly*, "[Western Australia] Gets CCS Facility."** Western Australia will develop a new geosequestration research facility to study advanced carbon storage technologies following a multi-million dollar investment from the Australian government. The new National Geosequestration Laboratory (NGL) will act as a "hub and spoke" model and will be part of the Australian Resources Centre at Technology Park, Kensington, Western Australia, along with nodes at other Australian sites forming part of the overall facility. The first NGL will house a carbon capture and storage geophysics and geochemistry research facility, and its first role will be a detailed analysis of the core and electronic data from the recently completed Harvey 1 Well. September 28, 2012, http://www.miningaustralia.com.au/news/geosequestration-research-facility-to-be-developed, and September 27, 2012, http://www.miningweekly.com/article/wa-gets-ccs-facility-2012-09-27.

November 2012

***Western Australia Business News*, "W. Australia CCS Plan Advances."** Following positive results from initial investigations, Western Australia's first onshore carbon capture and storage project, the South West Hub, has proceeded to the next step, as the Department of Mines and Petroleum is exploring the viability of capturing CO_2 from the Harvey region and transporting and storing it underground. The project is currently in the preparation phase and working to establish suitability of an underground reservoir for carbon storage. According to the project coordinators, the first exploratory drilling program confirmed indications of the Lesueur reservoir, a sandstone reservoir approximately 4,900 feet in size and approximately 1.5 miles underground. The results enabled the project team to plan for the next drilling program and three-dimensional seismic mapping of the underground area, which would be undertaken next year. A total of $330 million in Commonwealth funding has been contributed to the project; to date, $52 million of it has been committed through the CCS National Flagships Program. October 25, 2012, http://www.downstreamtoday.com/(X(1)S(54letw55nxxhy345m1d1s455))/news/article.aspx?a_id=37553.

***Bloomberg*, "Chevron's Gorgon Carbon Project on Track for Injection in 2015."** According to the Australian energy minister, Chevron's Gorgon liquified natural gas project, located off the northwest coast of Australia, is on track to begin CO_2 injections in 2015. The Gorgon project is designed to inject 3.5 million tons of CO_2 per year below Barrow Island off Western Australia at an approximate depth of 2,300 meters. Australia is aiming to reduce greenhouse gas (GHG) emissions at least five percent below 2000 levels by 2020, with a long-term goal of cutting GHG emissions by 80 percent below 2000 levels by 2050. October 23, 2012, http://www.businessweek.com/news/2012-10-23/chevron-s-gorgon-carbon-project-on-track-for-injection-in-2015.

***Bloomberg*, "U.K. Shortlists Four Projects Bidding for $1.6 Billion CCS Funds,"** and ***Reuters*, "U.K. Shortlists Projects for Carbon Capture Funding."** Four projects have been named to a shortlist by the U.K. government for $1.6 billion of funding for carbon capture and storage projects. The U.K. Department for Energy and Climate Change (DECC) narrowed a list of bids down to the following four projects: Drax's 304-megawatt (MW) coal plan in North Yorkshire; Shell and SSE's 1,180-MW combined cycle gas plant in Peterhead; National Grid and Petrofac's 570-MW coal-gasification project in Grangemouth; and Progressive Energy and GDF Suez's 330-MW coal-gasification project in Teesside. The U.K. government is expected to select the winner in 2013; the timetable will depend on the selected projects. October 30, 2012, http://www.bloomberg.com/news/2012-10-30/u-k-shortlists-four-projects-bidding-for-1-6-billion-ccs-funds.html, and October 30, 2012, http://uk.reuters.com/article/2012/10/30/uk-britain-energy-ccs-idUKBRE89T0UT20121030?feedType=RSS&feedName=domesticNews.

December 2012

***ULTimateCO2 Press Release*, "Step Forward for CCS as New [~$5.2M] European Project Aids Understanding the Long-Term Fate of CO_2 Storage."** ULTimateCO2, a new four-year, [~$5.2M] European project will advance understanding of the long-term fate of CO_2 when captured and stored in geologic formations as part of the carbon capture and storage (CCS) process. Detailed lab, field, and modeling studies of the main physical and chemical processes involved will be covered by the project, as will their long-term impacts, including: trapping mechanisms of CO_2 in geological formations; fluid-rock interactions and the effect on the integrity of caprocks; and release due to the lack of integrity of operating or abandoned wells. In addition, the project will develop recommendations for operators and regulators of CO_2 storage sites to improve their long-term performance. The project's outcomes will be disseminated to a broad audience to improve public understanding. November 18, 2012, http://www.ultimateco2.eu/documents/UltimateCO2_press_release_final_version.pdf.

***Carbon Management Canada*, "CMC Announces Eight New Research Projects."** Carbon Management Canada (CMC) has awarded a total of $3.75 million to eight new research projects. The projects include, but are not limited to: developing greenhouse gas (GHG) sensors using nanotechnology; improving ways of assessing caprock integrity for CO_2 storage; discovering ways to reduce CO_2 emissions in cement production; examining and testing methods to securely store CO_2 in mine tailing through formation of carbonate materials; and investigating ways carbon-pricing policies could drive innovation and the development of low-carbon economies. With the addition of these awards, CMC has committed a total of $22 million to 44 research projects at Canadian universities, with additional contributions and partners from more than 100 companies, stakeholder organizations, and universities from other countries. November 29, 2012, http://www.carbonmanagement.ca/cmc-announces-eight-new-research-projects/.

***Cranfield University Press Release*, "Cranfield [University] Opens New Clean Energy Research [Center]."** On behalf of the U.K. Department of Energy and Climate Change (DECC), Cranfield University opened its new $3.2 million high-tech energy laboratory. Housing a range of near industrial-scale equipment for the research and development (R&D) of clean and renewable energy technologies, the laboratory supports research into carbon capture and transport systems, clean fossil fuel technologies, bioenergy, and energy-from-waste. The facilities are used for process development; studies into materials performance; and the reliability of systems and components, such as the integrity of heat exchangers, gas turbine blades, and CO_2 pipelines. November 27, 2012, http://www.cranfield.ac.uk/news/pressreleases/2012/page59122.html.

January 2013

***Carbon Capture Journal*, "UK Online CO_2 Storage Database to be Launched."** The Energy Technology Institute (ETI) has agreed to a license with The Crown Estate and the British Geological Survey to host and further develop its United Kingdom (UK) CO_2 Storage Appraisal project into a web-enabled database of mapped UK offshore CO_2 storage capacity. The online database contains geological data, storage estimates, risk assessments and economics of nearly 600 potential CO_2 storage units of depleted oil and gas reservoirs, and saline formations around the UK. Interested stakeholders will be able access information concerning storage resource through the new, first-of-its-kind database, enabling them to make more informed, carbon capture and storage (CCS)-related decisions. The database is expected to go live in early 2013. December 15, 2012, http://www.carboncapturejournal.com/displaynews.php?NewsID=1070&PHPSESSID=l8dkjsha7qaa6s815mlrslvtg4.

***Callide Oxyfuel Project Media Release*, "Callide Oxyfuel Project Enters Demonstration Phase."** Construction and commissioning of the coal-fired, low-emission Callide Oxyfuel Project has been completed, with the project now moving into the demonstration phase. The $208 million project aims to demonstrate how CCS technology can be applied to existing coal-fired power stations to produce electricity with lower emissions. The project is a joint venture between CS Energy, the Australian Coal Association Low Emission Technologies (ACALET), Xstrata Coal, Schlumberger, and Japanese participants (J-Power; Mitsui & Co., Ltd.; and IHI Corporation). Funding has been received from the Australian ($50 million under the Lowe Emissions Technology Demonstration Fund), Japanese, and Queensland governments, and the Japan Coal Energy Center (JCOAL) has provided technical support. December 15, 2012, http://www.callideoxyfuel.com/Portals/0/News/Callide%20Oxyfuel%20Project%20-%202012%20-%20OPENING%20EVENT%20-%20FINAL%20-%20Media%20release%20-%2015%20December%202012.pdf.

***MiningWeekly.com*, "SA and World Urged to Accelerate Carbon-Capture Efforts."** Following Cabinet endorsement in 2012 of the "Carbon Capture and Storage Roadmap," developed by the South African Centre for Carbon Capture and Storage as one of the options for mitigating CO_2 emissions, South Africa is working to raise the profile of its CCS initiatives in 2013. The endorsement followed a voluntarily commitment by South Africa to reduce CO_2 emissions by 34 percent in 2020 and by 42 percent in 2025 if technological and financial support is available. South Africa has already published a carbon atlas and initiated preparations for its first CO_2 injection test by 2016. If feasible, the next step would be the development of a demonstration plant. The roadmap is available at: http://www.sacccs.org.za/roadmap/. On February 13-15, 2013, the European Commission (EC), along with Eskom and EcoMetrix Africa, will host a conference in Johannesburg, South Africa, at ESKOM's Academy of Learning in Midrand where information on the Octavius research program will be discussed. The Octavius project is dedicated to the demonstration of energy-efficient CO_2 capture processes at industrial pilot plants. More information on the Octavius project is available at: http://www.octavius-co2.eu/Octavius/jcms/xnt_15158/octavius-fp7-project. January 9, 2013, http://www.miningweekly.com/article/sa-and-world-urged-to-accelerate-carbon-capture-efforts-2013-01-09.

***The Korea Herald*, "Korea to Establish Carbon Storage Technology Research Center."** Korea's leading research institution, the Korea Advanced Institute of Science and Technology, and oil developer Saudi Aramco signed a Memorandum of Understanding (MOU) in Dhahran, Saudi Arabia, to establish a research center to develop technologies to capture, store, and utilize CO_2. The new facility will be located at the school's campus in Daejeon, South Korea, and financed equally by the two sides; the collaboration will initially run for six years and could be extended. The organizations will work to develop commercially viable processes for CCS, as well as utilization technologies like using and converting CO_2 to produce food, beverages, bio and renewable fuels, and chemical feedstock. January 9, 2013, http://www.eco-business.com/news/korea-to-establish-carbon-storage-technology-research-center/.

February 2013

"CCS Projects Financed Through Government [Program]." Costain, a UK engineering solutions provider, has secured financing from the UK Department of Environment and Climate Change (DECC) through a [~$26] million program for finding solutions to reduce the cost of CCS. Costain will collaborate with UK universities to develop two innovative technologies that aim to reduce the cost of low-carbon electricity generation through reducing costs associated with carbon capture. With the funding, Costain will: (1) investigate a concept for the design and construction of absorber columns for post-combustion carbon capture in coal and gas power plants; and (2) develop an oxy-fuel capture technology to study CO_2 separation and compression technology. From *Costain News Release* on January 8, 2013.

"RWE Starts Carbon Capture at UK Coal Plant" and **"First [Metric Ton] of CO_2 Captured at RWE npower Pilot Project."** The first metric ton of CO_2 has been captured at RWE npower's carbon capture

pilot plant at Aberthaw Power Station in Wales, UK. When commissioning with live flue gas is complete, the plant will capture approximately 50 metric tons of CO_2 per day (or the amount of CO_2 produced by 3 megawatts [MW] of electricity generation). RWE will optimize the performance of the technology during the R&D program, using the facility to gather a better understanding of the implications of operating a full-scale carbon capture facility in conjunction with normal power plant operations. In addition, RWE will work with the UK's Environment Agency to track the impact of the carbon capture process on the power plant's surroundings. From *Reuters* on January 17, 2013, and *Carbon Capture Journal* on January 20, 2013.

"CO_2 Solutions Receives $4.7 Million from the Harper Government for Oil Sands Carbon Capture Project." The Harper Government has made a $4.7 million investment to support the development of CO_2 Solutions' carbon capture technology in the Alberta oil sands. CO_2 Solutions is developing enzyme-enabled carbon capture technology for use in oil sands production, including in-situ methods such as Steam-Assisted Gravity Drainage (SAGD), and bitumen upgrading. Project results will also support the company's technology in other natural gas combustion sources, such as gas-fired power plants. CO_2 Solutions' management anticipates the project to cost $7.5 million; additional funds are being obtained through grants from other organizations. From *Canada Newswire* on January 24, 2013.

"[Technology Centre Mongstad] Launches International Test Centre Network." CO_2 Technology Centre Mongstad (TCM) has formed an international test center network for carbon capture test facilities around the world to share knowledge of technological developments, construction and operational experience, establish performance indicators, and promote technology standardization. The aim of the network is to reduce costs and investigate the technical, environmental, and financial risks associated with CCS. The eight founding members of the Test Centre Network are TCM (Norway), National Carbon Capture Center (Alabama, USA), Southern Company's 25-MW CCS demonstration facility (Alabama, USA), SaskPower, J-Power (Japan), ENEL Engineering and Research (IT), E.ON (Germany), and Doosan Power Systems (UK). TCM is comprised of two CO_2 capture plants, each with a capacity to capture approximately 80,000 tons of CO_2 from a nearby refinery or 20,000 tons from a gas-fired power plant. From *CO_2 Technology Centre Mongstad Press Release* on January 31, 2013.

March 2013

"CONSOL Energy, VCCER Announce Research Project Aimed at Identifying Coal Seam Carbon Storage Alternatives." CONSOL Energy and the Virginia Center for Coal and Energy Research (VCCER) at Virginia Tech will collaborate on a research project that will test the CO_2 storage potential of unmineable coal seams. CONSOL Energy's CNX Gas Virginia operations will donate the use of three coalbed methane (CBM) wells in the pilot project to be conducted by VCCER and NETL in Virginia. Up to 20,000 tons of CO_2 will be injected and stored in coal seams. The injection, which will take place during the course of one year, builds upon a recently completed, 1,000-ton injection test that took place in a neighboring county in 2009. VCCER and NETL have established a comprehensive plan to monitor the injected CO_2 to understand the feasibility of CO_2 storage in unmineable coal seams and explore the potential of enhanced coalbed methane (ECBM) recovery. The test is part of a larger effort funded by NETL for CCS projects. From *CONSOL Energy News Release* on February 4, 2013.

"Summit Power & Linde Join Forces to Develop Projects Deploying Carbon Capture from Natural Gas." Summit Power Group and The Linde Group announced a partnership to develop commercial-scale, natural gas-fired power plants that will capture up to 90 percent of CO_2. The new power plants, which will combine natural gas-fired power plant technology with carbon capture technology, will produce approximately 250 megawatts (MW) of net electric power while capturing up to 750,000 tons of CO_2 annually. The companies have identified several U.S. locations for this type of plant where the ultra-low carbon electric power could be sold to utilities and large consumers, and where suitable geologic storage sites are available for CO_2 injection. Both Summit Power and Linde are already developing carbon capture projects for CO_2 storage or EOR. Summit is currently developing two major coal gasification

projects that will capture 90 percent of the CO_2 they release: the Texas Clean Energy Project (TCEP) in the United States and the Captain Clean Energy Project (CCEP) in the United Kingdom. From *Summit Power* on February 7, 2013.

"DNV and PSE Report on Ship Carbon Capture and Storage." According to results released by Det Norske Veritas (DNV) and Process Systems Enterprise Ltd. (PSE), the Maritime CCS research and development (R&D) project successfully developed a concept design for onboard chemical CO_2 capture. The system consists of a chemical absorption plant to separate CO_2 from flue gases, a liquefaction unit to compress and condense the captured CO_2 using a refrigerant, and two storage tanks to temporarily store the liquid CO_2 until it is discharged into transmission and storage infrastructures at the next suitable port. Maritime CO_2 emissions are estimated at more than 1,000 million metric tons per year (three percent of total emissions) and are expected to reach 2,000 to 3,000 million metric tons by 2050. From *DNV Press Release* on February 12, 2013.

"UKCCSRC Offers Funding for 11 RAPID Research Projects." The UK CCS Research Center (UKCCSRC) will offer approximately $2.5 million in funding for 11 research projects in the areas of CO_2 capture, CO_2 transport, and CO_2 storage. The four capture projects will develop approaches for chemical looping for low-cost oxygen production; oxy-fuel and exhaust gas recycling at gas-fired power plants; computational fluid dynamic (CFD) modeling of oxy-coal combustion; and post-combustion capture using membranes. The four transport projects will deliver important knowledge and understanding for safe and cost-effective design and operations of CCS networks, with projects analyzing the development of flexible CO_2 transport systems; the behavior of dense-phase CO_2 with impurities in pipelines; water solubility limits in CO_2 mixture; and generating equations of state for CO_2 mixtures relevant to CCS applications. Lastly, the three storage projects will contribute to improved characterization for CO_2 storage in the North Sea; the development of processes to monitor CO_2 storage; and a scoping project that will explore a follow-on project monitoring the transport of potential release from the subsurface. More information on the individual projects can be found on the Projects Page. From *UKCCS Research Centre* on February 19, 2013.

April 2013

"Carbon Storage Drilling Project Begins at AA Quarry." Work has commenced on a 4,800-foot-deep research well in northeastern Kentucky. The stratigraphic-test well will be designed to collect geologic information about the nature of the deep subsurface formations in the region, without actual CO_2 injection; according to the Kentucky Geological Survey (KGS), who is monitoring the wells for changes, there are no plans to store CO_2 at the site. KGS will obtain rock cores, geophysical well logs, and water samples, and test properties of several deep formations penetrated in the well. The research will be used to better understand the reservoir rock properties of the region, and the data gathered will help KGS evaluate the potential for future CO_2 storage along the Ohio River industrial corridor. Comprehensive geologic and geophysical data will also be acquired in the well, including nearly 300 feet of core samples, native formation fluid samples, advanced downhole well logs, and standard reservoir tests. The project, part of CO_2 storage research mandated by the Kentucky General Assembly in 2007, will take place in northeastern Carter County, with Hanson Aggregates providing access to its AA Limestone quarry. From *Journal-Times* on March 27, 2013.

"CO_2 Solutions Announces Agreement with Statoil." CO_2 Solutions has entered into an agreement to provide certain project data and reports to Statoil, an international energy company headquartered in Norway. CO_2 Solutions is developing CO_2 capture technology for use in oil sands production. The data and reports to be provided under this agreement relate to the pre-pilot phase of CO_2 Solutions' Alberta oil sands project. Previously announced by CO_2 Solutions in January 2013, the Alberta oil sands project is partially funded through a $4.7 million investment from the ecoENERGY Innovation Initiative, as well as $500,000 from Alberta's CCEMC. From *CO_2 Solutions News Release* on March 12, 2013.

"Update on Elk Petroleum Projects: Grieve CO_2 EOR Project." Officials from Elk Petroleum announced that CO_2 injection started at Grieve in early March and is continuing at a rate of up to 40 million standard cubic feet per day, depending on the availability of CO_2 from ExxonMobil's gas plant at Shute Creek, Wyoming. The injection of water to re-pressurize the Grieve Muddy reservoir is expected to begin in April or May. The water will be sourced from the Grieve #62 well that was drilled to the Tensleep and Madison formations to assess down-dip and deeper geological information. The Grieve #62 well is now being completed as a water source well. Elk had previously stated that it expected this re-pressurization/miscibility process to take up to 18 months. During this process, CO_2 and water will be injected to raise the average reservoir pressure above the minimum miscible pressure throughout the main oil section in the reservoir. Officials said that oil production will commence once this is completed. The construction of the processing facilities to separate produced oil, gas, CO_2, and water (as well as compress and dehydrate CO_2 for recycling back into the reservoir) will begin in 2013 to handle the first oil produced. From *Elk Petroleum Ltd News Release* on April 3, 2013.

"Preferred Bidders Announced in UK's [~$1.5 billion] CCS Competition." Following a period of commercial negotiations with four projects shortlisted from an original eight in October 2012, the Peterhead Project in Aberdeenshire, Scotland, and the White Rose Project in Yorkshire, England, were announced as the two preferred bidders in the United Kingdom's (UK) [~$1.5 billion] Carbon Capture and Storage Commercialization Program Competition. The Peterhead Project will capture approximately 90 percent of the CO_2 from part of its existing gas-fired power station, and then transport and store it in a depleted gas field beneath the North Sea. The White Rose Project will capture 90 percent of the CO_2 from a new, coal-fired power station at the Drax site in North Yorkshire, and then transport and store it in a saline formation beneath the southern North Sea. The two preferred bidders and the UK government will now begin discussions to agree to terms for Front End Engineering Design (FEED) studies. Once the terms are agreed upon (expected by summer), the FEED studies, which are best practices for complex projects in the engineering and construction industry, are expected to last approximately 18 months. From *United Kingdom Department of Energy and Climate Change Press Release* on March 20, 2013.

"GCEP Will Award $6.6 Million for Novel Energy Research." Stanford University's Global Climate and Energy Project (GCEP) has awarded $6.6 million in funding to seven research teams (six from Stanford; one from Carnegie Mellon University [CMU]) to advance research on clean-burning fuels and technologies for capturing CO_2 emissions. Three Stanford research teams will utilize the funding to develop carbon-neutral technologies that produce electricity or clean-burning hydrogen fuel. Two Stanford research teams will use the funding to test new electrochemical catalysts that convert CO_2 into liquid fuels and chemicals. Lastly, in addition to the previously mentioned lab-oriented projects, two research teams (one from Stanford and one from CMU) will use the funding to develop computer models that evaluate the effectiveness of various technologies for capturing CO_2 emissions from power plants. From *GCEP News Release* on March 17, 2013.

May 2013

"Lithium Discovery Could Be New Industry for Wyoming." While working on a CO_2 storage site project, researchers at the University of Wyoming Carbon Management Institute (CMI) discovered a new lithium resource that could potentially offset the cost of creating the project's underground CO_2 storage space. According to early analyses of fluid samples collected from a well drilled on the Rock Springs Uplift, the reservoir brines from a 25-mi^2 nearby area could contain approximately 228,000 tons of lithium, which is a key component of "greener technologies," as lithium-ion batteries are employed by wind, solar, and smart-grid technologies. The high levels of lithium were originally found in formation waters last year while CMI researchers were working on the drill site, located east of Rock Springs and slightly north of Point of Rocks. The waters were sampled again in November 2012 with the same results. In order to offset costs, the production of the lithium would have to be integrated with the carbon storage work to utilize the deep wells drilled for CO_2. From *The Billings Gazette* on April 24, 2013.

"**Ottawa Funds $4.5m in Geological Research for Sydney Area.**" The Carbon Capture and Storage Research Consortium of Nova Scotia announced that they received $4.5 million through the ecoEnergy Innovation Initiative for geological research in Nova Scotia. Earlier research identified that the Sydney sub-basin has the largest theoretical capacity to permanently store captured CO_2 underground. Field research and community consultation will start this spring and a report will be released to the public by the winter of 2015. The information will be shared with the community. From *The Chronicle Herald* on May 3, 2013.

"Svalbard Prepares the Ground for CO_2 Storage." Researchers at the Svalbard University Center (UNIS) have found substantial CO_2 storage capacity in a major underground reservoir in Adventsdalen, near Longyearbyen at Svalbard (Norway), following several years of study. A total of six wells with depths varying from 190 to 970 meters have been drilled in Adventsdalen and water injection tests indicate that the reservoir is ideal for CO_2 storage. Researchers also believe the reservoir has a sufficient caprock. The reservoir capacity estimation is still uncertain and plans call for the injection of smaller amounts of CO_2 in the wells to make more precise estimations of the capacity. The project plans to inject up to 200,000 tons of CO_2 in the reservoir over a period of 10 years. The Lab, a project under the UNIS, has been engaged in the study of the reservoir since 2007 and partners include ConocoPhillips, Statoil, Store Norske, Gassnova, Statkraft, and Lundin Norway. From *Barents Observer* on May 13, 2013.

June 2013

"Recycling Carbon Dioxide to Make Plastics." A project funded in part by DOE's FE has led to the world's first successful large-scale production of a polypropylene (PPC) polymer using waste CO_2 as a key raw material. Conducted by Novomer in collaboration with specialty chemical manufacturer Albermarle Corporation, the PPC polymer production run tested scale-up of Novomer's novel catalyst technology, producing seven tons of finished polymer that will be used to accelerate product qualification. The Novomer process reduces the use of fossil fuels on the conventional production of plastics, such as polyethylene and polypropylene, by replacing up to half of the mass of the petroleum-based product with CO_2. Converting captured CO_2 into products such as chemicals, plastics, fuels, building materials, and other commodities is an important component of FE's Carbon Capture and Storage Program, which is managed by NETL. From *Office of Fossil Energy* on May 20, 2013.

"RTI Partners with Norwegian Firm on $15M Carbon Capture Project." RTI is partnering with Norcem, part of HeidelbergCement Group, on a $15 million project to test CO_2 capture technology developed by RTI International. The three-year pilot project will be conducted at Norcem's cement plant in Brevik, Norway. The RTI technology has been in development for nearly 10 years and the company is still developing the sorbent-based CO_2 capture technology for coal-fired power plants. This project will provide the opportunity to incorporate it into a cement plant. The technology will first be tested at RTI's Energy Technology Development Facility on RTI's Research Triangle Park campus. The research, intended for applications in coal-fired power plants, has been funded by DOE and developed in collaboration with the DOE's NETL. From *WRAL Tech Wire on May 28, 2013.*

"Research Agreement Signed to Promote Carbon Storage Development." Researchers from Scottish Carbon Capture & Storage, a partnership of the British Geological Survey, Heriot-Watt University, and the University of Edinburgh signed a new collaborative research agreement aimed at risk reduction and guiding development of offshore CO_2 storage sites. The CO_2 Multi Store project is supported by the Scottish government, Crown Estates, Scottish Enterprise, and Shell. The lessons learned from the project will inform leasing and licensing needs for multi-user CO_2 storage sites across the world; according to the research group, these sites could be developed for secure and permanent CO_2 storage. Specifically, researchers will work to predict the effect(s) of injecting CO_2 into two potential storage sites within an extensive sandstone formation more than one-half mile beneath the sea bed in the UK central North Sea, east of Scotland. The study will use 3-D computer models created from data

collected for oil and gas exploration and benefit from the input of industry knowledge and expertise in CO_2 geologic storage. The research project is expected to be completed by Spring 2014. From *New Civil Engineer* on May 30, 2013.

"South Korea Carbon Capture Plant Begins Operating." South Korea has initiated operations at its carbon capture and storage (CCS) unit at the Boryeong Thermal Power Plant Complex on the country's west coast. The unit is attached to a 10-megawatt station and expected to capture approximately 80,000 tons, or more than 90 percent, of CO_2 per year from the 10,000-kilowatt power generation facility. The CCS unit would help reduce greenhouse gas (GHG) emissions and meet its voluntary pledge in 2009 to cut GHG emissions by 30 percent from its business-as-usual levels in 2020. From *GlobalPost* on May 24, 2013.

"Government of Canada Investing in Technology to Reduce GHG Emissions in the Oil Sands." The Government of Canada announced an investment in a new technology to reduce industrial GHG emissions by converting CO_2 into commercial products. The Algal Carbon Conversion Pilot Project will use algae to recycle industrial CO_2 emissions from an oil sands facility into commercial products, such as biofuels. According to the Government of Canada, the three-year joint project has the potential to transform how industrial CO_2 emissions in the oil sands and other industrial facilities are managed. A demonstration-scale algal refinery will be established later this year at Canadian Natural's Primrose South oil sands site in Alberta. Industrial emissions will be recycled at the facility by using CO_2 to grow algal biomass, which will undergo further processing into products such as biofuels, livestock feed, and fertilizer. From *National Research Council Canada News Release* on May 10, 2013.

"Research on Geological Storage of CO_2 to Reduce Greenhouse Gas Emissions." The Engineering and Physical Sciences Research Council (EPSRC) has awarded [~$5 million] to four research projects to study the geologic viability and safety of underground CO_2 storage in North Sea oil and gas fields or saline formations. The EPSRC funding is part of the Research Council's UK Energy Program and all four projects are part of the UK CCS Research Center. The Parliamentary Committee on Climate Change identified CCS as a key technology to aid the UK government in meeting the goals of the Climate Change Act of 2008, which committed them to reduce GHG emissions by 80 percent by 2050. The UK has a four-year, cross-government CCS research, development, and innovation program funded by the UK Department of Energy and Climate Change (DECC), the Technology Strategy Board (TSB), the Energy Technologies Institute, and the Research Councils. More information on the four research projects is available via the link. From *EPSRC Press Release* on June 7, 2013.

July 2013

"Chaparral Energy Begins CO_2 Injection at Enhanced Oil Recovery Project in Historic North Burbank Oil Field." Chaparral Energy Inc. has begun injecting CO_2 into the North Burbank CO_2 EOR Project. The EOR project involved the installation of a CO_2 gathering facility at a fertilizer plant in Coffeyville, Kansas; the laying of an 8-inch, 68-mile CO_2 pipeline; and the construction of field infrastructure facilities for CO_2 injection into the North Burbank Unit (NBU). Chaparral expects to recover an additional 88 million barrels of oil from the NBU in Osage County, Oklahoma, which has already produced more than 319 million barrels. The CO_2 is captured by a 23,500-horsepower compressor station in Coffeyville, and is then pumped through the pipeline to the NBU for underground injection into a reservoir. From *Market Watch* on July 1, 2013.

"New Drive for Australian Carbon Reduction Research." A network of research facilities was announced by the Australian Resources and Energy Minister to increase Australian development of commercial-scale CCS. The Cooperative Research Center for Greenhouse Gas Technologies (CO2CRC) is eligible for funding from the Australian Government's Clean Energy Future package, which is administered by the Education Investment Fund (EIF), to support the CCSNET network – a network

made up of field facilities, onshore and offshore monitoring systems, and laboratories. While CCSNET will primarily support Victoria's CarbonNet Project, its facilities will also be made available for other Australian projects and, potentially, international collaborators. From *CO2CRC Media Release* on July 3, 2013.

"Carbon Storage Database Launched for CCS Developers." The United Kingdom CO_2 Storage Evaluation Database, CO_2 Stored, is now available via the British Geological Survey (BGS) and The Crown Estate. This site is based on the database produced in the United Kingdom Storage Appraisal Project, which was commissioned and funded by the Energy Technologies Institute (ETI). Through this website, users can view and investigate more than 500 potential CO_2 storage sites around offshore United Kingdom., The Crown Estate and BGS will develop and update CO_2 Stored from 2013 to 2018 to improve the data and functionality of the original database according to the needs of stakeholders. From *co2stored.co.uk* on June 19, 2013.

"New Heriot-Watt labs Take Global Approach to a Global Problem: Center for Innovation in Carbon Capture and Storage Set Up." Heriot-Watt University has opened a new research center, called the "The Center for Innovation in Carbon Capture and Storage," (CICCS) that allows researchers to study carbon capture technologies and how to transport, securely store, and develop CO_2 for future use. The facilities accommodate a team of 15 researchers. Research projects will investigate ways to make carbon capture cost-efficient for producers of CO_2 and understand the fate of the long-term storage of CO_2 in geologic formations under the seabed. Heriot-Watt University is one of the three partners in Scottish Carbon Capture & Storage (SCCS), a research partnership that also includes BGS and the University of Edinburgh. Prof Maroto-Valer is a member of the SCCS Directorate. From *Scottish Carbon Capture & Storage* News Release on June 18, 2013.

"Malaysian Tapis Oil Field EOR Project Set to Start Up End 2013: ExxonMobil." According to ExxonMobil's Malaysian subsidiary, the Tapis EOR project, which will help sustain the current production level, is expected to start up by the end of 2013. In 2009, ExxonMobil and Malaysia's state-owned Petronas signed a production-sharing contract (PSC) for further development of several fields located offshore Malaysia. According to the terms of the PSC, ExxonMobil and Petronas committed to spending $2.1 billion on EOR project work, the rejuvenation of facilities, and further development and drilling activities aimed at sustaining the current production level. Since production began in 1978, approximately 400 million barrels of oil have been produced. From *Platts* on July 10, 2013.

August 2013

"National Grid Completes Test Drilling for North Sea Carbon Dioxide Storage." National Grid has completed test drilling of a CO_2 storage site in the North Sea and early indications are that the undersea site, 40 miles off the Yorkshire coast, is viable for storing CO_2 and could store approximately 200 million metric tons. The site is located close to a number of power stations, oil refineries, and industrial plants in the Humber region, which create nearly a tenth of the United Kingdom's CO_2 emissions. National Grid officials said that the organization could use its experience with gas pipelines to create a network to transport CO_2 to a storage site. From *The Herald Scotland* on August 8, 2013.

"Magellan Petroleum Initiates CO_2-EOR Pilot at Poplar Dome, Montana." Magellan Petroleum Corporation announced that permits have been obtained from the U.S. Bureau of Land Management to drill five wells on its leases at Poplar Dome in Roosevelt County, Montana. The permits are the final regulatory requirement prior to commencing drilling operations for the previously announced CO_2-enhanced oil recovery (EOR) pilot program. Magellan Petroleum Corporation also announced a CO_2 supply contract with Air Liquide Industrial U.S. LP for the CO_2 for approximately two years. The project is intended to increase production and validate the reserves potential of EOR. The company has begun drill site preparation work and drilling is expected to occur in the August to November 2013 timeframe. The

current plan is to arrange the five pilot wells in a "five-spot" pattern, with a single CO_2-injection well in the center surrounded by four producing wells. All five wells will be vertical and drilled to a depth of approximately 5,800 feet with CO_2 injection expected to commence in October 2013. Following the first injection, the company expects it will take in the range of 12 to15 months to evaluate the effectiveness of CO_2-EOR and announce results. Magellan Petroleum Corporation is an independent oil and gas exploration and development company focused on the development of a CO_2-EOR program at Poplar Dome in eastern Montana. From *Magellan Petroleum Corporation* on August 12, 2013.

"University of Newcastle Wins $290,000 for Low Emissions Coal Research." A University of Newcastle team received a $290,000 grant from the Australian Low Emission Coal R&D (ANLEC R&D) agency to continue their research of low-emissions coal technologies. The research addresses oxyfuel, which is fossil fuel burnt in the presence of pure oxygen. Oxyfuel is one of three CCS technologies in development and has the ability to reduce carbon emissions from an operating power station by up to 90 percent. A project official said the technology will be tested at the Callide Power Station in Queensland. From *University of Newcastle Newsroom* on August 7, 2013.

"UW Enhanced Oil Recovery Research Lab Targets Stranded Reserves." The University of Wyoming's new Enhanced Oil Recovery Research Laboratory in its Energy Innovation Center is expected to help small oil operators in Wyoming retrieve 5 to 15 percent of the state's stranded oil through enhanced recovery methods. During 2011, approximately 14 percent of Wyoming's oil was produced using CO_2-EOR. According to the director of the University of Wyoming's Enhanced Oil Recovery Institute (EORI), infrastructure already exists at older fields, although some locations would need retrofitted to meet safety standards. The Enhanced Oil Recovery Research Laboratory provides researchers the ability to determine the types of rock and fluids that make up the reservoirs. Researchers can use the geographic information to create models of reservoirs; create descriptions of reservoirs and generate state-of-the-art, three-dimensional visualizations of the subsurface; experiment with cores in oil and water to see how the cores behave and fluids flow through them; and develop simulations to determine how the various EOR technologies work. From *University of Wyoming News Release* on August 8, 2013.

Science

September 2012

***UPI.com*, "Australia's Fish React to Climate Change,"** and ***ABC News*, "Climate Change Sees Tropical Fish Arrive in Tasmania."** According to a new report by CSIRO, some of Australia's fish species are moving southward due to warmer waters. More than 80 Australian marine scientists from 34 universities and research organizations contributed to the report, titled, "2012 Marine Climate Change in Australia Report Card," which also found that potential climate change is potentially causing a decline in some temperate fish stocks and that ocean acidification is beginning to affect shellfish. While some species found in tropical and temperate waters are relocating, researchers also discovered that some tropical fish species are better able to adjust to rising water temperatures than previously thought. To view the CSIRO report, click: http://www.oceanclimatechange.org.au/content/images/uploads/Marine_Report_Card_Australia_2012.pdf. August 17, 2012, http://www.upi.com/Business_News/Energy-Resources/2012/08/17/Australias-fish-react-to-climate-change/UPI-43531345225788/, and August 17, 2012, http://www.abc.net.au/news/2012-08-17/climate-change-sees-tropical-fish-head-south/4203830?section=tas.

***Science Daily*, "How Sea Otters Can Reduce CO_2 in the Atmosphere: Appetite for Sea Urchins Allows Kelp to Thrive."** A new study by UC Santa Cruz researchers suggests that a thriving sea otter population that feeds on sea urchins will allow kelp forests to flourish. Through photosynthesis, the kelp can absorb as much as 12 times the amount of CO_2 from the atmosphere than if it were subject to sea

urchins, the study finds. The paper, published in "Frontiers in Ecology and the Environment," combines 40 years of data on otters and kelp bloom from Vancouver Island to the western edge of Alaska's Aleutian Islands, resulting in the conclusion that otters affect the cycle of CO_2 storage. The research found that when otters are around, sea urchins hide in crevices and eat kelp; with no otters around, sea urchins graze on living kelp. The authors state that the restoration and protection of otters is an example of how managing animal populations can affect ecosystems abilities to store carbon. September 7, 2012, http://www.sciencedaily.com/releases/2012/09/120907161437.htm.

October 2012

***ScienceDaily*, "Greenhouse Gas Emissions Mapped to Building, Street Level for U.S. Cities."** Researchers from Arizona State University have developed a new software system capable of estimating greenhouse gas (GHG) emissions across entire urban landscapes. Scientists previously quantified CO_2 at a much broader level, but the new software system, presented in an October article in "Environment Science and Technology," allows for the estimating of GHG emissions down to the roads and individual building level. The system combines public database "data-mining" with traffic simulation and building-by-building energy-consumption modeling, generating high-resolution maps that identify CO_2 emission sources that can be utilized by policymakers and understood by the public. Data from a wide variety of sources – such as local emission reports, traffic counts, and tax assessor parcel information – was collected by the research team and combined within a modeling system for quantifying CO_2 emissions at the level of individual buildings and street segments. To date, the new system has been applied to Indianapolis, with work ongoing for it also to be applied in Los Angeles and Phoenix; researchers hope to map the CO_2 emissions in all major cities across the United States. Named "Hestia" after the Greek goddess of the hearth and home, the new system is part of larger effort that combines information on emissions with ground- and satellite-based measurements of atmospheric CO_2 concentration. October 9, 2012, http://www.sciencedaily.com/releases/2012/10/121009121603.htm.

***The Engineer*, "Material Could Lead to Cheaper Methods of CO_2 Capture."** Nottingham University researchers have developed an aluminum-based solid material with the potential of leading to cheaper, more efficient, and environmentally friendly methods of capturing CO_2. The material, known as NOTT-300, absorbs CO_2 and sulfur dioxide (SO_2) in a different way to materials used in existing carbon capture and storage technologies. Made with water and simple organic substances, NOTT-300 releases the captured gases while requiring less energy than conventional materials. NOTT-300 will next be tested with actual flue gas, as opposed to controlled laboratory substances, so that it can eventually be scaled-up for potential use in carbon capture and storage technology. The research, which appears in the journal "Nature Chemistry," was funded by the Engineering and Physical Sciences Research Council (EPSRC). September 24, 2012, http://www.theengineer.co.uk/sectors/energy-and-environment/news/material-could-lead-to-cheaper-methods-of-co2-capture/1013998.article.

November 2012

***CO2CRC Media Release*, "New Material Uses Trapdoors to Capture Carbon Dioxide."** Researchers from the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) have developed a new material capable of separating CO_2 from other gases. The material, a synthesized chabazite zeolite, uses a molecular "trapdoor" to separate molecules based on their properties rather than their size. The new material can separate the CO_2 from gas streams at a wide range of temperatures and pressures, and also has the potential to separate it from power station flue gases and natural gas production. The team of researchers included input from the Commonwealth Scientific and Industrial Research Organization (CSIRO), the Department of Materials Engineering and Mechanical Engineering at Monash University, and the Australian Synchrotron. The journal paper is available at: http://pubs.acs.org/doi/abs/10.1021/ja309274y. November 9, 2012, http://www.co2crc.com.au/dls/media/12/Trapdoor%20Capture.pdf. (Subscription may be required).

***Phys.Org*, "Dinosaur-Era Acoustics: Global Warming May Give Oceans the 'Sound' of the Cretaceous."** According to new research, potential climate change could be giving the Earth's oceans the same hi-fi sound qualities they possessed during the Dinosaurs Era more than 100 million years ago. The acidity of the ocean, and in turn the acoustical properties of sea water, is directly affected by global temperatures. The new research predicts that potential climate change will acidify saltwater sufficiently enough by 2100 that low-frequency sound near the ocean surface will travel significantly farther (possibly twice as far) than current levels permit. The data was built on investigations by other researchers, who reconstructed ocean acidity for the past 300 million years by analyzing historic levels of boron in seafloor sediments. The researchers were then able to predict the soundscape of ancient oceans to conclude the low-frequency sound transmission in the ocean 300 million years ago was similar to conditions today. They also found that as the ocean became more acidic, transmission improved, reaching its largest transmission value approximately 110 million years ago, allowing low-frequency sound to travel twice as far. October 18, 2012, http://phys.org/news/2012-10-dinosaur-era-acoustics-global-oceans-cretaceous.html.

December 2012

***The Canadian Press*, "Pine Beetles Contributing to Climate Change, Study Says."** According to research conducted by scientists from the University of Toronto, the widespread population of mountain pine beetles could be contributing to potential climate change. Published in the journal "Nature Geoscience," the research shows that the warming climate has allowed the beetle to spread into forests that had previously been too cold for their survival; specifically, the data showed that the tree-killing bugs have spread over approximately 20 percent of the total area of British Columbia over the last decade. To gauge its effect on the regional climate, researchers studied the results of turning approximately 60,000 square miles of green forest into grey, leafless stands of dead trees. By using temperature data from satellites, they concluded that, on average, beetle-ravaged forests were one degree warmer than healthy forests during summer months. November 25, 2012, http://www.ctvnews.ca/sci-tech/pine-beetles-contributing-to-climate-change-study-says-1.1053055.

***Sheffield University News Release*, "Innovative Project Set to Use Cosmic Rays Detectors to Map Out Carbon Storage Volumes."** Geoscientists, particle physicists, and engineers are collaborating on a bid to develop a novel technique using cosmic rays for monitoring CO_2 storage sites. The researchers will work together to examine the potential of using subatomic particles from cosmic rays (known as muons) that cascade from the upper atmosphere and penetrate rock deep underground; the developed devices will be tested at Boulby mine, on the edge of the North Yorkshire moors. The detection of cosmic ray muons can measure the ongoing CO_2 levels in any potential carbon store by mapping the density profile of the material above the detectors. Current monitoring technology typically involves the collection of seismic data, enabling snapshots of CO_2 storage levels to be taken over time; muon tomography offers the chance to develop a continuous, passive monitoring system for deep subsurface storage sites. Alongside matched funding from industry, DECC is providing funding for the monitoring project. November 21, 2012, http://www.sheffield.ac.uk/news/nr/particle-physics-carbon-dioxide-lee-thompson-muons-cosmic-rays-1.226552.

January 2013

***Science Daily*, "Researchers Find First Evidence of Ice Age Wolves in Nevada."** Researchers from the University of Nevada, Las Vegas, have unearthed fossil remains from a dire wolf (an extinct, Ice Age wolf species) in northwest Las Vegas, revealing the first evidence that the mammal once lived in Nevada. The fossil, which geologists estimate to be in the range of 10,000 to 15,000 years old, was discovered near the proposed Tule Springs Fossil Beds National Monument, an area known for Ice Age animal remains. The dire wolf is a larger relative of the gray wolf, and was present in North and South America

for more than 1 million years; scientists believe the Ice Age mammal's extinction was due to competition from other wolf species and potential food scarcity approximately 10,000 years ago. December 13, 2012, http://www.sciencedaily.com/releases/2012/12/121213181107.htm.

***ClimateWire*, "Warmest Year Ever Recorded in Lower 48 States Came in 2012."** According to the National Oceanic and Atmospheric Administration, 2012 was the warmest year ever recorded in the contiguous United States, as the average temperature in the lower 48 states reached 55.3 degrees Fahrenheit. This temperature was more than the previous record set in 1998 by one degree. The contiguous United States endured a record warm spring, its second warmest summer, fourth warmest winter, and an above average autumn. The government's temperature records for the contiguous United States date back to 1895. In addition, the research revealed that 2012 was the United States' second most extreme weather year on record, according to the U.S. Climate Extremes Index. The U.S. Climate Extremes Index tracks extreme weather activity by monitoring extremes of temperature and precipitation and tropical cyclones that make landfall. Finally, the researchers also stated that the global average temperature for 2012 appears to be the eighth warmest year in a record that goes back to 1880. January 9, 2013, http://www.eenews.net/climatewire/2013/01/09/2. (Subscription may be required.)

February 2013

"Earliest Blooms Recorded in [United States] Due to Global Warming." According to a new study, plants in the eastern United States produced flowers earlier in 2010 and 2012 than at any point in recorded history. The study, published in the journal "PLoS ONE," compared modern record-breaking high spring temperatures in Massachusetts and Wisconsin during 2010 and 2012 with historical bloom times in the same areas from as far back as 1852. The data showed that many spring-flowering plants were triggered by the two recent warm spells to blossom up to 4.1 days earlier for every one degree Celsius rise in average spring temperatures (2.3 days for every one degree Fahrenheit). From *National Geographic News* on January 16, 2013.

"Climate Change to Profoundly Affect the Midwest, New Report Says." A recently released draft National Climate Assessment report claims that potential climate change may lead to more frequent and more intense heat waves throughout the Midwest. In addition, the draft report, the development of which was overseen by the National Climate Assessment and Development Advisory Committee (NCADAC), also claims that air and water quality could degrade and intense rainstorms and floods could become more common. The draft report assesses key impacts in every region of the United States, analyzing its effects on human health, water, energy, transportation, agriculture, forests, ecosystems, and biodiversity. The draft report is available for download on the NCADAC website; public comments are being accepted through April 12, 2013. From *University of Michigan News Release* on January 18, 2013.

"Wolverines Threatened By Climate Change, Officials Propose Endangered Species Act Protection" and **"Climate Change Threatens Wolverines; Protections Proposed."** Federal wildlife officials have proposed Endangered Species Act protections for the wolverine throughout the contiguous United States. There are approximately 250 to 300 wolverines clustered in small, isolated groups located primarily in the Northern Rockies of Montana, Idaho, Wyoming, and Washington; larger populations exist in Alaska and Canada. According to scientists, potential warmer temperatures could lead to declines in the deep-mountain snows that female wolverine require to establish dens and raise their young. According to the U.S. Fish and Wildlife service, potential climate change, which would cause earlier spring melt, could also reduce the wolverine habitat in the contiguous United States by 31 percent over the next 30 years and 63 percent over the next 75 years. The proposed protections would eliminate wolverine trapping, which is still legal in Montana, and could allow reintroduction of the species to alpine regions where it is not currently found. From *The Huffington Post* on February 1, 2013, and *Los Angeles Times* on February 1, 2013.

March 2013

"Lizards Facing Mass Extinction from Climate Change." According to recently published research, dozens of lizard species could become extinct within the next 50 years due to potential climate change. Specifically, the study, which appears in the scientific journal "Global Ecology and Biogeography," suggests that lizards with viviparous reproduction (retention of embryos within the mother's body) are being threatened as global temperatures increase. Researchers investigated the hypothesis that historic invasions of cold climates by Liolaemus lizards have only been possible due to their evolution to viviparity (live birth) from oviparity (laying eggs). It was discovered that once the lizards evolve to viviparity, the process is irreversible and they remain restricted to cold climates. Thus, through analysis, scientists discovered that increasing temperatures in the species' historically cold habitats could result in a reduction of their areas of distribution. As a result, viviparous lizards may face potential extinction in the next few decades if global temperatures continue to rise at the same rate. From *ScienceDaily* on March 6, 2013.

"Climate Change Could Affect Monarch Butterfly's Migration, Study Says."According to a study published in the journal "Current Biology," global climate change could have an impact on the migration pattern of the monarch butterfly. Researchers found that monarch butterflies, which fly 2,000 miles south from North America to Mexico every fall and back again in the spring, would keep flying south if they did not feel winter weather. Researchers said that without a thermal stimulus, the annual migration cycle would be broken. In a previous study, the researchers revealed the butterflies use skylight cues and an internal compass to guide them in their migration south, and the new study found these navigation tools also help the butterflies return north. In order to determine what causes the monarchs to change direction, researchers captured a sample of butterflies as they were about to begin their fall migration south. These butterflies then experienced the same changes in temperature and light they would experience naturally in the Mexican mountains, except in a laboratory. After 24 days in the laboratory, the butterflies were released and headed north and not south, but the butterflies that were captured and kept warm continued to fly south. The study's authors confirmed the change in the monarch's direction was because of the cold temperatures, not day length. From *U.S. News & World Report* on February 21, 2013.

April 2013

"Computer Models Show How Deep Carbon Could Return to Earth's Surface." Researchers at the University of California, Davis, and John Hopkins University are using computer simulations of water under extreme pressure to gain a better understand how CO_2 might be recycled from hundreds of miles below Earth's surface. Replicating the conditions of water in Earth's mantle – pressures up to hundreds of tons per square inch and temperatures higher than 2,500°F – has been difficult according to geochemists, as they have lacked the dielectric constant, which determines how easily minerals dissolve in water. The research, published in the journal "Proceedings of the National Academy of Sciences," used computer simulations to predict how the water behaves under extreme pressures and temperatures, and showed that the dielectric constant changes significantly. Researchers then combined that with existing models, leading to a prediction that magnesium carbonate, which is insoluble at Earth's surface, would at least partially dissolve in water at that depth. From *ScienceDaily* on March 18, 2013.

"Sea Urchins Cope with Rising CO_2 Levels." According to a paper published in "Proceedings of the National Academy of Sciences," sea urchins can adapt to high CO_2 levels caused by potential climate change. Increasing atmospheric CO_2 levels can lead to oceans becoming more acidic, posing a threat to marine organisms with calcium carbonate shells (such as sea urchins) that corrode due to the acid. When exposed to high levels of CO_2, however, sea urchins experience changes in genes that affect their survival in an acidic environment. For the study, scientists collected adult purple sea urchins, due to their high levels of genetic variability, from the North American Pacific coast – a region that often experiences

CO_2-rich water. Scientists then fertilized eggs from the females and raised the produced larvae in conditions of either ambient acidity (atmospheric CO_2 levels of 400 parts per million [ppm]) or elevated acidity (atmospheric CO_2 levels of 900 ppm, matching expected concentrations in the year 2100). Gene sequencing showed that the high-CO_2 group experienced changes in genes related to mineral growth, lipid metabolism, and ion homeostasis, all of which affect the ability to cope with high acid levels. From *PhysOrg* on April 9, 2013.

May 2013

"Climate Change Compounds Rising Threats to Koala." According to the Australian Koala Foundation (AKF), the koala population has dropped approximately 40 percent in Queensland and approximately 33 percent in New South Wales due to a shrinking of their habitat from potential climate change. According to AKF estimates, there are 45,000 to 90,000 koalas left in the wild. Native only to Australia, the koalas derive much of their moisture needs from eucalyptus leaves. Climate scientists warn that forecasts of longer dry periods, rises in temperature, and severe droughts could pose a risk to the creature's habitat and could affect the "nutrition quality and moisture content" of leaves. From *Guardian Environment Network* on April 30, 2013.

"Earth's Greenhouse Gas Levels Approach 400-ppm Milestone." According to the Scripps Institution of Oceanography at UC San Diego, the ratio of CO_2 in Earth's atmosphere is approaching 400 parts per million (ppm), which would be the highest level in 2.5 million to 5 million years. A Keeling curve update launched by Scripps in late April showed measurements from Mauna Loa, Hawaii, that could soon breach the 400-ppm level. Measurements from Mauna Loa, which is far from major emission sources, are considered the most reliable indicators of Earth's atmospheric content, according to Scripps. Over the previous 800,000 years, CO_2 levels have not exceeded 300 ppm; the CO_2 level was approximately 280 ppm during the Industrial Revolution. According to Scripps, there is no known geologic period in which rates of increase have been so apparent. From *Los Angeles Times* on May 1, 2013.

"NASA Study Projects Warming-Driven Changes in Global Rainfall." A modeling study conducted by NASA has discovered new evidence that potential climate change may increase the risk for extreme rainfall and drought, showing for the first time that a rise in CO_2 concentrations could affect rainfall types on Earth. The study analyzed 14 climate model computer simulations that indicated wet regions of the world would see increases in heavy precipitation, and many land areas outside the tropics could become drier, due to the potential warming of the climate from projected increases in CO_2 levels. For every degree Fahrenheit of CO_2-induced warming, the models project heavy rainfall to increase by 3.9 percent, light rain to increase by one percent, and the length of periods without rain to increase by 2.6 percent (all globally). According to the study, which was accepted for publication in the American Geophysical Union journal "Geophysical Research Letter," areas projected to see an increase in heavy rainfall are in the tropical zones around the equator; areas most likely to be affected by drought include the deserts and arid regions. From *NASA News Release* on May 3, 2013.

June 2013

"Mount Everest's Glaciers Shrinking at Increasing Rate, Say Researchers." According to a University of Milan study, glaciers on or around Mount Everest have shrunk by 13 percent in the last 50 years. The Nepali researchers also found that the ends of glaciers around the peak have retreated by an average of 400 meters since 1962, and some smaller glaciers (less than a square kilometer) have seen a 43-percent decline in surface area since the 1960s. Data was gathered by using satellite imagery of the peak and the 713-mi^2 Sagarmatha national park around the mountain, as well as long-term meteorological data. From *The Guardian* on May 23, 2013.

"Climate Change Threatens 82 [Percent] of Native California Fish." According to a new study, four out of five of California's native freshwater fish will likely be driven to or near extinction within 100 years if climate change continues at its current pace. Of the 121 native fish species, 82 percent will see their population shrink as their need for cool, flowing water diminishes due to rising temperatures and lessening stream flow, according to researchers at the University of California-Davis' Center for Watershed Science. By comparison, 19 percent of the state's 50 non-native fish species face similar extinction risks. The study's findings support previous research that show 80 percent of California's native fish to be ranked as "vulnerable" to possible extinction by NatureServe – a non-profit group that focuses on species conservation. The research was funded by the California Energy Resources Conservation and Development Commission Instream Flow Assessment Program. From *USA Today* on June 1, 2013.

July 2013

"Major Changes Needed For Coral Reef Survival." According to a study conducted by researchers from the Carnegie Institution for Science, a reduction in CO_2 emissions is required to prevent coral reefs from dying off. Published in the journal "Environmental Research Letters," the study claims that if the CO_2 emission trajectory continues along its current path, all existing coral reefs face inhospitable ocean chemistry conditions by the end of the century. Coral reefs are sensitive to changes in ocean chemistry that result from several conditions. Data was gathered by focusing on the acidification of open water surrounding coral reefs, and how it affects the reef's ability to survive. Using results from simulations that were conducted using a collection of models, researchers calculated ocean chemical conditions that would occur under different future scenarios, determining whether these chemical conditions could sustain coral reef growth. According to the results, chemical conditions that can support coral reef growth can only be sustained with a reduction in CO_2 emissions. From the *Carnegie Institution for Science* on June 28, 2013.

"Climate Change Threatens Iberian Lynx." According to British researchers, the Iberian lynx could be extinct within the next 50 years unless steps are taken to address climate change and the impacts on prey. Published in the journal "Nature Climate Change," the study claims that the population decline of the Iberian lynx – the world's most endangered cat species – is related to a decline in the European rabbit. In addition, the researchers expect the habitat to become less hospitable. According to the study, there are approximately 250 Iberian lynx currently living in two communities in the wild; in the 1990s, there were nine communities. From *CBS News* on July 22, 2013.

August 2013

"Climate Change, Ticks Claiming Moose in New Hampshire." Biologists believe that climate change is affecting moose in New Hampshire due to winter ticks and other parasites. Specifically, the shorter winters are impacting moose because if the weather stays too warm, tick numbers remain high. A recent paper reveals that the number of winter ticks is related to fall and spring weather. If those seasons are mild and snowless, ticks can thrive. The winter ticks attach to the moose, mate, and lay eggs; the cycle repeats unless the state gets a long, cold winter. In the recent issue of New Hampshire Wildlife Journal, a biologist reported that the average number of winter ticks on a single moose in Alberta, Canada, is 32,000, but can rise as high as 150,000. New Hampshire approved a four-year study of the state's moose population to put radio collars on 80 to 100 moose and track their reproduction and mortality rates; the results of the study will help the state develop a moose management plan. Similar trends in moose population are being seen in Minnesota and Maine. From *Concord Monitor* on July 28, 2013.

"Young or Old, Song Sparrows Experience Climate Change Differently from Each Other." According to two recent studies, young and old song sparrows are experiencing the effects of climate change in different ways. In one study, the research shows the importance of examining the various

stages and ages of individuals in a species to understand how and why climate change could affect a whole species. Researchers found that climate change had opposite effects for adult and juvenile song sparrows in central coastal California. The researchers found that adult survival was sensitive to cold winter weather and expected a similar response from the young. However, warmer, drier winters translated to less food for the juvenile sparrows during the following summer. The research showed that juveniles have to survive their first summer and they are sensitive to how much food is available; thus, as winters get warmer, adults and juveniles respond in opposite directions. In another study, researchers found that parents provided a buffer against the weather for baby sparrows, but independent juveniles newly out on their own were more sensitive to changes in the weather because they lacked their parents' skills and experience. From *ScienceDaily* on August 12, 2013.

Policy

September 2012

***National Geographic News Watch*, "Singapore Issues National Climate Change Strategy."** Singapore has published its national climate change strategy, reflecting its efforts to prepare for potential climate change and support the transition to a lower emission economy. Singapore, the newest addition to the global C40 Cities Climate Leadership Group, is focused on adapting to impacts of potential climate change through integrated land use planning, water management, and investment in research and infrastructure. Singapore is also studying the reduction of its emissions by building on current efforts, as well as the long-term stabilization of its emissions. The report, titled, "Climate Change & Singapore: Challenges. Opportunities. Partnerships.," indicates that these efforts have delivered results, with Singapore ranking 123rd out of 137 countries in emissions per gross domestic product (GDP). To read Singapore's full climate change strategy, visit: http://app.nccs.gov.sg/data/resources/docs/Documents/NCCS-2012.pdf. August 16, 2012, http://newswatch.nationalgeographic.com/2012/08/16/singapore-issues-national-climate-change-strategy/.

"Long-Term Energy and Climate Implications of Carbon Capture and Storage Deployment Strategies in the [U.S.] Coal-Fired Electricity Fleet." The following is the Abstract of this article: "To understand the long-term energy and climate implications of different implementation strategies for CCS in the [U.S.] coal-fired electricity fleet, [the authors] integrate three analytical elements: scenario projection of energy supply systems, temporally explicit life cycle modeling, and time-dependent calculation of radiative forcing. Assuming continued large-scale use of coal for electricity generation, [the authors] find that aggressive implementation of CCS could reduce cumulative [GHG] emissions (CO_2, [methane (CH_4)], and [nitrous oxide (N_2O)]) from the [U.S.] coal-fired power fleet through 2100 by 37–58 [percent]. Cumulative radiative forcing through 2100 would be reduced by only 24–46 [percent], due to the front-loaded time profile of the emissions and the long atmospheric residence time of CO_2. The efficiency of energy conversion and carbon capture technologies strongly affects the amount of primary energy used but has little effect on [GHG] emissions or radiative forcing. Delaying implementation of CCS deployment significantly increases long-term radiative forcing. This study highlights the time-dynamic nature of potential climate benefits and energy costs of different CCS deployment pathways and identifies opportunities and constraints of successful CCS implementation." **Roger Sathre and Eric Masanet**, *Environ. Sci. Technol.*, Available online August 2, 2012, doi:10.1021/es3006332, http://pubs.acs.org/doi/abs/10.1021/es3006332. (Subscription required).

"The Canadian oil sands industry under carbon constraints." The following is the Abstract of this article: "[The authors] investigate the impact of climate policies on Canada's oil sands industry, the largest of its kind in the world. Deriving petroleum products such as gasoline and diesel from oils sands involves significant amounts of energy, and that contributes to a high level of CO_2 emissions. [The authors] apply the MIT Emissions Prediction and Policy Analysis (EPPA) model, a computable general

equilibrium model of the world economy, augmented to include detail on the oil sands production processes, including the possibility of CCS. [The authors] find: (1) without climate policy, annual Canadian bitumen production increases almost [four]-fold from 2010 to 2050; (2) with climate policies implemented in developed countries, Canadian bitumen production drops by 32 [percent] to 68 [percent] from the reference [four]-fold increase, depending on the viability of large-scale CCS implementation, and bitumen upgrading capacity moves to the developing countries; (3) with climate policies implemented worldwide, the Canadian bitumen production is significantly reduced even with CCS technology, which lowers CO_2 emissions at an added cost. This is mainly because upgrading bitumen abroad is no longer economic with the global climate policies." **Gabriel Chan, John M. Reilly, Sergey Paltsev, Y.-H. Henry Chen**, *Energy Policy*, Available online August 17, 2012, doi:10.1016/j.enpol.2012.07.056, http://www.sciencedirect.com/science/article/pii/S0301421512006507. (Subscription may be required.)

October 2012

***Reuters*, "California Governor Signs Cap-and-Trade Revenue Bills."** The Governor of California signed two bills related to the use of revenue raised through the sale of carbon allowances. Although details of how the money will be spent will not be determined until next year, the bills are the first to address the revenue generated during the first year of California's carbon cap-and-trade scheme, which begins in January 2013. A new account for the revenue will be created with the first bill, which also directs the Department of Finance and the California Air Resources Board to develop an investment plan for the funds. That plan will be submitted to the legislature for approval as part of the governor's budget, and will be reviewed and updated on an annual basis; it is expected to be released in the spring of 2013. Under the second bill, 25 percent of the auction revenue is required to go toward economically disadvantaged communities, with the California Environmental Protection Agency tasked with determining which communities qualify. Under California state law, money raised through the sale of carbon allowances must be spent on programs that help reduce the state's GHG emissions. The first carbon allowance auction will offer 61.3 million allowances for sale. October 2, 2012, http://www.reuters.com/article/2012/10/02/us-california-carbon-idUSBRE89108C20121002?feedType=RSS&feedName=domesticNews.

"Promoting global CCS RDD&D by stronger U.S.-China collaboration." The following is the Abstract of this article: "CCS is the only technology available to mitigate GHG emissions from large-scale fossil fuel usage. [The United States] and China are the world's largest GHG emitters. Collaboration between the two nations, therefore, offers the greatest opportunity for achieving meaningful reductions in global GHG emissions. Two countries' current cooperation on CCS through Clean Energy Research Center based on the U.S.–China Strategic Forum on Clean Energy Cooperation mechanism provides an important initial step towards even closer and stronger cooperation in the future. In this paper, [the authors] justify such possibility by discourse on the seemly different but complementary social–political context in two countries including political system, government structure, economic policy, national innovation system, energy strategy, and energy market structure. [The authors] further address the key elements of future cooperation model by carefully considering the principle of equality and mutual beneficiary, the role of two countries in the whole value chain according to their comparative advantages, and the scale and mechanism of the funding. A milestone for the cooperation until 2030 is drafted and priority areas for both countries in the cooperation are identified. Such cooperation will provide the imperative leadership for global climate change and speed up the global CCS deployment." **Jia-Hai Yuan and Thomas P. Lyon**, *Renewable and Sustainable Energy Reviews*, Available in December 2012 edition, doi:10.1016/j.rser.2012.08.014, http://www.sciencedirect.com/science/article/pii/S1364032112004832. (Subscription may be required.)

November 2012

***BusinessWeek*, "European Union to Propose 2030 Climate Framework by 2014."** By 2014, the European Union (EU) plans to propose a framework for reducing GHGs until 2030 to ensure the regulatory stability necessary for investment in clean technologies. According to the European Commission, the proposal will provide long-term perspective on how the EU will continue to move toward a low-carbon economy from its binding goal of cutting emissions by 20 percent in 2020 compared with 1990 levels and its political target of reducing GHGs by 80 percent to 95 percent in 2050. The planned 2030 framework for climate also has the potential to impact emission caps in the EU Emissions Trading System (EU ETS), which imposes emission caps on approximately 12,000 utilities and manufacturing companies in the region. October 23, 2012, http://www.businessweek.com/news/2012-10-23/european-union-to-propose-2030-climate-framework-by-2014.

"A Multiobjective Optimization Approach for CCS Infrastructure Considering Cost and Environmental Impact." The following is the Abstract of this article: "In this study, [the authors] address the design of a carbon capture and storage infrastructure with economic and environmental concerns. Given a set of available technologies to capture, [store], and transport CO_2, the problem consists of determining the optimal planning of the [carbon capture and storage] infrastructure capable of satisfying a predefined CO_2 reduction target. The planning task is formulated as a multiobjective mixed-integer linear programming (moMILP) problem, which simultaneously accounts for the minimization of cost and environmental impact. The environmental impact is measured through all contributions made by operation and installation of the [carbon capture and storage] infrastructure. The emissions considered in the environmental impact analysis are quantified according to the principles of Life Cycle Assessment (LCA), specifically the Eco-indicator 99 method. The multiobjective optimization problem was solved by using the ε-constraint method. The capability of the proposed modeling framework is illustrated and applied to a real case study based on Korea, for which valuable insights are obtained." **Jae-Uk Lee, Jee-Hoon Han, and In-Beum Lee**, *Ind. Eng. Chem. Res.*, Available online October 10, 2012, doi:10.1021/ie3009583, http://pubs.acs.org/doi/abs/10.1021/ie3009583. (Subscription required.)

December 2012

"Assessing socio-technical mindsets: Public deliberations on carbon capture and storage in the context of energy sources and climate change." The following is the Abstract of this article: "The adaptation and transition to new configurations of energy systems brought on by challenges of climate change, energy security, and sustainability have encouraged more integrative approaches that bring together the social and technical dimensions of technology. The perspectives of energy systems and climate change play an important role in the development and implementation of emerging energy technologies and attendant policies on [GHG] reduction. This research examines citizens' views on climate change and a number of energy systems, with a specific focus on the use of CCS as a technology to address [GHG] emissions. An all-day workshop with 82 local participants was held in the city of Calgary in Alberta, Canada to explore the views of climate change, energy and CCS. Participants were provided the opportunity to ask experts questions and discuss in small groups their views of climate change policy and energy systems. Results demonstrate that participants' assessments of energy systems are influenced by social–political–institutional–economic contexts such as trust in industry and government, perception of parties benefiting from the technology, and tradeoffs between energy systems. [The authors] discuss [their] findings in the context of understanding social learning processes as part of socio-technical systems change." **Edna F. Einsiedel, Amanda D. Boyd, Jennifer Medlock, and Peta Ashworth**, *Energy Policy*, Available online November 21, 2012, doi:10.1016/j.enpol.2012.10.042, http://www.sciencedirect.com/science/article/pii/S0301421512009238. (Subscription may be required.)

January 2013

"A novel graphical approach to target CO_2 emissions for energy resource planning and utility." The following is the Abstract of this article: "Many optimization techniques, both numerical and graphical, have recently been introduced for CO_2 emissions targeting. These targeting approaches have been applied to a wide range of applications including energy allocation and utility systems optimization. However, the trade-off between the operating cost and the associated CO_2 emissions cannot be easily assessed. This paper presents a new simple graphical approach to target CO_2 emissions associated with energy resources and utility systems. The principles of marginal energy cost and marginal CO_2 emissions are employed to construct two composite curves to be used as targeting tools. The CO_2 emissions composite curve (CO2CC) and cost composite curve (CCC) are used to determine the minimum cost associated with increasing energy demand whilst simultaneously meeting a given CO_2 emissions target. Multiple trade-off solutions so called Pareto optimal solutions can be generated using a range of emissions targets. The new graphical approach can be used to target CO_2 emissions related to utility systems and energy resources networks. Two case studies are used to demonstrate this targeting method." **Mohmmad A. Al-Mayyahi, Andrew F.A. Hoadley, and G.P. Rangaiah**, *Applied Energy*, Available in April 2013 edition, http://dx.doi.org/10.1016/j.apenergy.2012.11.077, http://www.sciencedirect.com/science/article/pii/S0306261912008872. (Subscription may be required.)

"The improvement of CO_2 emission reduction policies based on system dynamics method in traditional industrial region with large CO_2 emission." The following is the Abstract of this article: "Some traditional industrial regions are characterized by high industrial proportion and large CO_2 emission. They are facing dual pressures of maintaining economic growth and largely reducing CO_2 emission. From the perspective of study of typological region, taking the typical traditional industrial region—Liaoning Province of China as a case, this study establishes a system dynamics model named EECP and dynamically simulates CO_2 emission trends under different conditions. Simulation results indicate, compared to the condition without CO_2 emission reduction policies, CO_2 emission intensity under the condition of implementing CO_2 emission reduction policies of 'Twelfth Five-Year Plan' is decreased by 11 [percent] from 2009 to 2030, but the economic cost is high, making the policies implementation faces resistance. Then some improved policies are offered and proved by EECP model that they can reduce CO_2 emission intensity after 2021 and decrease the negative influence to GDP, realizing the improvement objects of reducing CO_2 emission and simultaneously keeping a higher economy growth speed. The improved policies can provide reference for making and improving CO_2 emission reduction policies in other traditional industrial regions with large CO_2 emission. Simultaneously, EECP model can provide decision-makers with reference and help for similar study of energy policy." **Fujia Li, Suocheng Dong, Zehong Li, Shantong Li, and Yongkun Wan**, *Energy Policy*, Available in January 2013 edition, http://dx.doi.org/10.1016/j.enpol.2012.09.014, http://www.sciencedirect.com/science/article/pii/S0301421512007720. (Subscription may be required.)

February 2013

"DNV KEMA Launches New Risk Management Guidance for the CCS Industry." DNV has released new risk management guidance as a comprehensive resource for CCS projects and operations across the world. The guidance results from the CO_2 Risk Management (CO2RISKMAN) Joint Industry Project (JIP), whose goal was to develop a publicly available guidance on risk management of the CO_2 stream within CSS projects. According to DNV, the CO2RISKMAN guidance systematically presents and explains issues associated with CO_2 that need to be considered within a hazard management process. The guidance discusses potential safety and environmental hazards, their causes, escalation routes, and possible consequences. The guidance also provides assistance on hazard identification, risk assessment, and what can be done to reduce the risks down to an acceptable level during each stage of the CCS chain. The CO2RISKMAN JIP guidance complements DNV's other JIPs: CO2CAPTURE, CO2PIPETRANS, CO2WELLS, and CO2QUALSTORE; all are available for free download via the DNV

website. The guidance was developed over the course of 15 months through a JIP with support from 16 industry and regulator organizations. From *DNV Press Release* on January 31, 2013.

"Brussels Steers Towards 'Resolute' New CCS Targets by 2014." According to draft European Union (EU) communications, Europe's plans to encourage CO_2 storage could be supported by new laws for emissions performance standards or mandatory CCS certificates. If approved, the Commission would be required to prepare an impact assessment and legislative proposals "before the end of the current mandate," in 2014, so that CCS could be deployed after 2020. The performance standards mentioned in the communications could set mandatory and potentially tradable limits to emissions from energy firms. In addition, the draft communications also covered a mandatory CCS system that would align with the current Emissions Trading System (ETS). From *EurActiv.com* on January 15, 2013.

"Rep. Waxman and Sen. Whitehouse Form Bicameral Climate Change Task Force." A bicameral Task Force on Climate Change has been formed to address potential climate change. The Task Force will be dedicated to focusing Congressional and public attention on potential climate change and developing effective policy responses. The Task Force will be open to all members of Congress interested in collaborating on these issues. Meetings will be convened in the coming months to seek relevant information and to release periodic reports, memoranda, and correspondence to advance the group's goal of increasing awareness and developing policy responses to potential climate change. From *U.S. Representative Henry A. Waxman Press Release* on January 24, 2013.

"U.S. DOE's Efforts to Promote Knowledge Sharing Opportunities from R&D Efforts: Development of the U.S. Carbon Utilization and Storage Atlas and Best Practices Manuals." The following is the Abstract of this article: "Knowledge sharing among various stakeholders is essential to promote the commercialization of CCUS technologies. DOE promotes information and knowledge sharing through various avenues, including the development and distribution of Best Practices Manuals (BPMs), the development of online tools and resources, involvement in working groups on CCUS, and other public outreach and education efforts. One of NETL's main initiatives to promote information and knowledge sharing is the development of a series of BPMs that outline uniform approaches to address a variety of CCUS-related issues and challenges. A major online resource developed by DOE is the National Carbon Sequestration Database and Geographic Information System (NATCARB), which is a geographic information system (GIS)-based tool developed to provide an interactive visual representation of CCUS potential. The series of past and future carbon storage Atlases featuring the RCSPs, such as the to be released 'United States Carbon Utilization and Storage Atlas,' complements NATCARB, and contains additional information regarding commercialization opportunities for CCUS technologies from each of DOE's RCSPs. Building on past successes, NETL is expanding the NATCARB effort through the North American Carbon Atlas Partnership (NACAP) to better assess CCUS potential throughout all of North America. NETL has been actively disseminating knowledge and developing the future required workforce through training centers that are focused on training personnel for future implementation of CCUS technology." **John Litynski, Andrea McNemar, Traci Rodosta, Dawn Deel, Derek Vikara, Larry Myer, and Robert Kane**, presented at the 11th Greenhouse Gas Control Technologies Conference (GHGT-11), held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"U.S. DOE's R&D Program to Develop Infrastructure for Carbon Storage: Overview of the Regional Carbon Sequestration Partnerships and other R&D Field Projects." The following is the Abstract of this article: "The Carbon Storage Program being implemented by [DOE's FE] and managed by NETL is focused on developing technologies to capture, separate, and store CO_2 in order to reduce greenhouse gas [(GHG)] emissions without adversely affecting energy use or hindering economic growth. NETL envisions having a technology portfolio of safe, cost-effective, [GHG] capture, transport, and storage technologies that will be available for commercial deployment. The Carbon Storage Program involves three key technology development elements: (1) Core R&D, (2) Infrastructure, and (3) Global Collaborations. The integration of these elements is addressing technological and marketplace

challenges…DOE's Carbon Storage Program has positioned the United States on a path toward ensuring that these enabling technologies will be available to effect broad CCUS deployment. NETL is helping to promote widespread CCUS deployment through the Carbon Storage Program's Infrastructure element, which to date has: (1) safely and efficiently injected and stored close to more than 3 million metric tons of CO_2 across 22 active or completed field projects; (2) generated lessons learned from those field projects and documented them in best-practices manuals; (3) refined national CO_2 storage assessments through characterization field projects; and (4) trained nearly 3,000 students through the Regional Carbon Sequestration Training Centers." **John Litynski, Traci Rodosta, Derek Vikara, and Rameshwar Srivastava**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

March 2013

"DNV KEMA Launches CO2MPETENCY." DNV KEMA has launched a new knowledge management service for the CO_2 management and CCS industries to accelerate worldwide competency building. The new service supports: (1) learning in CO_2 management projects (developing and implementing lessons learning at key milestones and critical points on the project timeline); (2) learning between CO_2 management projects (enabling connections between projects and the identification, capture and sharing of good practices, joint problem solving, and exchange of lessons learned between concurrent projects); and (3) learning from CO_2 management projects (the targeted capture, validation, and dissemination of project knowledge to inform a wider community of practice and future projects). According to a DNV official, the new project learning service can help to reduce the risks by sharing how to manage the risks associated with CO_2 capture, transport, and storage and develop standards that define safe and economical industry practice. Also, the learning service can accelerate technology development through the sharing of effective practices, which can allow the CCS industry to advance more quickly through technology readiness levels in existing and new areas and build public confidence through the distribution of material about the feasibility and safety of CO_2 management strategies. The official also stated that the new service will build regulatory knowledge and address regulatory concerns while regulators learn from real industry knowledge and, in turn, provide industry with opportunities to address concerns and improve organizational efficiencies by promoting mutual problem solving. From *DNV* on February 19, 2013.

"Public perception, knowledge and policy support for mitigation and adaption to Climate Change in Costa Rica: Comparisons with North American and European studies." The following is the Abstract of this article: "Over the past 20 years considerable efforts have been invested in exploring how the public understands climate change. However, the bulk of this research has been conducted in Europe and North America and little is known about public perceptions of climate change in developing countries. This article presents the results of the first nationally representative study ($n = 1473$) of public perceptions of climate change in Costa Rica. In Costa Rica, a large proportion of interviewees (i.e. over 85 percent) are highly concerned about climate change in general and feel, as noted in European and North American studies, that its impacts are more worrisome for people farthest away (e.g. in the developed countries or among future generations). At the local level, people feel that food (10.5 percent) and water (16.1 percent) shortages as well as poverty (11.3 percent) and heat waves (11.7 percent) are the most expected impacts of climate change. Analysis of adaptation behavior responses suggest that individuals have a relatively lower grasp of emergency and prevention disaster plans but are relatively more proactive in preventing hydro-meteorological extremes related to water scarcity or excess. A majority of respondents engage in mitigation behaviors largely for financial or contextual reasons. Finally, support for adaptation and mitigation policy responses is generally high (i.e. above 70 percent of interviewee supports them) except for the case of internalizing the cost of watershed protection increasing the water tariffs (52.5 percent). As discussions about mitigation and adaptation become increasingly common within developing countries, questions about public perceptions in that context are more pressing than ever. Work on climate perceptions needs to be carried out in specific countries to better understand which policies are most likely to resonate with public support, and which might be most

difficult to implement." **R. Vignola, S. Klinsky, J. Tam, and T. McDaniels**, *Mitigation and Adaptation Strategies for Global Change*. (Subscription may be required to view article.)

"India CCS scoping study: Final report." The following is a summary of this report: "The present report has been prepared as a part of a scoping study for CCS in India carried out by The Energy and Resources Institute (TERI), with support from the Global CCS Institute. The study was conducted to identify the potential role for CCS in India's GHG mitigation strategies through an examination of issues, opportunities and barriers to the deployment of CCS. The conclusions of the report should help in drawing a roadmap for CCS implementation in India."

April 2013

"Agreement Signed to Reduce Carbon Dioxide Emissions." Edinburgh-based Scottish Carbon Capture and Storage (SCCS), the UK's largest group of CCS researchers, and Korea Carbon Capture and Sequestration R&D Center (KCRC), South Korea's leading CCS research institute, have signed a Memorandum of Understanding (MOU) to reduce CO_2 emissions. Under the strategic agreement, scientists from both countries will collaborate to develop technologies for reducing CO_2 emissions from power generation and industry. In addition to creating a framework for a joint research program, the agreement will also facilitate knowledge sharing between the two institutes and provide training opportunities for researchers in both the UK and South Korea. This MOU, which is the first such agreement to be signed between the UK and South Korean CCS researchers, will run for three years. From *Gas World* on March 24, 2013.

"Competition and environmental policies in an electricity sector." The following is the Abstract of this article: "[The authors] study the impact of competition and environmental policy (feed-in tariff vs. the [European Union Emission Trading Scheme (EU ETS)]) on investment, CO_2 emissions and welfare in an electricity sector. [The authors] consider different market structures (a planner who [maximizes] social welfare vs. duopoly) and two types of consumers (those whose [behavior] depends on the weather vs. those whose [behavior] does not). The demand specification is innovative and takes incompressible consumption into account. Given the costs and demand functions, [the authors] find that competition can increase CO_2 emissions, as is highlighted by Mansur (2007). In duopoly, the EU ETS seems to be the only efficient policy for reducing CO_2 emissions but also to increase the share of production based on renewable energy sources. The retained feed-in tariff policy seems to be the most expensive policy in terms of 'social welfare.' Even if this policy seems to increase 'social welfare,' feed-in tariffs increase the CSPE, which is paid for by consumers in the form of higher electricity prices and only benefits new entrants. It is also less effective in terms of emission reduction." **Corinne Chaton and Marie-Laure Guillerminet**, *Energy Economics*. (Subscription may be required to view article.)

"Policy options to improve the effectiveness of the EU emissions trading system: A multi-criteria analysis." The following is the Abstract of this article: "This paper considers several policy options which have been proposed to improve the functioning of the ETS. These options require an intervention either on the ETS cap (−30 [percent] target, set-aside, carbon central bank, long-term target) or on the carbon price (European and national price floor). [The authors analyze] the impact of each policy on the ETS carbon price and emissions. A multi-criteria evaluation method is applied to compare the policy options against a plurality of environmental, economic and procedural criteria. [The authors] find that the final ranking depends on the goals to be achieved, i.e., the relative weights attributed to the criteria. When policymakers want mainly to support the carbon price both in the short and long-run, while improving ETS flexibility and harmonization, the CCB and the EU price floor are, respectively ranked as first and second-best options. As the preference for environmental and implementation goals gradually increases, the position of the EU price floor and CCB options tend to invert. The −30 [percent] target should be adopted when reducing emissions is the priority goal, while a national price floor is the worst option, in this case. Nevertheless, self-interested States looking for a relatively quick, feasible solution, may find it

optimal." **Stefano Clò, Susan Battles, and Pietro Zoppoli**, *Energy Policy*. (Subscription may be required to view article.)

May 2013

"Strategic climate policy with offsets and incomplete abatement: Carbon taxes versus cap-and-trade." The following is the Abstract of this article: "This paper provides a first analysis of a 'policy bloc' of fossil fuel importers which implements an optimal climate policy, faces a (non-policy) fringe of other fuel importers, and an exporter bloc, and purchases offset from the fringe. [The authors] compare a carbon tax and a cap-and-trade scheme for the policy bloc, in either case accompanied by an efficient offset mechanism for reducing emissions in the fringe. The policy bloc is shown to prefer a tax over a cap, since only a tax reduces the fuel export price and by more when the policy bloc is larger. Offsets are also more favorable to the policy bloc under a tax than under a cap. The optimal offset price under a carbon tax is below the tax rate, while under a cap and free quota trading the offset price must equal the quota price. The domestic carbon and offset prices are both higher under a tax than under a cap when the policy bloc is small. When the policy bloc is larger, the offset price can be higher under a cap. Fringe countries gain by mitigation in the policy bloc, more under a carbon tax since the fuel import price is lower." **Jon Strand**, *Journal of Environmental Economics and Management*. (Subscription may be required to view article.)

"Human health risk assessment of CO_2 [release] into overlying [formations] using a stochastic, geochemical reactive transport approach." The following is the Abstract of this article: "Increased human health risk associated with groundwater contamination from potential CO_2 [release] into a potable [formation] is predicted by conducting a joint uncertainty and variability (JUV) risk assessment. The approach presented here explicitly incorporates heterogeneous flow and geochemical reactive transport in an efficient manner and is used to evaluate how differences in representation of subsurface physical heterogeneity and geochemical reactions change the calculated risk for the same hypothetical [formation] scenario where a CO_2 [release] induces increased Pb2+ concentrations through dissolution of galena (PbS). A nested Monte Carlo approach was used to take Pb2+ concentrations at a well from an ensemble of numerical reactive transport simulations (uncertainty) and sample within a population of potentially exposed individuals (variability) to calculate risk as a function of both uncertainty and variability. Pb2+ concentrations at the well were determined with numerical reactive transport simulation ensembles using a streamline technique in a heterogeneous 3D [formation]. Three ensembles with variances of log hydraulic conductivity (σ2lnK) of 1, 3.61, and 16 were simulated. Under the conditions simulated, calculated risk is shown to be a function of the strength of subsurface heterogeneity, σ2lnK and the choice between calculating Pb2+ concentrations in groundwater using equilibrium with galena and kinetic mineral reaction rates. Calculated risk increased with an increase in σ2lnK of 1 to 3.61, but decreased when σ2lnK was increased from 3.61 to 16 for all but the highest percentiles of uncertainty. Using a Pb2+ concentration in equilibrium with galena under CO_2 [release] conditions (PCO_2 = 30 bar) resulted in lower estimated risk than the simulations where Pb2+ concentrations were calculated using kinetic mass transfer reaction rates for galena dissolution and precipitation. This study highlights the importance of understanding both hydrologic and geochemical conditions when numerical simulations are used to perform quantitative risk calculations." **Adam L Atchley, Reed Maxwell, and Alexis Navarre-Sitchler**, *Environ. Sci. Technol*. (Subscription may be required to view article.)

June 2013

"China Agrees to Impose Carbon Targets by 2016." China has proposed to cap its GHG emissions by 2016. The proposal was made by China's National Development and Reform Commission (NDRC), which is responsible for planning China's social and economic development; the proposal still needs to be accepted by China's cabinet, the State Council, for it to be adopted. China has already agreed to reduce its carbon intensity (the amount of CO_2 is produces per dollar of economic output) by

approximately 40 percent by 2020 compared to 2005 levels. Nearly 200 countries have pledged to agree to CO_2 emission-reduction targets at the next summit focused on reducing emissions, scheduled for Paris in 2015. From *The Independent* on May 21, 2103.

"Effects of carbon dioxide capture and storage in Germany on European electricity exchange and welfare." The following is the Abstract of this article: "In the course of European efforts to mitigate global warming, the application of CCS technologies is discussed as a potential option. Some political opposition was raised – inter alia – by uncertainties about the effective cost of such technologies. Because of the cost structure of CCS power plants with high 'flat' investment cost and – in case of high carbon allowance prices – comparable low variable cost, the application of CCS will induce a merit-order effect causing a decline in wholesale electricity prices on the spot market. On the one hand, the reduction of electricity supply cost raises suppliers' rents, while the decline of wholesale electricity prices augments consumers' surpluses. These positive welfare effects tend to mitigate political opposition against CCS. On the other hand, the merit-order effect reduces electricity suppliers' revenues as the wholesale prices decline. This mitigates their scope for additional investments in CCS capacity. In this study, [the authors] focus on the influence of CCS in Germany on electricity supplier and consumer surpluses and associated impacts on the scope for investments in additional CCS capacity. By means of the applied model of electricity markets, influences on European electricity exchange and welfare levels are investigated." **Dirk Rübbelke and Stefan Vögele**, *Energy Policy*. (Subscription may be required to view article.)

July 2013

"**From demonstration to deployment: An economic analysis of support policies for carbon capture and storage**." The following is the Abstract of this article: "This paper argues that an integrated policy architecture consisting of multiple policy phases and economic instruments is needed to support the development of CCS from its present demonstration phase to full-scale deployment. Building on an analysis of the different types of policy instruments to correct market failures specific to CCS in its various stages of development, [the authors] suggest a way to combine these into an integrated policy architecture. This policy architecture adapts to the need of a maturing technology, meets the requirement of policymakers to maintain flexibility to respond to changing circumstances while providing investors with the policy certainty that is needed to encourage private sector investment. This combination of flexibility and predictability is achieved through the use of 'policy gateways' which explicitly define rules and criteria for when and how policy settings will change. [The authors] findings extend to bioenergy-based CCS applications (BECCS), which could potentially achieve negative emissions. [The authors] argue that within a framework of correcting the carbon externality, the added environmental benefits of BECCS should be reflected in an extra incentive." **Max Krahé, Wolf Heidug, John Ward, and Robin Smale**, *Energy Policy*. (Subscription may be required to view article.)

"Development of a greenhouse gas accounting GIS-based tool to support local policy making—application to an Italian municipality." The following is the Abstract of this article: "Climate change is the issue of the century and, according to Agenda 21, local actions are essential to impact global mitigation of GHG emissions ('think globally, act locally'). However, in order to plan and implement effective, sustainable actions, local authorities need detailed information on their GHG emissions and their sources. This paper presents the work that led to the development of a GIS-based tool for local GHG accounting, which provides data for local decision-makers in an innovative manner different from traditional GHG inventories. The original aspects of the study are the geo-referencing of all results and the possibility of calculating all emissions (carbon sources) and removals (carbon [formations]) with input data of different accuracy. **F. Asdrubali, A. Presciutti, and F. Scrucca**, *Energy Policy*. (Subscription may be required to view article.)

"Stakeholder perspectives on carbon capture and storage in Indonesia." The following is the Abstract of this article: "CCS is being considered as an option to reduce CO_2 emissions worldwide. Yet recent cases show that CCS faces divergent public acceptance issues. This paper investigates stakeholder perspectives on CCS in Indonesia. Q methodology was adopted to [analyze] the diversity of stakeholder perspectives. Four perspectives were identified: (1) 'CO_2 emissions reduction through clean energy sources rather than CCS'; (2) 'CCS as one of the options in the transition to a sustainable energy system'; (3) 'CCS as the only optimal solution to reduce CO_2 emissions'; (4) 'CCS is only a tactic to keep burning coal forever.' Based on these results, [the authors] argue that stakeholder acceptance of CCS should be understood as a complex notion. This means that understanding whether or under what conditions stakeholders would be willing to support CCS, requires consideration of stakeholders' viewpoints about broader questions of CO_2 emission reduction and energy supply in Indonesia, rather than studying attitudes towards CCS in isolation. [The authors] discuss how the approach taken in this study can be used and followed up in policymaking on CCS in Indonesia." **Andri D. Setiawan and Eefje Cuppen**, *Energy Policy*. (Subscription may be required to view article.)

August 2013

"IOGCC Task Force Continues Work to Pave Way for CO_2 Storage." The Interstate Oil and Gas Compact Commission's (IOGCC) Carbon Geologic Storage (CGS) Task Force is finalizing work on liability issues related to CO_2 storage in geologic formations. DOE's Plains CO_2 Reduction (PCOR) Partnership is participating with other task force members, including state and provincial regulators and representatives of both industry and the environmental community. The task force focuses on assisting states and provinces in identifying the critical issues and developing model statutes and regulations necessary to allow and encourage the development of a carbon storage industry in U.S. states and Canadian provinces. The final work product (the third phase of the task force's effort) will provide further guidance to U.S. states and Canadian provinces on issues relating to pre-operational, operational, and post-operational liabilities in the geologic storage of carbon in non-hydrocarbon bearing subsurface formations. The Phase III Final Report is expected in Fall 2013. Previous CGS Task Force publications include: (1) A 2005 Phase I report examining "the legal, policy and regulatory issues related to the safe and effective geologic storage of CO_2 for both enhanced recovery and long-term CO_2 storage"; a 2007 Phase II report, "Storage of Carbon Dioxide in Geologic Structures: A Legal and Regulatory Guide for States and Provinces"; and (3) a 2010 Phase II report entitled "Biennial Review of the Legal and Regulatory Environment for the Storage of Carbon Dioxide in Geologic Structures." All publications can be found on the IOGCC website. The PCOR Partnership is a part of DOE's RCSP Initiative. From *Digital Journal News Release* on August 14, 2013.

"Emissions reduction potential from CO_2 capture: A life-cycle assessment of a Brazilian coal-fired power plant." The following is the Abstract of this article: "CCS is an effective technology for the mitigation of [greenhouse gas (GHG)] emissions from large-scale fossil fuel use. Nonetheless, it is not yet commercially viable on a large scale, and its inclusion into countries' energy planning agendas depends on realistic assessments of its emission reduction benefits. The use of CCS leads to energy penalties resulting from direct consumption of additional energy, and results in indirect CO_2 equivalent emissions outside plant boundaries, due to both energy consumption and [releases]. Accounting for these emissions allows for an evaluation of the mitigation benefits of CCS. This study performs a life-cycle assessment (LCA), with and without CCS, for a coal-fired power plant located in Brazil. Findings show that when indirect emissions are taken into account, a plant which captures 90 [percent] of its CO_2 will have its CO_2 equivalent emissions capture potential, based on a global warming potential metric with a 100-year time horizon, reduced to 72 [percent]. The advantage of the use of carbon capture towards climate change mitigation is reduced mainly as a result of an increase in [methane (CH_4)] emissions, significant in the coal-mining stage, an effect which is only taken into account when a LCA is performed." **David A. Castelo Branco, Maria Cecilia P. Moura, Alexandre Szklo, and Roberto Schaeffer**, *Energy Policy*. (Subscription may be required to view article.)

"A proposed methodology for CO_2 capture and storage cost estimates." The following is the Abstract of this article: "There are significant differences in the methods employed by various organizations to estimate the cost of CCS systems for fossil fuel power plants. Such differences often are not apparent in publicly reported CCS cost estimates, and thus contribute to misunderstanding, confusion, and [misrepresentation] of CCS cost information, especially among audiences not familiar with the details of CCS costing. Given the international importance of CCS as an option for climate change mitigation, efforts to harmonize methods of estimating CCS costs and improving the communication of cost assumptions and results are especially urgent and timely. Based on an analysis of current deficiencies, this paper recommends a common costing methodology plus guidelines for CCS cost reporting to improve the clarity and consistency of cost estimates for [GHG] mitigation measures." **Edward S. Rubin, Christopher Short, George Booras, John Davidson, Clas Ekstrom, Michael Matuszewski, and Sean McCoy**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"Characterizing CCS learning: The role of quantitative methods and alternative approaches." The following is the Abstract of this article: "A number of energy scenario studies have suggested that CCS could make a significant contribution to reducing global CO_2 emissions. This would require efforts to ensure rapid development and deployment. Since there is limited experience of CCS systems, it is hard to define 'business as usual' development. This leads to significant uncertainty for policy makers and other stakeholders with regard to characterizing potential CCS pathways and assessing the scope for and risks of acceleration. Quantitative analytical approaches to projecting costs and other parameters typically depend on best current estimates of critical input data, as well as implicit or explicit assumptions about technology development pathways and contextual factors such as evolving regulatory requirements. There are significant limitations in current quantitative (and qualitative) data on CCS that lead to significant difficulties in identifying robust assumptions. One way to handle this is to develop multiple scenarios to illustrate the uncertainty. Another strategy is to make more use of qualitative methods for analyzing CCS innovation processes. This latter approach could help to avoid some of the issues associated with CCS cost uncertainty and instead re-focus attention on understanding critical aspects of innovation processes." **Niles Markusson and Hannah Chalmers**, *Technological Forecasting and Social Change*. (Subscription may be required to view article.)

Geology

September 2012

"CO_2/Brine Transport into Shallow [Formations] along Fault Zones." The following is the Abstract of this article: "Unintended release of CO_2 from carbon [storage] reservoirs poses a well-recognized risk to groundwater quality. Research has largely focused on in situ CO_2-induced pH depression and subsequent trace metal mobilization. In this paper [the authors] focus on a second mechanism: upward intrusion of displaced brine or brackish-water into a shallow [formation] as a result of CO_2 injection. Studies of two natural analog sites provide insights into physical and chemical mechanisms controlling both brackish water and CO_2 intrusion into shallow [formations] along fault zones. At the Chimayó, New Mexico site, shallow groundwater near the fault is enriched in CO_2 and, in some places, salinity is significantly elevated. In contrast, at the Springerville, Arizona site CO_2 is [releasing] upward through brine [formations] but does not appear to be increasing salinity in the shallow [formation]. Using multiphase transport simulations [the authors] show conditions under which significant CO_2 can be transported through deep brine [formations] into shallow layers. Only a subset of these conditions favor entrainment of salinity into the shallow [formation]: high aspect-ratio [release] pathways and viscous coupling between the fluid phases. Recognition of the conditions under which salinity is favored to be cotransported with CO_2 into shallow [formations] will be important in environmental risk assessments." **Elizabeth H. Keating, Dennis L. Newell, Hari Viswanathan, J.W. Carey, G. Zyvoloski, and Rajesh**

Pawar, *Environ. Sci. Technol.*, Available online July 16, 2012, doi:10.1021/es301495x, http://pubs.acs.org/doi/abs/10.1021/es301495x. (Subscription required.)

"Supercritical CO_2 and Ionic Strength Effects on Wettability of Silica Surfaces: Equilibrium Contact Angle Measurements." The following is the Abstract of this article: "Wettability of reservoir mineral surfaces is a critical factor controlling CO_2 mobility, trapping, and safe-storage in geological carbon [storage]. Although recent studies have begun to show that wettability of some minerals can change in the presence of supercritical CO_2 ($scCO_2$), different laboratories have reported significantly different wetting behavior. [The authors] studied wettability alteration of silica in CO_2–brine systems through measuring equilibrium water contact angles under wide ranges of pressures (0.1 to 25 MPa) and ionic strengths (0 to 5.0 M NaCl), at 45°C. Using two independent approaches for each of the experiments, [the authors] found the following: (1) Equilibrium water contact angles on silica increased up to 17.6° ± 2.0° as a result of reactions with $scCO_2$. This increase occurred primarily within the pressure range 7–10 MPa, and the contact angles remain nearly constant at pressure greater than 10 MPa. (2) The contact angle increased with ionic strength nearly linearly, with a net increase of 19.6° ± 2.1° at 5.0 M NaCl. These changes in contact angle induced by changes in $scCO_2$ pressure and aqueous solution ionic strength are approximately additive over the range of tested conditions. These findings can be used to estimate the wetting behavior of silica surfaces in reservoirs containing supercritical CO_2." **Jong-Won Jung and Jiamin Wan**, *Energy Fuels*, Available online July 27, 2012, doi:10.1021/ef300913t, http://pubs.acs.org/doi/abs/10.1021/ef300913t. (Subscription required.)

October 2012

"Ganglion Dynamics and Its Implications to Geologic Carbon Dioxide Storage." The following is the Abstract of this article: "Capillary trapping of a nonwetting fluid phase in the subsurface has been considered as an important mechanism for geologic storage of CO_2. This mechanism can potentially relax stringent requirements for the integrity of [caprocks] for CO_2 storage and therefore can significantly enhance storage capacity and security. [The authors] here apply ganglion dynamics to understand the capillary trapping of supercritical CO_2 ($scCO_2$) under relevant reservoir conditions. [The authors] show that, by breaking the injected $scCO_2$ into small disconnected ganglia, the efficiency of capillary trapping can be greatly enhanced, because the mobility of a ganglion is inversely dependent on its size. Supercritical CO_2 ganglia can be engineered by promoting CO_2–water interface instability during immiscible displacement, and their size distribution can be controlled by injection mode (e.g., water-alternating-gas) and rate. [The authors] also show that a large mobile ganglion can potentially break into smaller ganglia due to CO_2–brine interface instability during buoyant rise, thus becoming less mobile. The mobility of $scCO_2$ in the subsurface is therefore self-limited. Vertical structural heterogeneity within a reservoir can inhibit the buoyant rise of $scCO_2$ ganglia. The dynamics of $scCO_2$ ganglia described here provides a new perspective for the security and monitoring of subsurface CO_2 storage." **Yifeng Wang, Charles Bryan, Thomas Dewers, Jason E. Heath, and Carlos Jove-Colon**, *Environ. Sci. Technol.*, Available online July 30, 2012, doi:10.1021/es301208k, http://pubs.acs.org/doi/abs/10.1021/es301208k. (Subscription required.)

"Energy recovery opportunities from mineral carbonation process in coal fired power plant." The following is the Abstract of this article: "Various CCS technologies are available worldwide to mitigate the effects of global warming. Mineral carbonation technology is one of the types of CCS technology. In this process gaseous CO_2 is converted into geologically stable carbonates. This process has some potential advantages compared to other available CCS technologies which have attracted the attention of researchers for further development of this technology for [storing] CO_2. One of the potential benefits of this technology is its exothermic reaction process. This exothermic heat energy can be recovered and used in other energy consuming components of carbonation plant. Heat energy from the products of the carbonation process can also be captured. This technology has not fully been developed yet, in particular for implementing it into power plants. In this study a thermodynamic mass and energy balance model is developed using Matlab/Simulink software for investigating energy recovery opportunities.

Wollastonite mineral is used as feed stocks. The amount of heat energy which can be recovered at different carbonation temperatures is determined and [analyzed] for a case study power plant with capacity of 1400 MW. It is found from this study that the carbonation process in case study power plant is energy self-sufficient, even only by the exothermic heat produced from the reaction and no heat recovery is needed from the products of carbonation process. It is also found that the energy required to supply to the carbonation plant (i.e. to grinder and compressor) decreases with increase in carbonation temperature. The surplus exothermic heat energy and heat energy from carbonated products can be utilized to reduce the fuel energy required for the existing power plant." **S. Moazzem, M.G. Rasul, and M.M.K. Khan**, *Applied Thermal Engineering*, Available in March 2013 edition, doi:10.1016/j.applthermaleng.2012.09.021, http://www.sciencedirect.com/science/article/pii/S1359431112006333 (Subscription may be required.)

November 2012

"Reactivity of Mount Simon Sandstone and the Eau Claire Shale Under CO_2 Storage Conditions." The following is the Abstract of this article: "The Mount Simon sandstone and Eau Claire shale formations are target storage and [caprock] formations for the Illinois Basin–Decatur Geologic Carbon Sequestration Project. [The authors] reacted rock samples with brine and supercritical CO_2 at 51°C and 19.5 MPa to access the reactivity of these formations at storage conditions and to address the applicability of using published kinetic and thermodynamic constants to predict geochemical alteration that may occur during storage by quantifying parameter uncertainty against experimental data. Incongruent dissolution of iron-rich clays and formation of secondary clays and amorphous silica will dominate geochemical alterations at this CO_2 storage site in CO_2-rich brines. The surrogate iron-rich clay in the model required significant adjustments to its thermodynamic constants and inclusion of incongruent reaction terms to capture the change in solution composition under acid CO_2 conditions. This result emphasizes the need for experiments that constrain the conceptual geochemical model, calibrate mean parameter values, and quantify parameter uncertainty in reactive-transport simulations that will be used to estimate long-term CO_2 trapping mechanisms and changes in porosity and permeability." **Susan A. Carroll, Walt W. McNab, Zurong Dai, and Sharon C. Torres**, *Environ. Sci. Technol.*, Available online August 8, 2012, doi:10.1021/es301269k, http://pubs.acs.org/doi/abs/10.1021/es301269k. (Subscription required.)

"CO_2-brine-caprock interaction: Reactivity experiments on Eau Claire shale and a review of relevant literature." The following is the Abstract of this article: "Long term containment of stored CO_2 in deep geological reservoirs will depend on the performance of the caprock to prevent the buoyant CO_2 from escaping to shallow drinking water [formations] or the ground surface. Here [the authors] report new laboratory experiments on CO_2–brine–caprock interactions and a review of the relevant literature. The Eau Claire Formation is the caprock overlying the Mount Simon sandstone formation, one of the target geological CO_2 storage reservoirs in the Midwest USA region. Batch experiments of Eau Claire shale dissolution in brine were conducted at 200°C and 300 bars to test the extent of fluid-rock reactions. Scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis indicate minor dissolution of K-feldspar and anhydrite, and precipitation of pore-filling and pore-bridging illite and/or smectite, and siderite in the vicinity of pyrite. [The authors] also reviewed relevant reactivity experiments, modeling work, and field observations in the literature in an attempt to help define the framework for future studies on the geochemical systems of the caprock overlain on geological CO_2 storage formations. Reactivity of the caprock is generally shown to be low and limited to the vicinity of the CO_2–caprock interface, and is related to the original caprock mineralogical and petrophysical properties. Stable isotope studies indicate that CO_2 exists in both free phase and dissolved phase within the caprock. Carbonate and feldspar dissolution is reported in most studies, along with clay and secondary carbonate precipitation. Currently, research is mainly focused on the micro-fracture scale geochemistry of the shaly caprock. More attention is required on the potential pore scale reactions that may become significant given the long time scale associated with geological carbon storage." **Faye Liu, Peng Lu, Craig Griffith, Sheila W. Hedges, Yee Soong, Helge Hellevang, and Chen Zhu**, *International Journal of Greenhouse Gas Control*, Available in

March 2012 edition, doi:10.1016/j.ijggc.2012.01.012, http://www.sciencedirect.com/science/article/pii/S1750583612000266. (Subscription may be required.)

"Coupled alkali feldspar dissolution and secondary mineral precipitation in batch systems – 2: New experiments with supercritical CO_2 and implications for carbon [storage]." The following is the Abstract of this article: "In order to evaluate the extent of CO_2–water–rock interactions in geological formations for [carbon storage], three batch experiments were conducted on alkali feldspars–CO_2–brine interactions at 150–200°C and 300 bars. The elevated temperatures were necessary to accelerate the reactions to facilitate attainable laboratory measurements. Temporal evolution of fluid chemistry was monitored by major element analysis of *in situ* fluid samples. SEM, TEM and XRD analysis of reaction products showed extensive dissolution features (etch pits, channels, kinks and steps) on feldspars and precipitation of secondary minerals (boehmite, kaolinite, muscovite and paragonite) on feldspar surfaces. Therefore, these experiments have generated both solution chemistry and secondary mineral identity. The experimental results show that partial equilibrium was not attained between secondary minerals and aqueous solutions for the feldspar hydrolysis batch systems. Evidence came from both solution chemistry (supersaturation of the secondary minerals during the entire experimental duration) and metastable co-existence of secondary minerals. The slow precipitation of secondary minerals results in a negative feedback in the dissolution–precipitation loop, reducing the overall feldspar dissolution rates by orders of magnitude. Furthermore, the experimental data indicate the form of rate laws greatly influence the steady state rates under which feldspar dissolution took place. Negligence of both the mitigating effects of secondary mineral precipitation and the sigmoidal shape of rate–ΔG_r relationship can overestimate the extent of feldspar dissolution during CO_2 storage. Finally, the literature on feldspar dissolution in CO_2-charged systems has been reviewed. The data available are insufficient and new experiments are urgently needed to establish a database on feldspar dissolution mechanism, rates and rate laws, as well as secondary mineral information at CO_2 storage conditions." **Peng Lu, Qi Fu, William E. Seyfried Jr. Sheila W. Hedges, Yee Soong, Kyle Jones, and Chen Zhu**, *Applied Geochemistry*, Available online May 18, 2012, doi:10.1016/j.apgeochem.2012.04.005, http://www.sciencedirect.com/science/article/pii/S0883292712001023. (Subscription may be required.)

December 2012

"Enhanced biomimetic CO_2 [storage] and $CaCO_3$ crystallization using complex encapsulated metal organic framework." The following is the Abstract of this article: "A new biomimetic complex (Co-BBP) that mimics the active site of carbonic anhydrase (CA) was prepared by the coordination of cobalt (II) with 2, 6-bis(2-benzimidazolyl) and was encapsulated into a metal organic framework (Co-BBP@Tb-MOF). Carbon dioxide [storage] was carried out via an *in vitro* mineralization approach using these biomimetic catalysts. The biomimetic catalysts were expected to enhance CO_2 hydration and calcium carbonate ($CaCO_3$) crystallization based on the same mechanism as that of CA." **Prakash C. Sahoo, Young Nam Jang, Seung Woo Lee**, *Journal of Crystal Growth*, Available online November 30, 2012, doi:10.1016/j.jcrysgro.2012.11.043, http://www.sciencedirect.com/science/article/pii/S0022024812008408?v=s5. (Subscription may be required.)

"Permeability Reduction Produced by Grain Reorganization and Accumulation of Exsolved CO_2 during Geologic Carbon [Storage]: A New CO_2 Trapping Mechanism." The following is the Abstract of this article: "Carbon [storage] experiments were conducted on uncemented sediment and lithified rock from the Eau Claire Formation, which consisted primarily of K-feldspar and quartz. Cores were heated to accentuate reactivity between fluid and mineral grains and to force CO_2 exsolution. Measured permeability of one sediment core ultimately reduced by 4 orders of magnitude as it was incrementally heated from 21 to 150°C. Water-rock interaction produced some alteration, yielding sub-μm clay precipitation on K-feldspar grains in the core's upstream end. Experimental results also revealed abundant newly formed pore space in regions of the core, and in some cases pores that were several times larger than the average grain size of the sediment. These large pores likely formed from elevated

localized pressure caused by rapid CO_2 exsolution within the core and/or an accumulating CO_2 phase capable of pushing out surrounding sediment. [Carbon dioxide] filled the pores and blocked flow pathways. Comparison with a similar experiment using a solid arkose core indicates that CO_2 accumulation and grain reorganization mainly contributed to permeability reduction during the heated sediment core experiment. This suggests that CO_2 injection into sediments may store more CO_2 and cause additional permeability reduction than is possible in lithified rock due to grain reorganization." **Andrew J. Luhmann; Xiang-Zhao Kong; Benjamin M. Tutolo; Kang Ding; Martin O. Saar; and William E. Seyfried, Jr.**, *Environ. Sci. Technol.*, Available online November 10, 2012, doi:10.1021/es3031209, http://pubs.acs.org/doi/abs/10.1021/es3031209. (Subscription required.)

"Impacts of Geochemical Reactions on Geologic Carbon [Storage]." The following is the Abstract of this article: "In the face of increasing energy demands, geologic CO_2 [storage] (GCS) is a promising option to mitigate the adverse effects of climate change. To ensure the environmental sustainability of this option, the rates and mechanisms of key geochemical reactions and their impacts on GCS performance, the multiphase reactive transport of CO_2, and the management of environmental risks [must be understood]. Strong interdisciplinary collaborations are required to minimize environmental impacts and optimize the performance of GCS operations." **Young-Shin Jun, Daniel E. Giammar, and Charles J. Werth**, *Environ. Sci. Technol.*, Available online November 6, 2012, doi:10.1021/es3027133, http://pubs.acs.org/doi/abs/10.1021/es3027133. (Subscription required.)

January 2013

"CO_2 capture from ethanol production and storage into the Mt Simon Sandstone." The following is the Abstract of this article: "Under the Industrial Carbon Capture and Storage (ICCS) program, funded by ARRA, DOE is co-sponsoring the Archer Daniels Midland Company's (ADM's) large-scale CCS project in Illinois. FE's NETL manages this project, which receives $141.4 million in ARRA funding and another $66.5 million in private sector cost-sharing. This project, also referred to as the Illinois ICCS project, is under construction in Decatur, Illinois, and is scheduled to begin operations in 2013. The project team members are ADM, DOE, Schlumberger Carbon Services, Illinois State Geological Survey (ISGS), and Richland Community College (RCC). The Illinois ICCS project will demonstrate an integrated system for collecting up to 907,000 tonnes per year of CO_2 from ADM's ethanol plant in Decatur and geologically [storing] it in the Mt Simon Sandstone, a saline reservoir. The project scope includes the design, construction, and integrated operation of CO_2 compression, dehydration, and injection facilities, and monitoring, verification, and accounting [MVA] of the stored CO_2. Significant field work has been completed, i.e. design of the integrated CCS system, 3-D seismic survey and site characterization, and mechanical construction of the compression and dehydration facilities. This is the largest saline storage project under construction in the [United States]. This paper will provide an overview and benefits of the Illinois ICCS project, present the field work results, and highlight the current status and future plans." **Sai Gollakota and Scott McDonald**, *Greenhouse Gases: Science and Technology*, Available online October 15, 2012, doi:10.1002/ghg.1305, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1305/abstract. (Subscription may be required.)

"Common attributes of hydraulically fractured oil and gas production and CO_2 geological [storage]." The following is the Abstract of this article: "Areal footprints of current and future hydraulically fractured oil and gas reservoirs and potential CO_2 geological-[storage] intervals often overlap in sedimentary basins. Significant vertical separations between prospective subsurface volumes, however, will limit their interaction, particularly if the carbon-storage site is deeper than the hydrocarbon resource. Recent intense development of shale resources translates into a reduced need for [storage] capacity. It has also resulted in technological innovations directly transferable to the carbon-storage industry, in particular progress on well completion, such as new approaches to cementing, more mature horizontal drilling methods, and development of field-treatment techniques for saline water. In addition, knowledge collected by operators on stratigraphy and faults – for example, using 3D seismic – and on abandoned wells is directly useful in reducing risk in future carbon-storage projects. Both industries can benefit from

development of regional transmission pipelines, pipeline rights-of-way, and a trained workforce. From a regulatory standpoint, hydraulic fracturing of shale and tight formations is not considered injection. Under the [U.S. Underground Injection Control (UIC)] program, because hydraulically fractured wells fall under the production category, they do not follow the same set of rules for protecting water resources as oil and gas industry disposal wells do (UIC Class II). Both subsurface uses share some risk elements, however. Environmental risks result mostly from abandoned wells and faults, poorly characterized for carbon storage, and from defective well completions and surface spills during oil and gas production. Operators of both fields are also concerned about disposal of large fluid volumes possibly generating seismic events." **Jean-Philippe Nicot and Ian J. Duncan**, *Greenhouse Gases: Science and Technology*, Available online September 14, 2012, doi:10.1002/ghg.1300, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1300/abstract. (Subscription may be required.)

"Characterizing CO_2 storage reservoirs and shallow overburden for above-zone monitoring in Texas Gulf Coast EOR fields." The following is the Abstract of this article: "Enhanced oil recovery (EOR) through CO_2 injection provides an excellent opportunity for commercial [storage] of anthropogenic CO_2. A fluvio-deltaic, deep-seated salt dome and a strand-plain, roll-over anticline from the Gulf Coast region are currently under investigation for the design and implementation of monitoring, verification, and accounting (MVA) plans, in coordination with the commercial surveillance of independent, large-volume (>1 million ton/year) CO_2-EOR operations. Characterization with wireline logs demonstrates the vertical extent and areal continuity of reservoir sands and geometries of faults that offset the reservoir. To develop the monitoring plan, [the authors] focused on several elements: (i) characterization of the zones above the confining unit for above-zone pressure monitoring, (ii) collection and development of input data for 'quick-look' dynamic modeling of CO_2 plume extent and pressure elevation, and (iii) identifying intersections of faults with wellbores in intervals above the regional confining unit for thermal monitoring. Other uncertainties addressed during characterization are the upper extent of faults and the juxtaposition of layers to assess the potential for cross-fault fluid migration. Successful use of such techniques for MVA, based on uniting elements of existing regulatory monitoring expectations, would lead to the establishment of commercial best practices for effective and rapid characterization of EOR sites in the Gulf Coast region." **Khandaker M. Zahid, Seyyed A. Hosseini, Vanessa Nuñez-López, and Susan D. Hovorka**, *Greenhouse Gases: Science and Technology*, Available online December 19, 2012, doi:10.1002/ghg.1320, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1320/abstract. (Subscription may be required.)

February 2013

"ULTimateCO_2 project: Field experiment in an underground rock laboratory to study the well integrity in the context of CO_2 geological storage." The following is the Abstract of this article: "Wells drilled through low-permeable caprock are potential connections between the CO_2 storage reservoir and overlying sensitive targets like [formations] and targets located at the surface. The wellbore integrity can be compromised due to in situ operations, including drilling, completion, operations and abandonment or to geochemical degradation of the caprock-cement-casing system. [The authors] present here an experimental set-up in the underground rock laboratory of Mont-Terri (St Ursanne, canton of Jura, Switzerland): the drilling and well completion in the laboratory will be done in the aim of reconstructing interfaces between the caprock, the cement and the casing steel that would be close to the ones observed in situ. These well features will then be dipped within a CO_2 stream, during a given time period before a final over-coring. Such an experiment should provide new insights on the quality of bounding between casing/cement/clay interfaces and its evolution due to geochemical reactions. In parallel, a modeling effort is performed focused on both geochemical and transport aspects of the interactions between the fluids and the well compartments." **JC. Manceau, P. Audigane, F. Claret, M. Parmentier, T.J. Tambach, L. Wasch, F. Gherardi, A. Dimier, O. Ukelis, E. Jeandel, F. Cladt, R. Zorn, T. Yalamas, C. Nussbaum, A. Laurent, T. Fierz, and M. Piedevache**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"Tracing back the pressure-impact zone of the CO_2 geological storage through a cyclic injection strategy." The following is the Abstract of this article: "Industrial-scale CO_2 injection into deep [formations] might induce far-field pressure perturbations on the basin scale, potentially impacting other underground uses present within the [same formation]. In the present paper, [the authors] investigate an approach to trace back the area of elevated pressure induced by CO_2 storage operations through an injection strategy in a cyclic manner over time. In this manner, the CO_2 injection-induced pressure field is characterized by a low magnitude harmonic signature very specific to the considered CO_2 storage, the frequency being chosen as different to naturally fluctuating phenomena or other anthropogenic underground activities. [The authors] rely on the combination of de-trending and FFT technique to detect the harmonic pattern associated the CO_2 storage injections. [The authors] apply the methodology on synthetic pressure signal numerically generated using a typical injection scenario in the Paris basin case. On this basis, [the authors] discuss how trace back the CO_2 storage site causing the pressure impact, in particular regarding the existing sources of noise." **Jeremy Rohmer and Jean-Charles Manceau**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"Natural mitigation of CO_2 [release] accumulations." The following is the Abstract of this article: "This study aims at investigating the role played by the overlying formation as a safety barrier in case of CO_2 [release] accumulation (i.e. CO_2 accumulated in an overlying [formation] after its [release] from the CO_2 storage reservoir) by focusing on its natural capacity to prevent any further upward migration. Based on numerical simulations performed using TOUGH2/ECO2N incl. hysteretic module, [the authors] assess the processes influencing the quantity of mobile CO_2 within the [releasing] plume and perform a sensitivity analysis to point out the key-parameters and conditions for an efficient natural trapping by dissolution and residual trapping. Additional simulations of a [release] – active remediation scenario on a complete system (storing reservoir connected to an overlying [formation]) show the importance of the natural trapping capacity of the overlying [formation]. This capacity could be integrated in the mitigation strategy, associating natural and engineered safety barriers. Gaining more knowledge on these formations can support first estimations of this natural capacity, and hence can help building the corrective measure plan and designing potential interventions during operations." **Jean-Charles Manceau, Jérémy Rohmer, Arnaud Réveillère**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"Geochemical effects of storing CO_2 in the Basal Aquifer that underlies the Prairie Region in Canada." The following is the Abstract of this article: "In the area underlain by the Basal [Formation] in the Prairie region of Canada, there are 20 large CO_2 sources (coal-fired power plants, oil sands and heavy oil production and upgraders, refineries, chemical and petrochemical plants, fertilizer plants and cement plants) that emit more than 1 Mt CO_2/year each, for a total of 83 Mt CO_2/year, which represents 12 [percent] of Canada's annual [GHG] emissions. If post-combustion capture technologies are used, 75 Gt CO_2/year can be captured from these sources, with a composition ([percent] mass) estimated to be 99.95 [percent] CO_2, 0.02 [percent] N_2/Ar/O_2, and 0.03 [percent] H_2O. The Basal [Formation] comprises Middle Cambrian sandstones that overlie the crystalline Precambrian basement in the Alberta basin and the Canadian part of the Williston basin. Shales constitute the primary caprock of the Basal [Formation]. Pressures in the [formation] generally follow a gradient of 10.8 kPa/m. Temperatures in the [formation] vary between >150°C in the deepest part of the Alberta Basin to less than 10°C in outcrop areas. Water salinity ranges from > 300,000 mg/L in central Alberta to < 10,000 mg/L in the southwest and in the east. The formation water in the [formation] region suitable for CO_2 storage is NaCl dominated. Generally, at in-situ conditions, these waters are saturated with $CaSO_4$ (anhydrite), with some at NaCl (halite) saturation. The mineralogy of the [formation] rocks and caprock were determined using a suite of laboratory analyses and normative calculations on core samples. The dominant mineral in the Basal formation in regions suitable for CO_2 storage is quartz, which is generally present in the 65 [percent] to 95 [percent] range, while potassium feldspar is the next most common silicate. Pyrite is present in trace amounts in many of the samples. Calcite and illite, when present, are primarily pore-filling minerals.

Calcium sulphate (anhydrite) is present in many of the samples, and, when present, is a pore-filling phase. In regard to the caprock, quartz is still a predominant mineral phase, comprising of at least one third of the rock for all samples. Potassium feldspar, illite and kaolinite are the next most common minerals. The ability of the rocks of the Basal [Formation] to react with CO_2 is limited, with potassium feldspar and complex clays providing the bulk the reactive capacity via the formation of kaolinite, or potentially a coupled reaction forming alunite and calcite in anhydrite-bearing zones. The effect of these reactions on CO_2 storage capacity, [formation] porosity and permeability is limited, allowing decoupling of flow from geochemical processes. Caprock reactivity towards CO_2 is much greater due to its more complex mineralogy, however they will not propagate far into the caprock due to its low permeability, thus allowing decoupling of flow and geochemical processes." **Stephen Talman, Ernie Perkins, Andrew Wigston, David Ryan, and Stefan Bachu**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

March 2013

"Multimodel Predictive System for Carbon Dioxide Solubility in Saline Formation Waters." The following is the Abstract of this article: "The prediction of [CO_2] solubility in brine at conditions relevant to carbon [storage] (i.e., high temperature, pressure, and salt concentration [T-P-X]) is crucial when this technology is applied. Eleven mathematical models for predicting CO_2 solubility in brine are compared and considered for inclusion in a multimodel predictive system. Model goodness of fit is evaluated over the temperature range 304–433 K, pressure range 74–500 bar, and salt concentration range 0–7 *m* (NaCl equivalent), using 173 published CO_2 solubility measurements, particularly selected for those conditions. The performance of each model is assessed using various statistical methods, including the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Different models emerge as best fits for different subranges of the input conditions. A classification tree is generated using machine learning methods to predict the best-performing model under different T-P-X subranges, allowing development of a multimodel predictive system (MMoPS) that selects and applies the model expected to yield the most accurate CO_2 solubility prediction. Statistical analysis of the MMoPS predictions, including a stratified [five]-fold cross validation, shows that MMoPS outperforms each individual model and increases the overall accuracy of CO_2 solubility prediction across the range of T-P-X conditions likely to be encountered in carbon [storage] applications." **Zan Wang, Mitchell J. Small, and Athanasios K. Karamalidis**, *Environ. Sci. Technol.* (Subscription may be required to view article.)

"Thermal Activation of Antigorite for Mineralization of CO_2." The following is the Abstract of this article: "This contribution demonstrates the sensitivity of antigorite dehydroxylation to treatment conditions and discusses the implications of the observations for scientific (i.e., dehydroxylation kinetics) and technological (i.e., energy efficient conditions and design of practical activation reactors) applications. At present, the energy cost of dehydroxylation of serpentinite ores represent the most important impediment for a large scale implementation of sequestering CO_2 by mineralization. [The authors] have analyzed changes in antigorite's derivative thermogravimetric curves (DTG) and deduced factors affecting the mass loss profiles. The imposed heating rate, type of purge gas, type of comminution and sample mass all influence the dehydroxylation curve. However, the results show no influence of material of construction of the heating vessel and flow rate of the purge gas. [The authors] report an important effect of oxidation of Fe^{2+} under air purge gas that occurs prior to dehydroxylation and leads to formation of hematite skins on serpentinite particles, slowing down subsequent mass transfer and increasing the treatment temperature. From the process perspective, 75 μm particles afford optimal conditions of temperature and rate of dehydroxylation. Overall, the practical considerations, in thermally activating serpentinite ores for storing CO_2 by carbonation, comprise rapid heating, proper size reduction, prior demagnetisation, and fluidization of the powder bed." **Reydick D. Balucan and Bogdan Z. Dlugogorski**, *Environ. Sci. Technol*. (Subscription may be required to view article.)

"Interactions of Supercritical CO_2 with Coal." The following is the Abstract of this article: "Carbon dioxide [storage] on coal with CO_2-ECBM is acknowledged as a promising way to mitigate CO_2 emissions. For successfully understanding and implementing CO_2-ECBM process, the potential interactions of CO_2 with coal during CO_2 [storage] in coal seams were investigated. Research methods consisting of low-temperature nitrogen adsorption–desorption and chromatographic analysis were used to address the transformation of coal pore morphology and the capability of supercritical CO_2 extraction when coal contacts with high pressure CO_2. According to the test results, interaction of coal with high pressure CO_2 does not create a significant influence on pore shape and mesoporous volume distribution of any rank of coal. However, this causes the coal surface fractal dimension and specific surface area to be changed, which implies that the coal's pore morphology change due to CO_2 sorption is irreversible. The results also indicate that the injection of high-pressure CO_2 does not only change the pore morphology of coal but also has the ability to extract the hydrocarbons present in the coal matrix. The extracted hydrocarbons are of biological toxicity and can be mobilized with gas or water to other geologic structures and [formations]. Thus, the potential environmental safety and health issues (ES&H issues) related to CO_2 [storage] in deep coal seams require thorough assessment." **Dengfeng Zhang, Lili Gu, Songgeng Li, Peichao Lian, and Jun Tao**, *Energy Fuels*. (Subscription may be required to view article.)

April 2013

"Liquid CO_2 injection for geological storage in deep saline [formations]." The following is the Abstract of this article: "[Carbon dioxide] will remain in supercritical (SC) state (i.e. $p > 7.382$ MPa and $T > 31.04$°C) under the pressure (p) and temperature (T) conditions appropriate for geological storage. Thus, it is usually assumed that CO_2 will reach the [formation] in SC conditions. However, inflowing CO_2 does not need to be in thermal equilibrium with the [formation]. In fact, surface operations are simpler for liquid than for SC CO_2, because CO_2 is transported in liquid state. Yet, problems might arise because of thermal stresses induced by cold CO_2 injection and because of phase changes in the injection tubing or in the formation. Here, [the authors] propose liquid CO_2 injection and analyze its evolution and the thermo-hydro-mechanical response of the formation and the caprock. [The authors] find that injecting CO_2 in liquid state is energetically more efficient than in SC state because liquid CO_2 is denser than SC CO_2, leading to a lower overpressure not only at the wellhead, but also in the reservoir because a smaller fluid volume is displaced. Cold CO_2 injection cools down the formation around the injection well. Further away, CO_2 equilibrates thermally with the medium in an abrupt front. The liquid CO_2 region close to the injection well advances far behind the SC CO_2 interface. While the SC CO_2 region is dominated by gravity override, the liquid CO_2 region displays a steeper front because viscous forces dominate (liquid CO_2 is not only denser, but also more viscous than SC CO_2). The temperature decrease close to the injection well induces a stress reduction due to thermal contraction of the media. This can lead to shear slip of pre-existing fractures in the [formation] for large temperature contrasts in stiff rocks, which could enhance injectivity. In contrast, the mechanical stability of the caprock is improved in stress regimes where the maximum principal stress is the vertical." **Víctor Vilarrasa, Orlando Silva, Jesús Carrera, and Sebastià Olivella**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view this article.)

"Tracing the movement and the fate of injected CO_2 at the IEA GHG Weyburn-Midale CO_2 Monitoring and Storage project (Saskatchewan, Canada) using carbon isotope ratios." The following is the Abstract of this article: "Stable isotope data can assist in successful monitoring of the movement and the fate of injected CO_2 in enhanced oil recovery and geological storage projects. This is demonstrated for the IEA-GHG Weyburn-Midale CO_2 Monitoring and Storage Project (Saskatchewan) where fluid and gas samples from multiple wells were collected and analyzed for geochemical and isotopic compositions for more than a decade. Carbon isotope ratios of the injected CO_2 (−20.4‰) were sufficiently distinct from median $\delta^{13}C$ values of background CO_2 ($\delta^{13}C = -12.7$‰) and HCO_3^- ($\delta^{13}C = -1.8$‰) in the reservoir to reveal the movement and geochemical trapping of injected CO_2 in the reservoir. The presented 10-year data record reveals the movement of injected CO_2 from injectors to

producers, dissolution of CO_2 in the reservoir brines, and ionic trapping of injected CO_2 in conjunction with dissolution of carbonate minerals. [The authors] conclude that carbon isotope ratios constitute an excellent and cost effective tool for tracing the fate of injected CO_2 at long-term CO_2 storage sites with injection rates exceeding 1 million tons per year." **Bernhard Mayer, Maurice Shevalier, Michael Nightingale, Jang-Soon Kwon, Gareth Johnson, Mark Raistrick, Ian Hutcheon, and Ernie Perkins**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"Effect of hydraulic fracturing on long-term storage of CO_2 in stimulated saline [formations]." The following is the Abstract of this article: "Stimulation techniques, primarily as hydraulic fracturing, can contribute to improve practical storage capacity of low-permeable saline [formations] by increasing injectivity. Since the shape of the CO_2 plume in the injection period can affect its subsequent migration, impact of hydraulic fracturing on post-injection plume migration should be investigated to assess CO_2 long-term trapping in stimulated saline [formations]. Compositional reservoir simulation results, based on a case study of Rose Run sandstone [formation] in Ohio River Valley, show the important role of methods for increasing near wellbore injectivity on CO_2 plume dynamics. Significant tradeoff between enhancing injectivity and long-term trapping of [CO_2] in hydraulically fractured saline [formations] in normal faulting regime is proven by analysis of parameters controlling CO_2 storage in saline [formations] such as gravity number. In addition, [the authors] discuss effects of the [formation] stress regime, fracture properties, and injection of water on immobilization of CO_2 by residual and solubility trapping inside the stimulated saline [formations]. Finally, [the authors] show that non-Darcy flow effects inside the fracture could reduce injectivity of the stimulated saline [formation] by causing additional pressure drop inside the fracture." **S. Raziperchikolaee and V. Alvarado**, *Applied Energy*. (Subscription may be required to view article.)

"The northernmost Adriatic Sea: A potential location for CO_2 geological storage?" The following is the Abstract of this article: "In 2009, the National Institute of Oceanography and Experimental Geophysics (OGS, Italy) has performed a geophysical survey in the northernmost sector of the Northern Adriatic Sea, between the Tagliamento and Po river deltas, with R/V OGS Explora. About 820 km of 2D multichannel seismic and Chirp profiles, together with multibeam data along the ship tracks, have been acquired, with the aim to reconstructing the Plio-Quaternary stratigraphic and tectonic setting of the study area. Data have been also analyzed to verify whether this region is suitable for CO_2 geological storage. Sites eligible for the application of CCS techniques have been already identified in the Adriatic Sea, except in the northernmost sector, due to the scarcity of available data. The analyses of the new OGS seismic dataset highlighted the occurrence of peculiar seismic anomalies, represented by sub-vertical wipe-out zones, that have been interpreted as due to gas [releases] affecting the Plio-Quaternary sequence. They could be possibly related to the formation of rock outcrops interpreted as methane-derived carbonates. It is suggested that gas migrates along sub-vertical chimneys throughout the Plio-Quaternary sequence. The correlation of these sub-vertical features among the seismic profiles reveals that two main alignments could be recognized: a NW–SE trend offshore the Venice Lagoon and a NE–SW in the northernmost part of the investigated area. It leads to hypothesize that the preferential conduits for gas migration are associated to tectonic lineaments. The analysis of the tectonic setting has been then addressed at defining the role of fault/fracture zones, which can affect the integrity of a CO_2 storage complex in this area. Tectonic features have been identified in the Mesozoic–Paleogene succession, but their relationship with the shallow faults/fractures representing the paths for gas leakages still need further work and additional data in order to be clearly constrained." **Federica Donda, Dario Civile, Edy Forlin, Valentina Volpi, Massimo Zecchin, Emiliano Gordini, Barbara Merson, and Laura De Santis**, *Marine and Petroleum Geology*. (Subscription may be required to view article.)

May 2013

"Reduction of lateral pressure propagation due to dissipation into ambient mudrocks during geological carbon dioxide storage." The following is the Abstract of this article: "CO_2 storage in deep

geological formations can lead to significant reductions in anthropogenic CO_2 emissions if large amounts of CO_2 can be stored. Estimates of the storage capacity are therefore essential to the evaluation of individual storage sites as well as the feasibility of the technology. One important limitation on the storage capacity is the radius of review, the lateral extent of the pressure perturbation, of the storage project. [The authors] show that pressure dissipation into ambient mudrocks retards lateral pressure propagation significantly and therefore increases the storage capacity. For a three-layer model of a reservoir surrounded by thick mudrocks, the far-field pressure is approximated well by a single-phase model…The combination of large uncertainty in mudrock properties and the sigmoid shape leads to wide and strongly skewed probability distributions for the predicted radius of review and storage capacity. Therefore, if the lateral extent of the pressure front limits the storage capacity, the determination of the mudrock properties is an important component of the site characterization." **Kyung Won Chang, Marc A. Hesse, and Jean-Philippe Nicot**, *Water Resources Research*. (Subscription may be required to view article.)

"Use of Reactive Species in Water for CO_2 Mineralization." The following is the Abstract of this article: "Various CCS technologies have been developed to address the issues concerning climate changes associated with anthropogenic CO_2 emissions. In the present work, possibilities of mineralizing CO_2 with the reactive species such as Mg^{2+}ions present in nature such as sea water and produced water have been explored. Laboratory tests conducted with solutions containing 1,400 ppm Mg^{2+} ions showed that nesquehonite ($Mg(OH)(HCO_3)\cdot 2H_2O$) is formed upon CO_2 injection to the solution at an atmospheric pressure. The results showed that for the mineralization to occur, the pH should be raised above 6.8 as predicted from thermodynamics. Kinetic studies conducted at different temperatures showed that the nesquehonite formation involves an activation energy of 66.7 kJ/mol, which can be overcome by increasing the mass and heat transfer efficiency, as well as the operative temperature. Based on the kinetics data obtained at a low agitation speed, the number and volume of the mineralization reactors required to capture the CO_2 emitted from a [600-MW] coal power plant have been determined. In addition, the amounts of alkalis needed to raise the pH for precipitation and subsequently to the natural pH of sea water have been estimated." **Juan Ma and Roe-Hoan Yoon**, *Energy Fuels*. (Subscription may be required to view article.)

"Regional capacity estimates for CO_2 geological storage in deep saline [formations] – Upper Miocene sandstones in the SW part of the Pannonian basin." The following is the Abstract of this article: "Deep saline [formations] are regarded as the most suitable sites or options for CO_2 geological storage, mainly due to their large storage capacity and extensive spatial distribution in most sedimentary basins. The estimation of the storage capacity in this type of sinks presents a problem due to the lack of subsurface data. A significant step from regional towards local capacity estimation is redefinition of regional storage capacity by applying modified methodology for integrated studies of hydrocarbon reservoirs. The suggested procedure was investigated by detailed mapping of the Sava West [formation] in the Croatian part of the Pannonian basin. First, the cap rock was chosen based on its depth, thickness and lateral continuity, and then the target reservoir – Upper Miocene Poljana sandstone layers underlying the regional cap rock. Their depth and effective thickness, as well as the subsurface pressure, temperature and resulting density of CO_2 were mapped based on the well data. The [formation] body was then divided into square elements and the storage capacity was calculated for each of them. Mapping of specific storage capacity in this way enables identification of the areas of greater potential for geological storage that should be further investigated for detailed definition of the potential storage objects." **Iva Kolenković, Bruno Saftić, and Dario Perešin**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

June 2013

"CO_2 rock physics as part of the Weyburn-Midale geological storage project." The following is the Abstract of this article: "To develop confidence in the seismic techniques that are used to (i) qualitatively

locate and track the movement of the CO_2 plume, and (ii) quantitatively determine the amount of CO_2 in place in the Weyburn pool, a good understanding of the effects of CO_2 on seismic waves is critical. For this purpose, an extensive series of ultrasonic measurements were performed on over [20] core samples from the Weyburn-Midale carbonates (Marly and Vuggy units) and the overlying and underlying formations. Care was taken to separate pore fluid effects from pore pressure build-up effects during the experiments. This allowed for the sampling of the effects of the CO_2's varying phase states (gas–liquid–supercritical fluid) on the overall rock seismic response. The current paper provides a subset of measurements conducted on four samples from the Marly and Vuggy units. Of the observations arising from the measurements, there are two that are of particular note. First, both the P- and S-wave speeds decrease substantially as the CO_2 transforms from gas to either liquid or supercritical phase. This observation is consistent with the increase of CO_2 fluid density across these phase boundaries. Second, across the gas–liquid phase transition both wave speeds drop abruptly as would be expected for the change in the physical properties of the CO_2 across this first order phase boundary. In contrast, across the gas–supercritical phase boundary the velocities change more gradually. This suggests that it may be difficult to distinguish the gas–supercritical boundary using seismic reflection techniques. Illustrative modelling of seismic reflectivities within a hypothetical geological formation with physical properties equal to that of one of the measured samples, however, suggests that a CO_2 liquid–water contact is a good seismic reflector." **Gautier Njiekak, Douglas R. Schmitt, Helen Yam, and Randolf S. Kofman**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"Reactive Transport Modeling to Address the Issue of CO_2 Geological [Storage]." The following is the Abstract of this article: "One way for a reduction in the release of CO_2 to the atmosphere is to inject CO_2 into deep saline geological formations. Reactive transport modeling of hydrogeochemical processes is necessary to evaluate the behavior and performance of CO_2 geological [storage]. In this paper, [the authors] present two examples, (1) short-term changes in groundwater chemistry, and (2) long-term fate of injected CO_2, to illustrate applicability of the modeling." **T. Xu and J. Li**, *Procedia Earth and Planetary Science*. (Subscription may be required to view article.)

July 2013

"Assessing the feasibility of CO_2 storage in the New Albany Shale (Devonian–Mississippian) with potential enhanced gas recovery using reservoir simulation." The following is the Abstract of this article: "The feasibility of storing CO_2 in geologic formations as a means to mitigate global climate change is being evaluated around the globe. One option that has received limited attention is to store CO_2 in shale formations that are currently productive unconventional shale gas plays. While CO_2 trapping mechanisms in saline [formations] are primarily structural, capillary, solubility, and mineral trapping, the mechanisms are fundamentally different in gas shales, and CO_2 adsorption onto organic materials and clay minerals plays a key role. Shale gas formations have a high content of organic matter that may store significant amounts of adsorbed natural gas, ranging from 20 percent to 80 percent of original-gas-in-place. Laboratory and theoretical calculations suggest that CO_2 is adsorbed preferentially over methane onto the organics and could displace the methane (with up to a 5:1 ratio by molecule). This mechanism could be the basis of a new method of CCS that stores the CO_2 in gas shales with the potential added benefit of enhanced gas recovery …" **Faye Liu, Kevin Ellett, Yitian Xiao, and John A. Rupp**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"Effect of oxygen co-injected with carbon dioxide on Gothic shale caprock-CO_2-brine interaction during geologic carbon [storage]." The following is the Abstract of this article: "Co-injection of oxygen, a significant component in CO_2 streams produced by the oxyfuel combustion process, can cause a significant alteration of the redox state in deep geologic formations during geologic carbon [storage]. The potential impact of co-injected oxygen on the interaction between synthetic CO_2–brine (0.1 M NaCl) and shale caprock (Gothic shale from the Aneth Unit in Utah) and mobilization of trace metals was investigated at ~ 10 MPa and ~ 75°C. A range of relative volume percentages of O_2 to CO_2 (0, 1, 4 and 8

[percent]) were used in these experiments to address the effect of oxygen on shale–CO_2–brine interaction under various conditions. Major mineral phases in Gothic shale are quartz, calcite, dolomite, montmorillonite, and pyrite. During Gothic shale–CO_2–brine interaction in the presence of oxygen, pyrite oxidation occurred extensively and caused enhanced dissolution of calcite and dolomite. Pyrite oxidation and calcite dissolution subsequently resulted in the precipitation of Fe(III) oxides and gypsum ($CaSO_4 \cdot 2H_2O$). In the presence of oxygen, dissolved Mn and Ni were elevated because of oxidative dissolution of pyrite. The mobility of dissolved Ba was controlled by barite ($BaSO_4$) precipitation in the presence of oxygen. Dissolved U in the experimental brines increased to ~ 8–14 µg/L, with concentrations being slightly higher in the absence of oxygen than in the presence of oxygen. Experimental and modeling results indicate the interaction between shale caprock and oxygen co-injected with CO_2 during geologic carbon [storage] can exert significant impacts on brine pH, solubility of carbonate minerals, stability of sulfide minerals, and mobility of trace metals. The major impact of oxygen is most likely to occur in the zone near CO_2 injection wells where impurity gases can accumulate. Oxygen in CO_2–brine migrating away from the injection well will be continually consumed through the reactions with sulfide minerals in deep geologic formations." **Hun Bok Jung, Wooyong Um, and Kirk J. Cantrell**, *Chemical Geology*. (Subscription may be required to view article.)

"Experimental Assessment of CO_2-Mineral-Toxic Ion Interactions in a Simplified Freshwater [Formation]: Implications for CO_2 [Release] from Deep Geological Storage." The following is the Abstract of this article: "The possible intrusion of CO_2 into a given freshwater [formation] due to [release] from deep geological storage involves a decrease in pH, which has been directly associated with the remobilization of hazardous trace elements via mineral dissolution and/or via desorption processes. In an effort to evaluate the potential risks to potable water quality, the present study is devoted to experimental investigation of the effects of CO_2 intrusion on the mobility of toxic ions in simplified equilibrated [formations]. [The authors] demonstrate that remobilization of trace elements by CO_2 intrusion is not a universal physicochemical effect. In fact goethite and calcite, two minerals frequently found in [formations], could successfully prevent the remobilization of adsorbed Cu(II), Cd(II), Se(IV), and As(V) if CO_2 is intruded into a drinking water [formation]. Furthermore, a decrease in pH resulting from CO_2 intrusion could reactivate the adsorption of Se(IV) and As(V) if goethite and calcite are sufficiently available in underground layers. [The authors'] results also suggest that adsorption of cadmium and copper could be promoted by calcite dissolution. These adsorbed ions on calcite are not remobilized when CO_2 is intruded into the system, but it intensifies calcite dissolution. On the other hand, arsenite As(III) is significantly adsorbed on goethite, but is partially remobilized by CO_2 intrusion." **German Montes-Hernandez, François Renard , and Romain Lafay**, *Environ. Sci. Technol.* (Subscription may be required to view article.)

August 2013

"Pore system changes during experimental CO_2 injection into detritic rocks: Studies of potential storage rocks from some sedimentary basins of Spain." The following is the Abstract of this article: "The effects of experimental injection of CO_2 into potential deep sedimentary formations are investigated, focusing on detrital rocks with interconnected pore networks. This approach consisted in the qualitative and quantitative determination of mineralogical and textural changes in selected sedimentary rock samples after injection of supercritical CO_2 ($P \approx 75$ bar, $T \approx 35$°C, 12–970 h exposure time and dry conditions). The mineralogy and texture were studied before and after the injection by optical and scanning electron microscopy, and quantification was done with digital image analysis. The studied rocks were sampled from different sedimentary basins in Spain and consist of feldspar sandstones with similar mineralogy but different textures (homogeneous vs. heterogeneous). The results obtained in the CO_2-treated samples indicate a porosity increase ($\Delta n = 3.75$ [percent]) and a qualitative permeability rise. Intergranular clay matrix detachment and partial removal from the rock sample (due to CO_2 input/release drag and electrical-polarity forces) are the main processes that explain the porosity increase. In contrast, carbonate cements were stable and no substantial changes were observed. Additional textural changes

were minor and consisted on variations in the roughness of grain-pore contacts, pore shape and aspect ratio. Primary texture of the rock subjected to CO_2 injection is an important factor and seems to enhance textural/mineralogical changes in heterogeneous systems. These results simulate the CO_2 injection nearest to the injection well and indicate that, in this environment, where CO_2 push out the brine fluids and interacts with rocks in dry conditions, several mineralogy/texture re-adjustments take place. Consequences derived from these changes are variable. Possible porosity and permeability increases could facilitate further CO_2 injection but textural re-adjustment could also affect the rock physical properties." **E. Berrezueta, L. González-Menéndez, D. Breitner, and L. Luquot**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"Strategy for ranking potential CO_2 storage reservoirs: A case study for Belgium." The following is the Abstract of this article: "CCS is likely to become a necessary option in mitigating global climate change. However, lack of detailed knowledge on potential deep geological reservoirs can hamper the development of CCS. In this paper a new methodology is presented to assess and create exploration priority lists for poorly known reservoirs. Geological expert judgements are used as a basis in a two-stage geo-techno-economic approach, where first an estimate of the practical reservoir capacity is calculated, and secondly source–sink matching is used for calculating an estimate of the matched capacity and the reservoir development probability. This approach is applied to Belgium, demonstrating how a priority ranking for reservoirs can be obtained based on limited available data and large uncertainties. The results show the Neeroeteren Formation as the most prospective reservoir, followed by the Buntsandstein Formation and the Dinantian reservoirs. The findings indicate that CO_2 export to reservoirs in [neighboring] countries seems inevitable; still, there is a 70 [percent] chance storage will happen in Belgian reservoirs, with an average matched capacity estimate of 110 Mt CO_2. These quantitative results confirm the qualitative resource pyramid classification of potential reservoirs. For Belgium, a high economic risk is attached to reservoir exploration and development. Exploration remains however a necessity if CCS is to be deployed. Furthermore, it is shown that the presented methodology is indeed capable of producing realistic results, and that using expert judgements for reservoir assessments is valid and beneficial." **Kris Welkenhuysen, Andrea Ramírez, Rudy Swennen, and Kris Piessens**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"Development of a rate-based model for CO_2 absorption using aqueous NH_3 in a packed column." The following is the Abstract of this article: "A rigorous rate-based model for CO_2 absorption using aqueous ammonia in a packed column has been developed and used to simulate results from a recent pilot plant trial of an aqueous ammonia-based post-combustion capture process at the Munmorah Power Station, New South Wales, Australia. The model is based on the RateSep module, a rate-based absorption and stripping unit operation model in Aspen Plus, and uses the available thermodynamic, kinetic and transport property models for the NH_3–CO_2–H_2O system to predict the performance of CO_2 capture. The thermodynamic and transport property models satisfactorily predict experimental results from the published literature. The [modeling] results from the rate-based model also agree reasonably well with pilot plant results, including CO_2 absorption rate, NH_3 loss rate, temperature profiles and mass transfer coefficients in the absorber. To gain insights into absorption performance, [the authors] used the rate-based model to [analyze] the species concentration profile, temperature profile, mass transfer rate and coefficient in the gas and liquid bulk phase along the packing height." **Guojie Qi, Shujuan Wang, Hai Yu, Leigh Wardhaugh, Paul Feron, and Changhe Chen**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

Technology

September 2012

"Uncertainty Quantification in CO_2 Sequestration Using Surrogate Models from Polynomial Chaos Expansion." The following is the Abstract of this article: "In this paper, surrogate models are built iteratively using polynomial chaos expansion (PCE) and detailed numerical simulations of a carbon [storage] system. Output variables from a numerical simulator are approximated as polynomial functions of uncertain parameters. Once generated, PCE representations can be used in place of the numerical simulator and often decrease simulation times by several orders of magnitude. However, PCE models are expensive to derive unless the number of terms in the expansion is moderate, which requires a relatively small number of uncertain variables and a low degree of expansion. To cope with this limitation, instead of using a classical full expansion at each step of an iterative PCE construction method, [the authors] introduce a mixed-integer programming (MIP) formulation to identify the best subset of basis terms in the expansion. This approach makes it possible to keep the number of terms small in the expansion. Monte Carlo (MC) simulation is then performed by substituting the values of the uncertain parameters into the closed-form polynomial functions. On the basis of the results of MC simulation, the uncertainties of injecting CO_2 underground are quantified for a saline [formation]. Moreover, based on the PCE model, [the authors] formulate an optimization problem to determine the optimal CO_2 injection rate so as to maximize the gas saturation (residual trapping) during injection, and thereby minimize the chance of [release]." **Yan Zhang and Nikolaos V. Sahinidis**, *Ind. Eng. Chem. Res.*, Available online June 6, 2012, doi:10.1021/ie300856p, http://pubs.acs.org/doi/abs/10.1021/ie300856p. (Subscription required.)

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

"Molecular Simulation Studies of CO_2 Adsorption by Carbon Model Compounds for Carbon Capture and [Storage] Applications." The following is the Abstract of this article: "Effects of oxygen-containing surface functionalities on the adsorption of mixtures including CO_2/CH_4, CO_2/[nitrogen (N_2)], and CO_2/H_2O have been investigated in the current work. Together with Bader charge analysis, electronic structure calculations have provided the initial framework comprising both the geometry and corresponding charge information required to carry out statistical-based molecular simulations. The adsorption isotherms and selectivity of CO_2 from CO_2/N_2, CO_2/CH_4, and CO_2/H_2O gas mixtures were

determined by grand canonical Monte Carlo simulations at temperature/pressure conditions relevant to [CCS] applications. The interactions between the surfaces with induced polarity and nonpolar/polar molecules have been investigated. It has been observed that, due to the induced polarity of the surface functionalization, the selectivity of CO_2 over CH_4 increases from approximately 2 to higher than 5, and the selectivity of CO_2 over N_2 increases from approximately 5 to 20, especially in the low-pressure regime. However, water vapor will always preferentially adsorb over CO_2 in carbon-based systems containing oxygen functionalized surfaces at conditions relevant to carbon capture application. Molecular simulation results indicate that the surface chemistry in micropores is tunable thereby influencing the selectivity for enhanced uptake of CO_2." **Yangyang Liu and Jennifer Wilcox**, *Environ. Sci. Technol.*, Available online July 2, 2012, doi:10.1021/es3012029, http://pubs.acs.org/doi/abs/10.1021/es3012029. (Subscription required.)

October 2012

"Evaluation Method of CO_2 [Storage] and Enhanced Oil Recovery in an Oil Reservoir, as Applied to the Changqing Oilfields, China." The following is the Abstract of this article: "Injecting CO_2 into oil reservoirs was proven to have a great CO_2 [storage] capacity to reduce [GHG] emission and economic potentials via EOR. This paper proposes a CO_2 [storage] estimation method based on the material balance method, which considered the CO_2 displacement efficiency, CO_2 sweep efficiency, CO_2 dissolution, and some reservoir and fluid properties. The CO_2 EOR estimation method is also proposed and refers to the traditional petroleum engineering method. In the evaluation method of CO_2 [storage] and EOR potential, the [storage] coefficient and recovery factor are two important parameters. In this study, the stream tube simulation method is introduced to determine them. The evaluation method is applied to estimate the CO_2 [storage] capacity and EOR potential in the Changqing oilfield of China. The Changqing oilfield province lies in the Ordos Basin of western China. Published data indicate that the Changqing oilfield includes about 22 oilfields, and the majority of oil reservoirs are low-permeability reservoirs. The estimation results of CO_2 [storage] and EOR potential show that the Changqing oilfield is suitable for CO_2 [storage] and EOR and has great potential. Detailed evaluation of sequestration and EOR is worth further study." **Xiaoliang Zhao and Xinwei Liao**, *Energy Fuels*, Available online July 9, 2012, doi.10.1021/ef300783c, http://pubs.acs.org/doi/abs/10.1021/ef300783c (Subscription required.)

"Predicting Possible Effects of H_2S Impurity on CO_2 Transportation and Geological Storage." The following is the Abstract of this article: "For CO_2 geological storage, permitting impurities, such as [hydrogen sulfide (H_2S)], in CO_2 streams can lead to a great potential for capital and energy savings for CO_2 capture and separation, but it also increases costs and risk management for transportation and storage. To evaluate the cost–benefits, using a recently developed model, this study predicts phase equilibria and thermodynamic properties of the system H_2S–CO_2–[water (H_2O)]–[sodium chloride (NaCl)] under transportation and storage conditions and discusses potential effects of H_2S on transportation and storage. The prediction shows that inclusion of H_2S in CO_2 streams may lead to two-phase flow. For H_2S–CO_2 mixtures, at a given temperature, the bubble and dew pressures decrease with increasing H_2S content, while the mass density increases at low pressures and decreases at high pressures. For the CO_2–H_2S–H_2O system, the total gas solubility increases while the mass density of the aqueous solution with dissolved gas decreases. For the CO_2–H_2S–H_2O–NaCl system, at a given temperature, pressure and NaCl concentration, the solubility of the gas mixture in aqueous phase increases with increasing H_2S content and then decreases, while the mass density of aqueous solution decreases and may be lower than the mass density of the solution without gas dissolution." **Xiaoyan Ji and Chen Zhu**, *Environ. Sci. Technol.*, Available online July 23, 2012, doi:10.1021/es301292n, http://pubs.acs.org/doi/abs/10.1021/es301292n. (Subscription required.)

"Evaporite Caprock Integrity: An Experimental Study of Reactive Mineralogy and Pore-Scale Heterogeneity during Brine-CO_2 Exposure." The following is the Abstract of this article: "[The authors] present characterization and geochemical data from a core-flooding experiment on a sample from the Three Fingers evaporite unit forming the lower extent of caprock at the Weyburn-Midale reservoir,

Canada. This low-permeability sample was characterized in detail using X-ray computed microtomography before and after exposure to CO_2-acidified brine, allowing mineral phase and voidspace distributions to be quantified in three dimensions. Solution chemistry indicated that CO_2-acidified brine preferentially dissolved dolomite until saturation was attained, while anhydrite remained unreactive. Dolomite dissolution contributed to increases in bulk permeability through the formation of a localized channel, guided by microfractures as well as porosity and reactive phase distributions aligned with depositional bedding. An indirect effect of carbonate mineral reactivity with CO_2-acidified solution is voidspace generation through physical transport of anhydrite freed from the rock matrix following dissolution of dolomite. The development of high permeability fast pathways in this experiment highlights the role of carbonate content and potential fracture orientations in evaporite caprock formations considered for both geologic carbon [storage] and CO_2-[EOR] operations." **Megan M. Smith, Yelena Sholokhova, Yue Hao, and Susan A. Carroll**, *Environ. Sci. Technol.*, Available online July 25, 2012, doi:10/1021.es3012723, http://pubs.acs.org/doi/abs/10.1021/es3012723. (Subscription required.)

November 2012

"A SAFT equation of state for the quaternary H_2S-CO_2-H_2O-NaCl system." The following is the Abstract of this article: "Phase equilibria and thermodynamic properties of the quaternary H_2S–CO_2–H_2O–NaCl system were studied using a statistical associating fluid theory (SAFT)-based equation of state (EOS) at temperatures from 0 to 200°C (373.15–473.15 K), pressures up to 600 bar (60 MPa) and concentrations of NaCl up to 6 mol/kgH_2O. The understanding of the physical–chemical properties of this system is critical for predicting the consequences of co-injection of CO_2 and H_2S into geological formations (geological carbon [storage]) as an option for mitigating the global warming trend. [EOS] parameters were generated from regression of available and reliable experimental data and incorporation of existing parameters for some subsystems. Densities were predicted and compared with available experimental results. Using the EOS developed in this study, [the authors] predicted equilibrium compositions in both liquid and vapor phases, fugacity coefficients of components, the equilibrium pressures at a given composition of the H_2O-rich phase in electrolyte solutions with NaCl varying from 0 to 4 mol/kgH_2O, and the aqueous solution densities. These predicted values are tabulated and available as supplementary data in the electronic version online. These predictions provide information and guidance for future experiments regarding the thermodynamic properties and phase behaviors in the H_2S–CO_2–H_2O–NaCl system." **Xiaoyan Ji and Chen Zhu**, *Geochimica et Cosmochimica Acta*, Available online August 15, 2012, doi:10.1016/j.gca.2012.05.023, http://www.sciencedirect.com/science/article/pii/S0016703712003109. (Subscription may be required.)

"Process-based approach to CO_2 [release] detection by vadose zone gas monitoring at geologic CO_2 storage sites." The following is the Abstract of this article: "A critical issue for geologic carbon [storage] is the ability to detect CO_2 in the vadose zone. Here [the authors] present a new *process-based* approach to identify CO_2 that has [released] from deep geologic storage reservoirs into the shallow subsurface. Whereas current CO_2 concentration-based methods require years of background measurements to quantify variability of natural vadose zone CO_2, this new approach examines chemical relationships between vadose zone N_2, O_2, CO_2, and CH_4 to promptly distinguish a [release] signal from natural vadose zone CO_2. The method uses sequential inspection of the following gas concentration relationships: 1) O_2 versus CO_2 to distinguish in-situ vadose zone background processes (biologic respiration, methane oxidation, and CO_2 dissolution) from exogenous deep [release] input, 2) CO_2 versus N_2 to further distinguish dissolution of CO_2 from exogenous deep [release] input, and 3) CO_2 versus N_2/O_2 to assess the degree of respiration, CH_4 oxidation and atmospheric mixing/dilution occurring in the system. The approach was developed at a natural CO_2-rich control site and successfully applied at an engineered site where deep gases migrated into the vadose zone. The ability to identify gas [release] into the vadose zone without the need for background measurements could decrease uncertainty in [release] detection and expedite implementation of future geologic CO_2 storage projects." **K.D. Romanak, P.C. Bennett, Changbing Yang, and Susan D. Hovorka**, *Geophysical Research*

Letters, Published on August 15, 2012, doi:10.1029/2012GL052426, http://www.agu.org/pubs/crossref/2012/2012GL052426.shtml. (Subscription may be required.)

"Workflow using sparse vintage data for building a first geological and reservoir model for CO_2 geological storage in deep saline [formation]. A case study in the St. Lawrence Platform, Canada." The following is the Abstract of this article: "Among all geological CO_2 storage possibilities, deep saline [formations] are of great interest due to their worldwide repartition and their important storage volume. [The authors] present a workflow using available vintage data with poor 2D seismic coverage for building a first geological and reservoir model for CO_2 geological storage in the deep saline [formations] of the St. Lawrence Platform in the Bécancour area (Québec, Canada). In order to optimize the sparse available geoinformation using a geostatistical method, [the authors] krige the tops of the geological formations recorded at 11 wells using surfaces modeled from seismic horizons picked on 99.4 line-km of 2-D seismic reflection data. Modeled geological horizons show a good compromise between the geometric structure expressed by the variograms and the interpreted variations evaluated from seismic horizons. Using available well logs, distribution of porosity and permeability are computed for generating multiple realizations of the petrophysical properties of the targeted aquifer by sequential Gaussian simulations. The scarcity of available petrophysical data in the targeted aquifer generates high variability between the different realizations. Due to this uncertainty, the population of the 3-D geological model with petrophysical properties that are required for further geostatistical simulations of CO_2 injection do not allow to achieve reliable results. The methodology presented in this paper shows the possibilities and limits of using vintage data, and provides evidence that geophysical data acquired in a 3-D fashion are important to fully characterize a reservoir for CO_2 geological storage." **Maxime Claprood, Erwan Gloaguen, Bernard Giroux, Elena Konstantinovskaya, Michel Malo, and Mathieu J. Duchesne**, *Greenhouse Gases: Science and Technology*, Available online June 27, 2012, doi:10.1002/ghg.1292, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1292/abstract. (Subscription may be required.)

"Simulations of long-column flow experiments related to geologic carbon [storage]: efects of outer wall boundary condition on upward flow and formation of liquid CO_2." The following is the Abstract of this article: "Improving understanding of CO_2 migration, phase change, and trapping processes motivates the development of large-scale laboratory experiments to bridge the gap between bench-scale experiments and field-scale studies. Critical to the design of such experiments are defensible configurations that mimic relevant subsurface flow scenarios. [The authors] use numerical simulation with TOUGH2/ECO2M and ECO2N to design flow and transport experiments aimed at understanding upward flows including the transition of CO_2 from supercritical to liquid and gaseous forms. These experiments are designed for a large-scale facility such as the proposed laboratory for underground CO_2 investigations (LUCI). LUCI would consist of one or more long-column pressure vessels (LCPVs) several hundred meters in length filled with porous materials. An LCPV with an insulated outer wall corresponds to the column being at the center of a large upwelling plume. If the outer wall of the LCPV is assigned fixed temperature boundary conditions corresponding to the geothermal gradient, the LCPV represents a narrow upwelling through a fault or well. Numerical simulations of upward flow in the columns reveal complex temporal variations of temperature and saturation, including the appearance of liquid CO_2 due to expansion cooling. The results are sensitive to outer thermal boundary conditions. Understanding of the simulations is aided by time-series animations of saturation-depth profiles and trajectories through P-T (pressure-temperature) space with superimposed phase saturations. The strong dependence of flow on hydrologic properties and the lack of knowledge of three-phase relative permeability and hysteresis underlines the need for large-scale flow experiments to understand multiphase [release] behavior." **Curtis M. Oldenburg, Christine Doughty, Catherine A. Peters, and Patrick F. Dobson**, *Greenhouse Gases: Science and Technology*, Available online August 1, 2012, doi:10.1002/ghg.1294, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1294/abstract. (Subscription may be required.)

December 2012

"[Storage] of Flue Gas CO_2 by Direct Gas-solid Carbonation of Air Pollution Control System Residues." The following is the Abstract of this article: "Direct gas-solid carbonation reactions of residues from an air pollution control system (APCr) were conducted using different combinations of simulated flue gas to study the impact on CO_2 [storage]. X-ray diffraction analysis of APCr determined the existence of CaClOH, whose maximum theoretical CO_2 [storage] potential of 58.13 g CO_2/kg APCr was calculated by the reference intensity ratio method. The reaction mechanism obeyed a model of a fast kinetics-controlled process followed by a slow product layer diffusion-controlled process. Temperature is the key factor in direct gas-solid carbonation and had a notable influence on both the carbonation conversion and the CO_2 [storage] rate. The optimal CO_2 [storage] temperature of 395°C was conveniently obtained for APCr using a continuous heating experiment. [Carbon dioxide] content in the flue gas had a definite influence on the CO_2 [storage] rate of the kinetics-controlled process, but almost no influence on the final carbonation conversion. Typical concentrations of [sulfur dioxide (SO_2)] in the flue gas could not only accelerate the carbonation reaction rate of the product layer diffusion-controlled process, but also improve the final carbonation conversion. Maximum carbonation conversions of between 68.6 [percent] and 77.1 [percent] were achieved in a typical flue gas. Features of rapid CO_2 [storage] rate, strong impurities resistance, and high capture conversion for direct gas-solid carbonation were proved in this study, which presents a theoretical foundation for the applied use of this encouraging technology on [CCS]." **Sicong Tian and Jianguo Jiang**, *Environ. Sci. Technol.*, Available online November 26, 2012, doi:10.1021/es303713a, http://pubs.acs.org/doi/abs/10.1021/es303713a. (Subscription required.)

"Detecting Supercritical CO_2 in Brine at Sequestration Pressure with an Optical Fiber Sensor." The following is the Abstract of this article: "Monitoring of [stored] carbon is essential to establishing the environmental safety and the efficacy of geological carbon [storage]. [Storage] in saline [formations] requires the detection of supercritical CO_2 and CO_2-saturated brine as distinct from the native reservoir brine. Here [the authors] demonstrate an all-optical approach to detect both supercritical CO_2, and saturated brine under [storage] conditions. The method employs a long-period grating written on an optical fiber with a resonance wavelength that is sensitive to local refractive index within a pressure- and temperature-controlled apparatus at 40°C and 1400 [pounds per square inch (psi)] (9.65 MPa). The supercritical CO_2 and brine are clearly distinguished by a wavelength shift of 1.149 nm (refractive index difference of 0.2371). The CO_2-saturated brine is also detectable relative to brine, with a resonance wavelength shift of 0.192 nm (refractive index difference of 0.0396). Importantly, these findings indicate the potential for distributed, all-optical monitoring of CO_2 [storage] in saline [formations]." **Bo Bao, Luis Melo, Benjamin Davies, Hossein Fadaei, David Sinton, and Peter Wild**, *Environ. Sci. Technol.*, Available online November 15, 2012, doi:10.1021/es303596a, http://pubs.acs.org/doi/abs/10.1021/es303596a. (Subscription required.)

"Practical and Economic Aspects of the Ex-Situ Process: Implications for CO_2 [Storage]." The following is the Abstract of this article: "The risk of CO_2 [release] and the very slow rate of CO_2 dissolution in brine present major technical challenges for secure implementation of CO_2 [storage] at large scale in saline [formations]. To tackle these issues, a new technology based on Ex-Situ Dissolution Approach (ESDA) was developed recently aiming at dissolving CO_2 in brine phase prior to injection into the [formation] to eliminate or minimize the risk of [release] and accelerate CO_2 dissolution rate in brine. The ESDA is based on the mass transfer from CO_2 droplets into brine in co-current pipeline flow. This paper presents mass transfer modeling associated with the ESDA process concerning the evolution of the droplet size and the pressure change along the pipeline. In addition, a technical and economic feasibility of the ESDA in comparison with the standard CCS technologies is presented. Various aspects such as CO_2 displacement, geochemical reactions, CO_2 [release], pressure build-up, well spacing and dissolution efficiency for the ESDA are also discussed. This study enables the evaluation of the ESDA process for CO_2 [storage] through a systematic way." **Sohrab Zendehboudi, Alireza Bahadori, Ali**

Lohi, Ali Elkamel, and Ioannis Chatzis, *Energy Fuels*, Available online November 13, 2012, doi:10.1021/ef301278c, http://pubs.acs.org/doi/abs/10.1021/ef301278c. (Subscription required.)

January 2013

"Measurement of CO_2 Diffusivity for Carbon [Storage]: A Microfluidic Approach for Reservoir-Specific Analysis." The following is the Abstract of this article: "Predicting CO_2 security and capacity in [storage] requires knowledge of CO_2 diffusion into reservoir fluids. In this paper [the authors] demonstrate a microfluidic based approach to measuring the mutual diffusion coefficient of [CO_2] in water and brine. The approach enables formation of fresh CO_2–liquid interfaces; the resulting diffusion is quantified by imaging fluorescence quenching of a pH-dependent dye, and subsequent analyses. This method was applied to study the effects of site-specific variables—CO_2 pressure and salinity levels—on the diffusion coefficient. In contrast to established, macro-scale pressure–volume–temperature cell methods that require large sample volumes and testing periods of hours/days, this approach requires only microliters of sample, provides results within minutes, and isolates diffusive mass transport from convective effects. The measured diffusion coefficient of CO_2 in water was constant (1.86 [±0.26] × 10^{-9} m^2/s) over the range of pressures (5–50 bar) tested at 26°C, in agreement with existing models. The effects of salinity were measured with solutions of 0–5 M NaCl, where the diffusion coefficient varied up to [three] times. These experimental data support existing theory and demonstrate the applicability of this method for reservoir-specific testing." **Andrew Sell, Hossein Fadaei, Myeongsub Kim, and David Sinton**, *Environ. Sci. Technol.*, Available online October 23, 2012, doi:10.1021/es303319q, http://pubs.acs.org/doi/abs/10.1021/es303319q. (Subscription required.)

"A study of the effects of friction, heat transfer, and stream impurities on the decompression behavior in CO_2 pipelines." The following is the Abstract of this article: "A transient multi-phase outflow model is employed to study the effects of heat transfer and friction on the decompression behavior in CO_2 pipelines. The model's predictions are compared to measurements obtained from a number of shock tube experiments for gaseous phase CO_2 as well its various mixtures, typical of those found in the different capture technologies. Particular attention is paid to studying the impact of the stream impurities on the CO_2 mixtures saturation pressures and the decompression wave speeds given their direct influence on the pipeline's propensity to running ductile fractures." **Haroun Mahgerefteh, Solomon Brown, and Sergey Martynov**, *Greenhouse Gases: Science and Technology*, Available online September 24, 2012, doi:10.1002/ghg.1302, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1302/abstract. (Subscription may be required.)

"Model verification and evaluation of the rich-split process modification at an Australian-based post combustion CO_2 capture pilot plant." The following is from the Abstract of this article: "The [Commonwealth Scientific and Industrial Research Organization (CSIRO)] is involved in three CO_2 capture pilot plants operating at different coal-fired power stations throughout Australia. The most recently completed of these is the Tarong CO_2 capture pilot plant located at Tarong power station, Nanango, Queensland. The first phase of the experimental program with this pilot plant included operation with monoethanolamine (MEA). This involved parametric studies, process modifications, and finally implementation of [24-hour] operation. Operation of the pilot plant has shown MEA to be effective in capturing CO_2 from the flue gas from Tarong Power Station. CO_2 capture efficiencies of up to 94 [percent], and regeneration energies as low as 3.6 MJ/kgCO_2 have been achieved..." **Ashleigh Cousins, Aaron Cottrell, Anthony Lawson, Sanger Huang, and Paul H.M. Feron**, *Greenhouse Gases: Science and Technology*, Available online September 24, 2012, doi:10.1002/ghg.1295, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1295/abstract. (Subscription may be required.)

"Upscaling and its application in numerical simulation of long-term CO_2 storage." The following is the Abstract of this article: "Numerical simulations of long-term geological CO_2 storage could be particularly useful in predicting the capacity, security, and other consequences of CO_2 [storage]. The physics of this flow is essentially a multiphase multicomponent phenomenon in a strongly heterogeneous

medium necessitating the need for a computationally prohibitive resolution to capture the various physical processes at all scales. Upscaling is an important step in these simulations when going from geostatistical models featuring strong heterogeneities to the simulation models which in practice are limited because of computational restrictions. Although many different upscaling techniques exist, including dynamic and steady-state methods, thorough analyses of their application to CO_2 [storage] are not yet established. This review aims to highlight the recent developments in the application of upscaling to the modeling of long-term CO_2 storage and provide insights into aspects that could prove valuable to numerical simulations." **Wasim A. Akber Hassan and Xi Jiang**, *Greenhouse Gases: Science and Technology*, Available online October 26, 2012, doi:10.1002/ghg.1306, http://onlinelibrary.wiley.com/doi/10.1002/ghg.1306/abstract. (Subscription may be required.)

February 2013

"Development of CO_2 terminal and CO_2 carrier for future commercialized CCS market." The following is the Abstract of this article: "So far CO_2 shipping has only been introduced as a secondary option for long distances and small amounts because of the prevailing idea that CO_2 shipping is more expensive than CO_2 pipeline for transporting large amount CO_2. This paper shows that CO_2 terminal and large CO_2 carrier can play a role of collecting CO_2 from several sources and transporting CO_2 in large volume so transport cost per tonnage of CO_2 can be reduce in commercialized CCS market. Multi-stage CO_2 liquefaction processes are developed to reduce total cost of CO_2 compression and transport. For high pressure CO_2 inlet stream, newly developed multi-stage liquefaction process with serial flash tanks enables power consumption reduced to 44 [percent] compared to single stage liquefaction process. By adopting new design concept of very large CO_2 Carrier more than 40,000 m^3, optimal size of CO_2 carrier can be provided for each voyage route and total cost of CO_2 compression and transport is reduced. The results of economic assessment of CO_2 transport show that CO_2 shipping is economically competitive to CO_2 pipeline even in the distance of 200–300 km for large amount of CO_2 transport such as 10 Mt CO_2/year or 20 Mt CO_2/year. [Carbon dioxide] transport by ship should be seriously re-considered as an effective transport method for commercialized CCS projects as well as early demonstration projects." **Byeong-Yong Yoo, Dong-Kyu Choi, Hyun-Jin Kim, Young-Sik Moon, Hee-Seung Na, and Sung-Geun Lee**, *International Journal of Greenhouse Gas Control*, (Subscription may be required to view article.)

"U.S. Department of Energy Efforts to Advance Remote Sensing Technologies for Monitoring Geologic Storage Operations." 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 storage technologies. Monitoring, verification, accounting and assessment (MVA) is an essential element of geologic CO_2 storage projects, since without MVA it is not possible to understand the fate of CO_2 in the injection formation or to monitor any potential CO_2 releases to underground sources of drinking water (USDW) or the atmosphere. Determining the location of CO_2 in the subsurface and identifying indicators of the potential release of CO_2 to the atmosphere are significant challenges requiring the adoption of existing technologies as well as novel approaches for monitoring large areas above a storage reservoir. Remote sensing technologies could offer a solution. Remote sensing refers to the use of monitoring tools that can gather data at a location remote to the area of interest, and could provide an option for non-invasive and large scale spatial monitoring. NETL has been developing and deploying remote sensing applications over the past decade to improve monitoring of both geologic and terrestrial carbon storage projects. MVA remote sensing tools being developed or improved by NETL sponsored research include interferometric synthetic aperture radar (InSAR), tiltmeters/GPS, remote operated vehicles (ROVs), SEQURE™, light detection and ranging (LIDAR), and multi-spectral/hyper-spectral scanning. Benefits associated with NETL's remote sensing effort include development and deployment of non-intrusive tracking and monitoring technologies, reduced manpower requirements needed to meet potential regulated MVA requirements, and reduced costs to implement monitoring technologies. These technologies can provide early detection of CO_2 releases which, in turn, will allow for further refinement of project monitoring protocols using more conventional detection and mitigation technologies to better

pinpoint CO_2 location. This paper addresses selected remote sensing techniques under NETL development and field deployment of these Technologies." **John Litynski, Derek Vikara, Malcolm Webster, and Rameshwar Srivastava**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"The Synergistic Pursuit of Advances in MMV Technologies for CO_2-Enhanced Recovery and CO_2 Storage." The following is the Abstract of this article: "The importance of using a full suite of reservoir diagnostic and feedback systems [monitoring, verification, and accounting (MMV)] for CO_2-EOR and CO_2 storage was first learned at the classic CO_2 flood at SACROC in the Permian Basin of West Texas. With information gained from MMV leading to well remediation and changes in operating practices, the new operator of the SACROC CO_2 flood (Kinder-Morgan) converted a low performing, being terminated CO_2 flood producing 3,000 B/D into a CO_2 flood that currently provides 25,000 B/D. Since then, a significant number of companies have begun to incorporate sophisticated MMV technologies into management of [CO_2-EOR]. Comparable advances in MMV technologies for CO_2 storage are being supported by [DOE/NETL's] CCUS Regional Partnership Program. As a result, The DOE-funded research into technologies that 'see' CO_2 underground, developed for the purpose of ensuring CO_2 [storage] within the target formation, are gaining significant spill-over applications for optimizing [CO_2-EOR] operations." **Vello Kuuskraa, Phil Dipietro, and John Litynski**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

March 2013

"Opportunities for Utilizing Anthropogenic CO_2 for Enhanced Oil Recovery and CO_2 Storage." The following is the Abstract of this article: "[Carbon dioxide]-EOR has emerged as a major option for productively utilizing CO_2 emissions captured from electric power and other industrial facilities as part of CCS operations. Not only can depleting oil fields provide secure, well characterized sites for storing CO_2, such fields can also provide a source of revenues to offset the costs of capturing CO_2 by producing incremental oil. This paper draws significantly on work by Advanced Resources, sponsored by DOE/NETL, and IEAGHG, that demonstrates that CO_2-EOR offers large CO_2 storage capacity potential, and could accommodate a major portion of the CO_2 captured from industrial facilities for the next 30 years. This work also demonstrates that CO_2 can be effectively and permanently stored when deployed in association with CO_2-EOR, with the amount stored depending on the priority placed on maximizing storage. In addition to showing that CCS benefits from CO_2-EOR by providing the revenues from sale of CO_2, overcoming other barriers, while producing oil with a lower CO_2 emissions 'footprint.' The report demonstrates that CO_2-EOR needs CCS; because large-scale future implementation of CO_2-EOR will be dependent on CO_2 supplies from industrial sources." **Michael L. Godec, Vello A. Kuuskraa, and Phil Dipietro**, *Energy Fuels*. (Subscription may be required to view article.)

"Chemical and Mechanical Properties of Wellbore Cement Altered by CO_2-Rich Brine Using a Multianalytical Approach." The following is the Abstract of this article: "Defining chemical and mechanical alteration of wellbore cement by CO_2-rich brines is important for predicting the long-term integrity of wellbores in geologic CO_2 environments. [The authors] reacted CO_2-rich brines along a cement-caprock boundary at 60°C and pCO_2 = 3 MPa using flow-through experiments. The results show that distinct reaction zones form in response to reactions with the brine over the [eight]-day experiment. Detailed characterization of the crystalline and amorphous phases, and the solution chemistry show that the zones can be modeled as preferential portlandite dissolution in the depleted layer, concurrent calcium silicate hydrate (CSH) alteration to an amorphous zeolite and Ca-carbonate precipitation in the carbonate layer, and carbonate dissolution in the amorphous layer. Chemical reaction altered the mechanical properties of the core lowering the average Young's moduli in the depleted, carbonate, and amorphous layers to approximately 75, 64, and 34 [percent] of the unaltered cement, respectively. The decreased elastic modulus of the altered cement reflects an increase in pore space through mineral dissolution and different moduli of the reaction products." **Harris E. Mason, Wyatt L. Du Frane, Stuart**

D.C. Walsh, Zurong Dai, Supakit Charnvanichborikarn, and Susan A. Carroll, *Environmental Science and Technology*. (Subscription may be required to view article.)

"A Methodology for Phased Development of a Hypothetical Pipeline Network for CO_2 Transport During Carbon Capture, Utilization, and Storage." The following is the Abstract of this article: "If implemented on a commercial scale, [CCS] has the potential to significantly reduce CO_2 emissions. Moving the CO_2 from the point sources to the geologic storage locations will likely require a pipeline network. The Plains CO_2 Reduction (PCOR) Partnership developed a four-step methodology that can be used to estimate the length, cost, and time frame of a hypothetical pipeline network that would be built in phases. The methodology was tested during a case study in which a hypothetical phased pipeline network was estimated for the PCOR Partnership region. The hypothetical pipeline network consisted of trunk lines roughly 10,780 km in total length that could provide an overall CO_2 reduction for the region of about 555.6 M[metric tons] CO_2/yr by 2050. The results also indicate that an extensive pipeline network may not be required to transport to storage locations the quantity of CO_2 required to meet the emission reduction targets for the PCOR Partnership region." **Melanie D. Jensen, Peng Pei, Anthony C. Snyder, Loreal V. Heebink, Lisa S. Botnen, Charles Gorecki, Edward N. Steadman, and John A. Harju,** *Energy Fuels*. (Subscription may be required to view article.)

"Effects of CO_2 and acid gas injection on enhanced gas recovery and storage." The following is the Abstract of this article: "[Storage] of CO_2 and other associated waste gases in natural gas reservoirs is an option to mitigate [GHGs] and enhanced gas recovery. This paper examines strategies to maximize enhanced gas recovery in a natural gas reservoir via subsurface storage of potential associated waste gases such as CO_2 and hydrogen sulfide (H_2S). Numerical simulations are performed with a compositional reservoir simulator 'Tempest' using experimental data initially produced by Clean Gas Technology Australia (CGTA) at Curtin University in 2009. The simulation results shows that additional gas is recovered by gas-gas displacement after injecting CO_2 and acid gas (CO_2–H_2S) in two separate scenarios. Importantly, when pure CO_2 is injected, CO_2 breakthrough at the production well occurred faster than the breakthrough under mixed CO_2–H_2S injection." **Chawarwan Khan, Robert Amin, and Gary Madden**, *Journal of Petroleum Exploration and Production Technology*. (Subscription may be required to view article.)

"Porous Media Compressed-Air Energy Storage (PM-CAES): Theory and Simulation of the Coupled Wellbore–Reservoir System." The following is the Abstract of this article: "Expansion in the supply of intermittent renewable energy sources on the electricity grid can potentially benefit from implementation of large-scale compressed air energy storage in porous media systems (PM-CAES) such as [formations] and depleted hydrocarbon reservoirs. Despite a large government research program 30 years ago that included a test of air injection and production in a [formation], and an abundance of literature on CAES mostly relevant to caverns, there remain fundamental questions about the hydrologic and energetic performance of PM-CAES. [The authors] have developed rigorous simulation capabilities for PM-CAES that include modeling the coupled wellbore–reservoir system. Through consideration of a prototypical PM-CAES wellbore–reservoir system representing a depleted hydrocarbon reservoir, [the authors] have simulated 100 daily cycles of PM-CAES. [The authors] find that (1) PM-CAES can store energy but that pervasive pressure gradients in PM-CAES result in spatially variable energy storage density in the reservoir, (2) the wellbore–reservoir storage component of PM-CAES is very efficient, (3) [caprock] and hydrologic seals along with proper sizing of the PM-CAES reservoir prevent excess pressure diffusion from being a problem, and (4) injection and production of air does not significantly mobilize residual liquid water in the reservoir." **Curtis M. Oldenburg and Lehua Pan**, *Transport in Porous Media.* (Subscription may be required to view article.)

April 2013

"A review of carbon dioxide capture and storage technology using coal fly ash." The following is the Abstract of this article: "This work reviews the availability and the potential of the CCS technology

using coal fly ash (FA). Because the technology can be effectively applied on-site to coal fired power plants and as FA contains sufficient alkali components, the technology may be another option of CCS technology to a limited extent. The technology can be divided into wet and dry processes. In the former, the available components for CCS in FA are leached into solution by the solvent where they are subsequently consumed for carbonation to store CO_2. Particularly, the CO_2 storage capacity of [calcium oxide (CaO)]-enriched FA solution mixed with brine under high pressure may be equal to or greater than the true CO_2 emission reduction achieved by applying FA as a cement additive. In the dry process, FA can be used as a direct support or as the raw material of the sorbent supports for CO_2 capture. The dry process is effectively applied for CO_2 capture rather than storage because the sorbents should be regenerated. Another advantage of the technology is the stabilization of the harmful components present in FA, which are mostly co-precipitated with carbonated FA during the process." **Jung-Ho Wee**, *Applied Energy*. (Subscription may be required to view article.)

"Adsorption of Carbon Dioxide, Methane, and Their Mixtures in Porous Carbons: Effect of Surface Chemistry, Water Content, and Pore Disorder." The following is the Abstract of this article: "The adsorption of [CO_2], methane, and their mixtures in nanoporous carbons in the presence of water is studied using experiments and molecular simulations. Both the experimental and numerical samples contain polar groups that account for their partially hydrophilicity. For small amounts of adsorbed water, although the shape of the adsorption isotherms remain similar, both the molecular simulations and experiments show a slight decrease in the CO_2 and CH_4 adsorption amounts. For large amounts of adsorbed water, the experimental data suggest the formation of methane or [CO_2] clathrates in agreement with previous work. In contrast, the molecular simulations do not account for the formation of such clathrates. Another important difference between the simulated and experimental data concerns the number of water molecules that desorb upon increasing the pressure of [CO_2] and methane. Although the experimental data indicate that water remains adsorbed upon [CO_2] and methane adsorption, the molecular simulations suggest that 40 to 75 [percent] of the initial amount of adsorbed water desorbs with [CO_2] or methane pressure. Such discrepancies show that differences between the simulated and experimental samples are crucial to account for the rich phase behavior of confined water–gas systems. [The authors'] simulations for [CO_2]–methane coadsorption in the presence of water suggest that the pore filling is not affected by the presence of water and that adsorbed solution theory can be applied for pressures as high as 15 MPa." **Pierre Billemont, Benoit Coasne, and Guy De Weireld**, *Langmuir*. (Subscription may be required to view article.)

"Evaluation of Cubic, SAFT, and PC-SAFT Equations of State for the Vapor-Liquid Equilibrium Modeling of CO_2 Mixtures with Other Gases." The following is from the Abstract of this article: "Accurate thermodynamic models for phase equilibria calculations of [CO_2] mixtures with other gases are of high importance for the safe and economic design of CCS technologies. In this work, [the authors] assess the capability of Redlich–Kwong (RK), Soave–Redlich–Kwong (SRK), Peng–Robinson (PR) cubic equations of state (EoS), as well as Statistical Associating Fluid Theory (SAFT) and Perturbed-Chain SAFT (PC-SAFT) in modeling vapor–liquid equilibria for binary mixtures of CO_2 with [methane (CH_4), nitrogen (N_2), oxygen (O_2), sulfur dioxide (SO_2), argon (Ar), and hydrogen sulfide (H_2S)], and for the ternary mixture CO_2–N_2–O_2. Liquid density calculations for some of these mixtures are also performed. Experimental data available are used to assess the accuracy of the models. Two different expressions are used for the calculation of parameter α in PR EoS. PC-SAFT is, on average, more accurate than cubic EoS and SAFT when no binary interaction parameter is used. However, when a binary interaction parameter fitted to the experimental data is used, model correlations from SRK, PR, SAFT, and PC-SAFT are of comparable accuracy." **Nikolaos I. Diamantonis, Georgios C. Boulougouris, Erum Mansoor, Dimitrios M. Tsangaris, and Ioannis G. Economou**, *Ind. Eng. Chem. Res*. (Subscription may be required to view article.)

"Geochemical tracers applied to reservoir simulation of the Weyburn CO_2 EOR field." The following is the Abstract of this article: "The results of integrating processes affecting selected geochemical tracers into a model of fluid flow and phase [behavior] at the Weyburn CO_2 EOR Field are

presented. Flow patterns, and phase [behaviors] are obtained from a reservoir model, which had been history matched to fluid (oil and water) production rates as part of the IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project. The reservoir model was updated by including tracer components with properties similar to those measured in produced fluids as part of the same project. The [modeling] results are compared with field values of chloride in produced water and the carbon isotope ratio of ethane, $\delta^{13}C(C_2H_6)$, in produced gases. An accurate representation of the processes responsible for generating these, relatively simple, signals is a prerequisite for any future simulations incorporating reactive transport, such as would be needed to quantify rates of reactions between the injected CO_2 and the host-rock. [Modeling] runs based on the previously developed history-matched single-porosity reservoir model failed to reproduce the variability seen in produced fluids for either a conservative major ion or $\delta^{13}C(C_2H_6)$. Modifications incorporating fracture flow through use of a dual-porosity reservoir description lead to calculated chemical signals that were more compatible with the field observations." **S. Talman, E. Perkins, A. Jafari, and M. Shevalier**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"Multiphase compositional [modeling] of CO_2 injection under subcritical conditions: The impact of dissolution and phase transitions between liquid and gaseous CO_2 on reservoir temperature." The following is the Abstract of this article: "[Modeling] of CO_2–H_2O mixture flows in a porous media under subcritical conditions remains a challenging issue for carbon [storage] and possible [release] scenarios. Currently, there is no widely used and generally accepted numerical model that can simulate three-phase flows with both gaseous and liquid CO_2-rich phases. [The authors] propose a new compositional [modeling] approach for sub- and supercritical three-phase flows of water, liquid CO_2 and gaseous CO_2. The new approach is based on the calculation of the thermodynamic potential of the mixture as a function of pressure, total enthalpy and mixture composition and storing it values as a spline table, which is then used for the hydrodynamic simulation. A three-parametric [generalization] of the Peng–Robinson equation of state is used to fit the experimental data on CO_2–H_2O mixture properties. Using the approach developed in this paper, [the authors] assess several sample problems of CO_2 injection in shallow reservoirs for the purpose of testing the model. [The authors] provide the simulation results for a simple 1D problem with a homogeneous reservoir and for a more complicated 2D problem with a highly heterogeneous reservoir using data from the 10th SPE comparative project reservoir. [The authors analyze] the temperature variations in the reservoir due to the dissolution of CO_2 in water and the evaporation of liquid CO_2. The interplay of these processes results in a complicated non-monotonic temperature distribution. At different distances from the CO_2 injection point, the temperature can either decrease or increase with respect to the reservoir temperature before injection. The main phenomenon responsible for the considerable temperature decline around the CO_2 injection point is the liquid CO_2 evaporation process." **Andrey A. Afanasyev**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

May 2013

"Experimental study of potential wellbore cement carbonation by various phases of carbon dioxide during geologic carbon [storage]." The following is the Abstract of this article: "Hydrated Portland cement was reacted with CO_2 in supercritical, gaseous and aqueous phases to understand the potential cement alteration processes along the length of a wellbore, extending from a deep CO_2 storage reservoir to the shallow subsurface during geologic C [storage]. The 3-D X-ray microtomography (XMT) images showed that the cement alteration was significantly more extensive with CO_2-saturated synthetic groundwater than dry or wet supercritical CO_2 at high P (10 MPa)-T (50°C) conditions. Scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS) analysis also exhibited a systematic Ca depletion and C enrichment in cement matrix exposed to CO_2-saturated groundwater. Integrated XMT, XRD and SEM-EDS analyses identified the formation of an extensive carbonated zone filled with $CaCO_3$(s), as well as a porous degradation front and an outermost silica-rich zone in cement after exposure to CO_2-saturated groundwater. Cement alteration by CO_2-saturated groundwater for [two to

eight] months overall decreased the porosity from 31 [percent] to 22 [percent] and the permeability by an order of magnitude. Cement alteration by dry or wet supercritical CO_2 was slow and minor compared to CO_2-saturated groundwater. A thin single carbonation zone was formed in cement after exposure to wet supercritical CO_2 for [eight] months or dry supercritical CO_2 for 15 months. An extensive calcite coating was formed on the outside surface of a cement sample after exposure to wet gaseous CO_2 for [one to three] months. The chemical-physical characterization of hydrated Portland cement after exposure to various phases of CO_2 indicates that the extent of cement carbonation can be significantly heterogeneous depending on the CO_2 phase present in the wellbore environment. Both experimental and geochemical modeling results suggest that wellbore cement exposure to supercritical, gaseous and aqueous phases of CO_2 during geologic C [storage] is unlikely to damage the wellbore integrity because cement alteration by all phases of CO_2 is dominated by carbonation reactions. This is consistent with previous field studies of wellbore cement with extensive carbonation after exposure to CO_2 for [three] decades. However, XMT imaging indicates that preferential cement alteration by supercritical CO_2 or CO_2-saturated groundwater can occur along the cement-steel or cement-rock interfaces. This highlights the importance of further investigation of cement degradation along the interfaces of wellbore materials to ensure permanent geologic C storage." (Subscription may be required to view article.)

"Modeling the investment in carbon capture retrofits of pulverized coal-fired plants." The following is the Abstract of this article: "This paper focuses on the investment decision to retrofit an existing supercritical pulverized coal (SCPC) unit with CCS technology. [The authors] establish a valuation model with discrete sequential investment decision-making based on real options theory, and [the authors] consider the following uncertainty factors: electricity price, carbon price, CCS investment cost and CO_2 additional [operation and maintenance (O&M)] cost. [The authors] also take CCS operation flexibility into account. [The authors] solve the model using the least squares Monte Carlo (LSM) method. [The authors] employ four indicators—cost saving value, investment risk, emission abatement amount and average capture rate—to evaluate the investment decision to retrofit China's existing SCPC unit with CCS. The results illustrate the following: (1) CO_2 capture (additional O&M) cost can be the most significant factor that will affect CCS retrofit investment; (2) the existing level of CCS technology and policy framework cannot support the plant owner to retrofit the existing SCPC unit with CCS; and (3) the carbon price or capture subsidy must be at a high level to control the CCS retrofit investment risk such that it is less than [five percent]. [The authors'] proposed model is most suitable for plant owners' CCS retrofit decisions." **Lei Zhu and Ying Fan**, *Energy*. (Subscription may be required to view article.)

"Planning of carbon capture and storage with pinch analysis techniques." The following is the Abstract of this article: "CCS is a means for reducing CO_2 emissions from fossil fuel combustion in power generation and industrial processes. It involves the capture of CO_2 for subsequent storage in various geological formations. The selection and matching of the power plants and storage sites are often an issue of optimization due to various constraints, i.e., time of availability, injection rate, and storage capacity limits. In this work, a novel graphical targeting tool based on pinch analysis is proposed to address the planning problem of the storage of captured CO_2 from power generating plants into corresponding reservoirs. The main consideration for the problem is the time of availability of the latter, since reservoirs need to be developed prior to CO_2 storage. The time limitation is addressed by the graphical technique where time is taken as the governing element in solving the problem. Hypothetical examples are used to elucidate the proposed approach." **Raymond E.H. Ooi, Dominic C.Y. Foo, Denny K.S. Ng, and Raymond R. Tan**, *Chemical Engineering Research and Design*. (Subscription may be required to view article.)

June 2013

"Mesoporous Carbon-Supported Solid Amine Sorbents for Low-Temperature Carbon Dioxide Capture." The following is the Abstract of this article: "A novel solid amine sorbent has been developed based on polyethylenimine (PEI)-impregnated mesoporous carbon (MC) supports for regenerative removal of pure CO_2 at low temperature. The adequate pore volume, proper pore size, and

interconnected 3D framework of as-prepared MC allow the easy dispersion and immobilization of PEI within their channels. The structure generates considerable gas/amine interfacial area and provides access to fast CO_2 diffusion for reactivity with the amine groups. In addition, the kinetic inhibition of CO_2 diffusion within the PEI films could be alleviated by the introduction of polymer-based surfactant, offering an increased number of reactive sites and higher utilization efficiency of amine groups. Owing to the advanced support and facilitating kinetic diffusion, as-prepared MC-based solid amines display outstanding sorption features for CO_2 capture at low-temperature range. The highest sorption capacities of 4.67 $mmol \cdot g^{-1}$ at 30°C and 2.80 $mmol \cdot g^{-1}$ at 0°C for pure CO_2 are attained. They also show fast kinetics, a good selectivity for CO_2/[nitrogen (N_2)] separation, and very reversible and durable CO_2 capturing performance at low temperature. All the results suggest that MC-based solid amine sorbent is a promising CO_2 sorbent to meet the challenges of the current CO_2 capture and storage technology." **Jitong Wang, Mei Wang, Beibei Zhao, Wenming Qiao, Dong hui Long, and Licheng Ling**, *Ind. Eng. Chem. Res*. (Subscription may be required to view article.)

"Large-Scale Screening of Zeolite Structure for CO_2 Membrane Separations." The following is the Abstract of this article: "[The authors] have conducted large-scale screening of zeolite materials for CO_2/[methane (CH_4)] and CO_2/N_2 membrane separation applications using the free energy landscape of the guest molecules inside these porous materials. [The authors] show how advanced molecular simulations can be integrated with the design of a simple separation process to arrive at a metric to rank performance of [more than 87,000] different zeolite structures, including the known IZA zeolite structures. [The authors'] novel, efficient algorithm using graphics processing units can accurately characterize both the adsorption and diffusion properties of a given structure in just a few seconds and accordingly find a set of optimal structures for different desired purity of separated gases from a large database of porous materials in reasonable wall time. [The authors'] analysis reveals that the optimal structures for separations usually consist of channels with adsorption sites spread relatively uniformly across the entire channel such that they feature well-balanced CO_2 adsorption and diffusion properties. [The authors'] screening also shows that the top structures in the predicted zeolite database outperform the best known zeolite by a factor of 4–7. Finally, [the authors] have identified a completely different optimal set of zeolite structures that are suitable for an inverse process, in which the CO_2 is retained while CH_4 or N_2 is passed through a membrane." **Jihan Kim, Mahmoud Abouelnasr, Li-Chiang Lin, and Berend Smit**, *J. Am. Chem. Soc*. (Subscription may be required to view article.)

"Dynamic Evolution of Cement Composition and Transport Properties under Conditions Relevant to Geological Carbon [Storage]." The following is the Abstract of this article: "Assessing the possibility of CO_2 [release] is one of the major challenges for geological carbon [storage]. Injected CO_2 can react with wellbore cement, which can potentially change cement composition and transport properties. In this work, [the authors] develop a reactive transport model based on experimental observations to understand and predict the property evolution of cement in direct contact with CO_2-saturated brine under diffusion-controlled conditions. The model reproduced the observed zones of portlandite depletion and calcite formation. Cement alteration is initially fast and slows down at later times. This work also quantified the role of initial cement properties, in particular the ratio of the initial portlandite content to porosity (defined here as φ), in determining the evolution of cement properties. Portlandite-rich cement with large φ values results in a localized 'sharp' reactive diffusive front characterized by calcite precipitation, leading to significant porosity reduction, which eventually clogs the pore space and prevents further acid penetration. Severe degradation occurs at the cement–brine interface with large φ values. This alteration increases effective permeability by orders of magnitude for fluids that preferentially flow through the degraded zone. The significant porosity decrease in the calcite zone also leads to orders of magnitude decrease in effective permeability, where fluids flow through the low-permeability calcite zone. The developed reactive transport model provides a valuable tool to link cement–CO_2 reactions with the evolution of porosity and permeability. It can be used to quantify and predict long-term wellbore cement behavior and can facilitate the risk assessment associated with geological CO_2 [storage]." **Jean-Patrick Leopold Brunet, Li Li, Zuleima T. Karpyn, Barbara G. Kutchko, Brian Strazisar, and Grant Bromhal**, *Energy Fuels*. (Subscription may be required to view article.)

"Wettability of Supercritical Carbon Dioxide/Water/Quartz Systems: Simultaneous Measurement of Contact Angle and Interfacial Tension at Reservoir Conditions." The following is the Abstract of this article: "Injection of [CO_2] in deep saline [formations] is considered as a method of carbon [storage]. The efficiency of this process is dependent on the fluid–fluid and rock-fluid interactions inside the porous media. For instance, the final storage capacity and total amount of capillary-trapped CO_2 inside [a formation] are affected by the interfacial tension between the fluids and the contact angle between the fluids and the rock mineral surface. A thorough study of these parameters and their variations with temperature and pressure will provide a better understanding of the carbon [storage] process and thus improve predictions of the [storage] efficiency. In this study, the controversial concept of wettability alteration of quartz surfaces in the presence of supercritical carbon dioxide (sc-CO_2) was investigated. A novel apparatus for measuring interfacial tension and contact angle at high temperatures and pressures based on Axisymmetric Drop Shape Analysis with no-Apex (ADSA-NA) method was developed and validated with a simple system. Densities, interfacial tensions, and dynamic contact angles of CO_2/water/quartz systems were determined for a wide range of pressures and temperatures relevant to geological [storage] of CO_2 in the subcritical and supercritical states. Image analysis was performed with ADSA-NA method that allows the determination of both interfacial tensions and contact angles with high accuracy. The results show that supercritical CO_2 alters the wettability of quartz surface toward less water-wet conditions compared to subcritical CO_2. Also [the authors] observed an increase in the water advancing contact angles with increasing temperature indicating less water-wet quartz surfaces at high temperatures." **Soheil Saraji, Lamia Goual, Mohammad Piri, and Henry Plancher**, *Langmuir*. (Subscription may be required to view article.)

July 2013

"Heavy oil production by carbon dioxide injection." The following is the Abstract of this article: "With the depletion of light oil, heavy oil is becoming one of the most promising resources for meeting future energy consumption. Heavy oil resources are abundant, but the traditional water flooding method can only achieve less than 20 [percent] of heavy oil recovery. Thermal recovery has proven effective in producing heavy oil, but not suitable for many heavy oil formations that are either thin or buried deep underground. Carbon Dioxide injection is a 'win-win' EOR technique for many heavy oil fields. Injected CO_2 not only increases heavy oil output, but also traps injected CO_2 underground. Carbon dioxide effectively recovers heavy oil thanks to several mechanisms, including oil swelling, viscosity reduction, and blow-down recovery. This review discusses the advances of CO_2 flooding at both laboratory scale and field scale. Laboratory tests show that CO_2 can significantly improve heavy oil recovery. Several field cases in the USA, Turkey, Trinidad, and China are reviewed. Field experiences show that CO_2 flooding is a successful EOR method for heavy oil fields. However, some issues were encountered in field applications, such as early gas breakthrough, corrosion, CO_2 availability, and high costs." **Changhong Gao, Xiangliang Li, Lanlei Guo, and Fangjian Zhao**, *Greenhouse Gases: Science and Technology*. (Subscription may be required to view article.)

"Uncertainty in static CO_2 storage capacity estimates: Case study from the North Sea, UK." The following is the Abstract of this article: "[The authors] used a sub-salt Rotliegend Group sandstone saline [formation] in the North Sea as a case study site for Monte-Carlo-based CO_2 geostorage capacity assessment. In the area of interest, this unit is characterized by sparse, low resolution, subsurface data typical of the margins of global petroleum provinces, favored for CO_2 storage. Such data scarcity leads to uncertainty regarding the complex trap geometries and ultimate CO_2 storage capacity. The Rotliegend reservoir, estimated to have porosity and permeability ranges of 11–27 percent and 0.2 mD–125 mD, respectively, is sealed by Zechstein salt. The salt, predominantly halite, is a proven hydrocarbon seal in the central and southern North Sea hosting oil and gas columns of >140 m (>450 ft) and >150 m (>500 ft). Utilizing 2D-seismic data, boreholes and analogues, [the authors] estimate the pore volume of a 5-km^2 4-way dip-closed structure through Monte-Carlo-based capacity simulations. [The authors] estimated storage capacity using published methodologies and compared this against a theoretical total storage

calculation analogous to the gas in place equation used in the petroleum industry. [The authors] found that different methods yield a capacity range of $<10^4$ to $>10^9$ [metric tons] CO_2 where sensitivity analysis indicates variability in reservoir properties to be the dominant control. Thus static estimates based upon Monte-Carlo calculations present no advantage over theoretical pore volume estimations. This leaves 3D dynamic modeling of storage capacity populated by 3D seismic data and direct down-hole measurement of reservoir properties to improve confidence in capacity estimations as the recommended method." **Benjamin J. Hedley, Richard J. Davies, Simon A. Mathias, David Hanstock, and Jon G. Gluyas**, *Greenhouse Gases: Science and Technology*. (Subscription may be required to view article.)

"Thermodynamic and transport property models for carbon capture and sequestration (CCS) processes with emphasis on CO_2 transport." The following is the Abstract of this article: "CCS is one of the most promising technologies for the reduction of CO_2 concentration in the atmosphere, so that global warming can be controlled and eventually eliminated. A crucial part in the CCS process design is the model that is used to calculate the physical properties (thermodynamic, transport etc.) of pure CO_2 and CO_2 mixtures with other components. In this work, an overview of various thermodynamic models together with calculations from cubic and higher order equations of state (EoS) are provided. Calculations are compared to experimental data and a discussion on the accuracy of the models is given. The CO_2 mixture properties studied include phase equilibria, density, isothermal compressibility, speed of sound, and Joule-Thomson inversion curve. The Peng-Robinson, Soave-Redlich-Kwong, and the Perturbed Chain-Statistical Associating Fluid Theory (PC-SAFT) are the EoS used for the calculations. In addition, various models for transport properties are discussed and calculations for viscosity and diffusion coefficient are presented." **Nikolaos I. Diamantonis, Georgios C. Boulougouris, Dimitrios M. Tsangaris, Mohamad J. El Kadi, Hisham Saadawi, Shahin Negahban, and Ioannis G. Economou**, *Chemical Engineering Research and Design*. (Subscription may be required to view article.)

August 2013

"Benchmarking of CO_2 transport technologies: Part I – Onshore pipeline and shipping between two onshore areas." The following is the Abstract of this article: "This paper focuses on illustrating the CCS chain methodology and the functionality of two transport assessment modules developed within the BIGCCS Research Centre for onshore pipeline and shipping between onshore areas. On the basis of these two modules, technical, costs and climate impact assessments of transport infrastructure and conditioning processes were assessed and compared for a base case. In this case study, onshore pipeline and CO_2 shipping between two onshore harbors are compared for different distances and capacities. As expected, for a given annual capacity, onshore pipeline transport should be used for 'short' distances, while shipping between harbors is employed for longer distances. Regarding the distance at which the cost-optimal technology switches between the two options, the results show that higher annual capacity and volume would lead to a preference for onshore pipeline transport. The base case can be used as a guide to draw conclusions on particular case studies under the hypotheses presented in this paper. The results also appear to be consistent with the few papers that have compared onshore pipeline and shipping between harbors. Sensitivity analyses were used to address and quantify the impact of several important parameters on the choice of technology. The influences of the individual parameters were then ranked showing that the four most influent parameters on the technology choice are the geographical context, the regional effect of pipeline costs, the First-Of-A-Kind effect, and the ownership effect. Additional work that focuses on transport between a coastal area and an offshore site using either an offshore pipeline or shipping will be presented in Part II of this paper." **Simon Roussanaly, Jana P. Jakobsen, Erik H. Hognes, and Amy L. Brunsvold**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"A mechanistic model for pipeline steel corrosion in supercritical CO_2-SO_2-O_2-H_2O environments." The following is the Abstract of this article: "A mechanistic model was established to predict uniform corrosion rate and investigate the corrosion mechanisms of pipeline steel in supercritical

CO_2–SO_2–O_2–H_2O environments. A six-region division (SIWDES: Supercritical CO_2, Interface, Water film, Deposition, Electrodic, and Solid) was applied to mathematically describe the model. The modified three-characteristic-parameter correlation model was used to calculate the ion activity coefficients, which calculates the activity coefficients of ions in thin water film with high ionic strength. The model can reasonably predict the corrosion rate of pipeline steel for the primary variables, determine the concentration distribution of each component in the water and product films, and also reflect the impact of corrosion product film on corrosion rate. A comparative analysis between the model and the experimental results showed that the model reasonably predicted the effects of the main factors on corrosion rate." **Yong Xiang, Zhe Wang, Minghe Xu, Zheng Li, and Weidou Ni**, *The Journal of Supercritical Fluids*. (Subscription may be required to view article.)

"Investigating the effect of salt and acid impurities in supercritical CO_2 as relevant to the corrosion of carbon capture and storage pipelines." The following is the Abstract of this article: "A series of corrosion exposure tests were performed in a supercritical CO_2 environment used to represent the potential conditions for CCS pipelines. Impurities from various CO_2 capture processes are potentially present, which segregate to the aqueous phase, hence combining with any free water present in the pipeline. Herein, salt ($NaNO_3$, Na_2SO_4, NaCl) and acid (HNO_3) impurities were added, along with 10 g of water, to an autoclave at 7.6 MPa and 50°C (supercritical CO_2) for a [seven] day steel specimen exposure. The tests conducted in supercritical CO_2 were also compared with aqueous tests in atmospheric conditions. Weight loss and optical profilometry revealed that corrosion rates for all samples are significant, along with the potential for [localized] attack. The corrosion mechanism differs for each solution tested. The work herein contributes to a holistic appraisal of understanding the corrosion of CO_2 pipelines." **S. Sim, I.S. Cole, F. Bocher, P. Corrigan, R.P. Gamage, N. Ukwattage, and N. Birbilis**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

"**Direct electrolytic dissolution of silicate minerals for air CO_2 mitigation and carbon-negative H_2 production."** The following is the Abstract of this article: "[The authors] experimentally demonstrate the direct coupling of silicate mineral dissolution with saline water electrolysis and H_2 production to effect significant air CO_2 absorption, chemical conversion, and storage in solution. In particular, [the authors] observed as much as a 105-fold increase in OH^- concentration (pH increase of up to 5.3 units) relative to experimental controls following the electrolysis of 0.25 M Na_2SO_4 solutions when the anode was encased in powdered silicate mineral, either wollastonite or an ultramafic mineral. After electrolysis, full equilibration of the alkalized solution with air led to a significant pH reduction and as much as a 45-fold increase in dissolved inorganic carbon concentration. This demonstrated significant spontaneous air CO_2 capture, chemical conversion, and storage as a bicarbonate, predominantly as $NaHCO_3$. The excess OH^- initially formed in these experiments apparently resulted via neutralization of the anolyte acid, H_2SO_4, by reaction with the base mineral silicate at the anode, producing mineral sulfate and silica. This allowed the NaOH, normally generated at the cathode, to go unneutralized and to accumulate in the bulk electrolyte, ultimately reacting with atmospheric CO_2 to form dissolved bicarbonate. Using nongrid or nonpeak renewable electricity, optimized systems at large scale might allow relatively high-capacity, energy-efficient (<300 kJ/mol of CO_2 captured), and inexpensive (<$100 per [metric ton] of CO_2 mitigated) removal of excess air CO_2 with production of carbon-negative H_2. Furthermore, when added to the ocean, the produced hydroxide and/or (bi)carbonate could be useful in reducing sea-to-air CO_2 emissions and in neutralizing or offsetting the effects of ongoing ocean acidification." **Greg H. Rau, Susan A. Carroll, William L. Bourcier, Michael J. Singleton, Megan M. Smith, and Roger D. Aines**, *Proceedings of the National Academy of Sciences of the United States of America*. (Subscription may be required to view article.)

Terrestrial

September 2012

"Early Public Impressions of Terrestrial Carbon Capture and Storage in a Coal-Intensive State." The following is the Abstract of this article: "While CCS is considered to be critical to achieving long-term climate-protection goals, public concerns about the CCS practice could pose significant obstacles to its deployment. This study reports findings from the first state-wide survey of public perceptions of CCS in a coal-intensive state, with an analysis of which factors predict early attitudes toward CCS. Nearly three-quarters of an Indiana sample (*N* = 1001) agree that storing carbon underground is a good approach to protecting the environment, despite 80 [percent] of the sample being unaware of CCS prior to participation in the two-wave survey. The majority of respondents do not hold strong opinions about CCS technology. Multivariate analyses indicate that support for CCS is predicted by a belief that humankind contributes to climate change, a preference for increased use of renewable energy, and egalitarian and individualistic worldviews, while opposition to CCS is predicted by self-identified political conservatism and by selective attitudes regarding energy and climate change. Knowledge about early impressions of CCS can help inform near-term technology decisions at state regulatory agencies, utilities, and pipeline companies, but follow-up surveys are necessary to assess how public sentiments evolve in response to image-building efforts with different positions on coal and CCS." **Sanya R. Carley, Rachel M. Krause, David C. Warren, John A. Rupp, and John D. Graham**, *Environ. Sci. Technol.*, Available online Jun 7, 2012, doi:10.1021/es300698n, http://pubs.acs.org/doi/abs/10.1021/es300698n. (Subscription required.)

"Improving regional soil carbon inventories: Combining the IPCC carbon inventory method with regression kriging." The following is the Abstract of this article: "Regional assessments of change in soil organic carbon (SOC) stocks due to land-use change are essential for supporting policy and management decisions related to [GHG] emissions and mitigation through carbon [storage] in soils. [The authors] have developed an improved approach by integrating geostatistical techniques with the Intergovernmental Panel on Climate Change (IPCC) carbon inventory approach to assess the impact of no-till management and crop-residue retention on SOC changes at a regional scale. Specifically, the improved approach utilizes regression kriging (RK) to estimate reference carbon stocks for the IPCC method. In [the authors'] case study, [they] compared the results from the RK method with a simple averaging (SA) method to derive the reference stocks as implemented in the Tier 2 IPCC approach, for a seven state area of the Midwestern United States. Using this improved method, [the authors] predict that eliminating tillage and retaining crop residues on all croplands of the study area would result in 11,735 Gg C yr^{-1} [storage] for 20 years in the top 30 cm of the soil profile. Most cropland area would [store] 0.2–0.75 Mg C ha^{-1} yr^{-1}. However, at a few places, the predicted rate of [storage] was more than 0.75 Mg C ha^{-1} yr^{-1}, with an upper limit of 1.1 Mg C ha^{-1} yr^{-1}. The highest rates of carbon accumulation were associated with favorable environmental conditions, such as lower slope positions and cold, temperate, moist climates. Validating predicted SOC change at 18 sites with varying soil types and environmental conditions showed that the RK approach to estimate reference carbon stocks decreased global prediction errors by 45 [percent] relative to the default reference values. The increase in prediction accuracy was due to using spatially varying SOC stocks rather than simple data averaging to derive reference SOC values. The uncertainty analysis demonstrated that there was more precision in the results from the RK approach in comparison to the results from the SA approach. These results suggest that improved geostatistical approach is a promising technique for improving soil carbon inventories that utilize the IPCC method, and will provide more precise results for informing public policy and management decisions while retaining ease of application." **Umakant Mishra, Margaret S. Torn, Eric Masanet, and Stephen M. Ogle**, *Geoderma*, Available online August 18, 2012, doi:10.1016/j.geoderma.2012.06.022, http://www.sciencedirect.com/science/article/pii/S0016706112002571. (Subscription may be required.)

October 2012

"Soil carbon lost from Mollisols of the North Central U.S.A. with 20 years of agricultural best management practices." The following is the Abstract of this article: "Soil organic carbon (SOC) is highly sensitive to agricultural land management, so there is a great deal of interest in managing cultivated soils to [store] atmospheric CO_2. In this study [the authors] evaluated the influence of six cropping systems on SOC at the Wisconsin Integrated Cropping System Trial (WICST) over a 20-year period. Analysis of SOC on either a concentration or mass per volume of soil basis indicated a significant decline across all of the systems at WICST. While the rotationally grazed pasture system [stored] carbon (C) in the surface 15 cm these gains were offset by losses at depth. Both no-till (NT) practices and inclusion of perennial crops reduced SOC loss, but neither resulted in C [storage] in the soil profile. Results from this study demonstrate the importance of (i) comparing current and initial soil samples when evaluating SOC [storage] and (ii) evaluating SOC changes throughout the soil profile. The losses of SOC at depths below the plow layer point to either a lack of C input from roots, increased oxidative loss at these depths or both." **Gregg R. Sanford, Joshua L. Posner, Randall D. Jackson, Christopher J. Kucharik, Janet L. Hedtcke, and Ting-Li Lin**, *Agriculture, Ecosystems & Environment*, Available in November 2012 edition, doi:10.1016/j.agee.2012.08.011, http://www.sciencedirect.com/science/article/pii/S0167880912003222. (Subscription may be required.)

November 2012

"An assessment of forest landowner interest in selling forest carbon credits in the Lake States, USA." The following is the Abstract of this article: "The [Nation's] family forest lands can be an important contributor to carbon [storage] efforts. Yet very little is known about how family forest landowners view programs that enable them to sell carbon credits generated from the growth of their forest and the compensation that would be required to encourage a meaningful level of participation. To address this information gap, [the authors] conducted a study to identify and quantify family forest landowner interest in participating in a voluntary carbon market trading program in the Lake States, USA. A mail survey was administered to 2,200 randomly selected family forest owners in Michigan, Wisconsin, and Minnesota. The questionnaire assessed landowner interest in participating in a hypothetical carbon credit trading program and sought information on landowner objectives and practices, perspectives on carbon credit programs and forest land characteristics. A total of 850 usable responses were received. A logistic regression model was developed to examine the factors affecting participation in a forest carbon offset project by family forest owners and estimate landowner participation probability. Results show that carbon program characteristics alongside landowner and parcel characteristics are associated with the decision to participate in a carbon credit program. Specifically, carbon credit payment amount, contract length, gender, value placed on other non-market forest amenities, need for additional income, attitude towards climate change, absentee status, land tenure and total acres owned were found to be significant determinants. [The authors'] findings indicate that carbon [storage] management may align with the ownership goals of many family forest owners in the Lake States." **Kristell A. Miller, Stephanie A. Snyder, and Michael A. Kilgore**, *Forest Policy and Economics*, Available online October 23, 2012, doi:10.1016/j.forpol.2012.09.009, http://www.sciencedirect.com/science/article/pii/S1389934112002201. (Subscription may be required.)

December 2012

"Effect of Freeze-Thaw on the Mineralization of Organic Carbon, and Organic Nitrogen in Wetland Soil." The following is the Abstract of this article: "The mineralization of organic carbon and organic nitrogen in soil is one of the key processes in the carbon and nitrogen cycles in wetland soil. In general it is believed that the mineralization of organic carbon and organic nitrogen in soil mainly depends on the moisture and temperature. Conditions of soil moisture affect the soil respiration rate by restricting the penetration of oxygen and the types of microorganisms, but temperature affects the mineralization rates

of organic carbon and organic nitrogen in soil by affecting microbial activity. Because of the interaction between temperature and moisture, the real mineralization rate in a soil often depends on both moisture and temperature conditions at the same time." **Xiaofei Yu**, *Material Cycling of Wetland Soils Driven by Freeze-Thaw Effects*, Available online January 1, 2013, doi:10.1007/978-3-642-34465-7_7, http://link.springer.com/chapter/10.1007/978-3-642-34465-7_7. (Subscription required.)

"Biochar Fertilizer for Soil Amendment and Carbon [Storage]." The following is the Abstract of this article: "Use of biochar fertilizer is potentially an attractive approach for soil amendment and carbon [storage] possibly at giga tons of carbon (GtC) scale. Cation exchange capacity (CEC) is an important parameter in retaining inorganic nutrients, such as K^+ and NH_4^+ in soil. This experimental study showed that the CEC value of biochar is related to the biomass pyrolysis temperature. Biochar materials made from the pelletized peanut hulls at pyrolysis temperature of about [400°C] yield the best CEC value. As the pyrolysis temperature increases over [400°C], the CEC value decreases. The biochar produced from the [400°C] pyrolysis possesses certain binding affinity for ammonium bicarbonate (NH_4HCO_3) probably because of the presence of more biochar surface functional groups. Addition of ammonium bicarbonate to biochar can help neutralize the pH of biochar material potentially beneficial for certain agricultural soil applications in relation to soil amendment and carbon [storage]." **James Weifu Lee, Bob Hawkins, Xiaonian Li, and Danny M. Day**, *Advanced Biofuels and Bioproducts*, Available online January 1, 2013, doi:10.1007/978-1-4614-3348-4_6, http://link.springer.com/chapter/10.1007/978-1-4614-3348-4_6. (Subscription required.)

January 2013

"CO_2 uptake by a soil microcosm." The following is the Abstract of this article: "[Storage] of CO_2 via biological [formations] is a matter of great scientific importance due to the potential lowering of atmospheric CO_2. In this study, a custom built incubation chamber was used to cultivate a soil microbial community to instigate chemoautotrophy of a temperate soil. Real-time atmospheric CO_2 concentrations were monitored and estimations of total CO_2 uptake were made. After careful background flux corrections, 4.52 ± 0.05 g CO_2 kg^{-1} dry soil was [stored] from the chamber atmosphere over 40 [hours]. Using isotopically labeled $^{13}CO_2$ and GCMS–IRMS, labeled fatty acids were identified after only a short incubation, hence confirming CO_2 [storage] for soil. The results of this *in vivo* study provide the ground work for future studies intending to mimic the *in situ* environment by providing a reliable method for investigating CO_2 uptake by soil microorganisms." **Kris M. Hart, Seth F. Oppenheimer, Brian W. Moran, Christopher C.R. Allen, Vassilis Kouloumbos, Andre J. Simpson, Leonid A. Kulakov, Leon Barron, and Brian P. Kelleher**, *Soil Biology and Biochemistry*, Available in February 2013 edition, http://dx.doi.org/10.1016/j.soilbio.2012.10.036, http://www.sciencedirect.com/science/article/pii/S0038071712004154. (Subscription may be required.)

February 2013

"The Laboratory Simulation and Field Verification of Seasonal Soil-Respired CO_2 flux at a Proposed CCS Project Site." The following is the Abstract of this article: "As part of any terrestrial CCS project, a risk-driven Measurement Monitoring and Verification (MMV) [(referred to as "Monitoring, Verification, and Accounting by DOE)] plan may include the measurement of soil gas and related surface CO_2 efflux in order to determine the natural (or baseline) concentration range and variation of CO_2. Subsequent measurements of these parameters may then act as a measure of stored CO_2 containment and conformance during operational, closure and post-closure phases. There are several practical challenges involved in the collection of representative soil-respired CO_2 efflux measurements. These include (i) the assessment of natural baseline variations of soil-respired CO_2 efflux across potentially large areas expected for commercial CCS operations, (ii) even if field measurements of soil-respired CO_2 are recorded over one season or several seasonal cycles, the full concentration and CO_2 flux range may not be captured due to reliance upon environmental (i.e. climate) conditions prevalent during field

surveys, and (iii) when field based soil CO_2 flux measurements are taken, climatic and environmental conditions are likely to change throughout the day, resulting in a number of dislocated flux measurements taken under different conditions. Ideally, it would be useful to be able to carry out an initial field survey measurements, collect soil samples at a project site and develop a simulated baseline in the laboratory under controlled conditions, reducing the seasonal baseline survey duration from one or two years down to several weeks of simulation supported by field verification. Soil cores and bulk material from each soil horizon at selected locations were sampled from the previously proposed Heartland Area Redwater Project (HARP) near Edmonton, Alberta. Soil columns were reconstituted in the laboratory and subjected to a range of temperature and moisture conditions similar to those expected for the CCS project area over a seasonal cycle. Efflux data were directly compared to field-based measurements collected over a [12-month] period under a range of climatic conditions. Comparisons between laboratory simulations and field data suggest a strong temperature-efflux correlation consistent with many studies related to the carbon cycle and ecosystem productivity. It is suggested that the simulation of environmental conditions using soils from a CCS area of review may be a useful tool for the prediction of the range of CO_2 efflux expected as a function of soil characteristics and environmental conditions, thereby accelerating baseline studies, establishing the range of CO_2 efflux to guide monitoring strategies and for the facilitation and validation of remote sensing data in support of large scale CCS site characterization." **James Brydie, Bob Faught, Mark Olson, Andrew Underwood, and Bonnie Drozdowski**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

March 2013

"Modeling Interactions Between Economic Activity, Greenhouse Gas Emissions, Biodiversity and Agricultural Production." The following is the Abstract of this article: "In this article, [the authors] develop a modeling approach which examines selected drivers of ecosystem functioning and agricultural productivity. In particular, [the authors] develop linkages between land use and biodiversity and between biodiversity and agricultural productivity. [The authors] review the literature for quantitative estimates of key relationships and their parameters for modeling human consumption, land use, energy use, and [GHG] emissions on biodiversity and agricultural productivity. [The authors] assemble these specifications into an iterative causal model and carry out a number of scenario projections of country-level consumption, production, land use, energy use, [GHG] emissions, species diversity, and agricultural production up to 2050. Finally, [the authors] dissect the projections into key drivers using structural decomposition and sensitivity analyses." **Manfred Lenzen, Christopher Dey, Barney Foran, Asaph Widmer-Cooper, Ralf Ohlemüller, Moira Williams, and Thomas Wiedmann**, *Environmental Modeling & Assessment*. (Subscription may be required to view article.)

April 2013

"The response of abyssal organisms to low pH conditions during a series of CO_2-release experiments simulating deep-sea carbon sequestration." The following is the Abstract of this article: "The effects of low-pH, high-pCO_2 conditions on deep-sea organisms were examined during four deep-sea CO_2 release experiments simulating deep-ocean [carbon storage] by the direct injection of CO_2 into the deep sea. [The authors] examined the survival of common deep-sea, benthic organisms (microbes; macrofauna, dominated by Polychaeta, Nematoda, Crustacea, Mollusca; megafauna, Echinodermata, Mollusca, Pisces) exposed to low-pH waters emanating as a dissolution plume from pools of liquid [CO_2] released on the seabed during four abyssal CO_2-release experiments. Microbial abundance in deep-sea sediments was unchanged in one experiment, but increased under environmental hypercapnia during another, where the microbial assemblage may have benefited indirectly from the negative impact of low-pH conditions on other taxa. Lower abyssal metazoans exhibited low survival rates near CO_2 pools. No urchins or holothurians survived during 30–42 days of exposure to episodic, but severe environmental hypercapnia during one experiment (E1; pH reduced by as much as ca. 1.4 units). These large pH

reductions also caused 75 [percent] mortality for the deep-sea amphipod, *Haploops lodo*, near CO_2 pools. Survival under smaller pH reductions (ΔpH<0.4 units) in other experiments (E2, E3, E5) was higher for all taxa, including echinoderms. Cephalopods, gastropods, and fish were more tolerant than most other taxa. The gastropod *Mohnia vernalis* and octopus *Benthoctopus* sp. survived exposure to pH reductions that episodically reached −0.3 pH units. Ninety percent of abyssal zoarcids (*Pachycara bulbiceps*) survived exposure to pH changes reaching ca. −0.3 pH units during 30–42 day-long experiments." **J.P. Barry, K.R. Buck, C. Lovera, P.G. Brewer, B.A. Seibel, J.C. Drazen, M.N. Tamburri, P.J. Whaling, L. Kuhnz, and E. Pane**, *Deep Sea Research Part II: Topical Studies in Oceanography*. (Subscription may be required to view article.)

May 2013

"Tracking the fate of microbially [stored] carbon dioxide in soil organic matter." The following is the Abstract of this article: "The microbial contribution to soil organic matter (SOM) has recently been shown to be much larger than previously thought and thus its role in carbon [storage] may also be underestimated. In this study [the authors] employ 13C ($13CO_2$) to assess the potential CO_2 [storage] capacity of soil chemoautotrophic bacteria and combine Nuclear Magnetic Resonance (NMR) with Stable Isotope Probing (SIP); techniques that independently make use of the isotopic enrichment of soil microbial biomass. In this way molecular information generated from NMR is linked with identification of microbes responsible for carbon capture. A mathematical model is developed to determine real-time CO_2 flux so that net [storage] can be calculated. [Twenty-eight] groups of bacteria showing close homologies with existing species were identified. Surprisingly, Ralstonia eutropha was the dominant group. Through NMR [the authors] observed the formation of lipids, carbohydrates and proteins produced directly from CO_2 [utilized] by microbial biomass. The component of SOM, directly associated with CO_2 capture, was calculated at 2.86 mg C (89.21 mg kg-1) after 48 hours. This approach can differentiate between SOM derived through microbial uptake of CO_2 and other SOM constituents and represents a first step in tracking the fate and dynamics of microbial biomass in soil." **Kris M Hart, Anna L Kulakova, Chris Allen, Andre J Simpson, Seth F Oppenheimer, Hussain Masoom, Denis Courtier-Murias, Ronald Soong, Leonid A Kulakov, Brian T Murphy, and Brian P. Kelleher**, *Environ. Sci. Technol*. (Subscription may be required to view article.)

June 2013

"Carbon balance of citrus plantations in Eastern Spain." The following is the Abstract of this article: "Global warming due to the continuous rise in CO_2 emissions has been documented in the last few decades. This work is a first effort to estimate the net carbon incorporation in citrus plantations cultivated under typical land use. The approach involves a biomass-based study of carbon accumulation and a complementary analysis of the associated CO_2 fluxes. The total C content allocated to trees aged 2–14 years was determined through the direct and destructive harvesting of all tree organs. A stable pattern of biomass production in tree components was observed in plants 12 years old and older and was responsible for the [storage] of more than 50 kg C $tree^{-1}$. Annual C fixation in fruit and new vegetative flushes accounted for up to approximately 75 [percent] of the total amount [stored] per year, whereas the contribution of the old, permanent organs (branches, trunk, and tap-coarse roots) was minor (approximately 25 [percent]). Further experiments were conducted on adult 12-year-old trees to confirm the data and determine the particular contribution of CO_2 fluxes from tree organs and soil to the final values. Data revealed that leaves were responsible for a total net C fixation of 15.4 Mg C ha^{-1} yr^{-1} (higher than 55 [percent] of the total C fixed). The complementary, regular monitoring of fruit respiration rates showed that fruit respiration played only a minor role, responsible for the emission of 2.3 Mg C ha^{-1} yr^{-1}. Minimum losses were also found when soil respiration rates were investigated, accounting for a total annual C loss of 2.7 Mg C ha^{-1} yr^{-1}. Taken together, these results indicate that [the authors'] plantation was responsible for a net C fixation of close to 10 Mg C ha^{-1} yr^{-1}. Assimilatory processes in leaves accounted for the highest proportion of C allocated to the tree, while losses due to leaf and fruit

respiration were of minor importance. Under typical culture conditions (drip irrigation and absence of ground cover), soil respiration rates accounted for a low level of C loss to the atmosphere. Because citrus is the second largest fruit crop cultivated in the [European Union (EU)], such data are very relevant to the mitigation of climate change." **Domingo J. Iglesias, Ana Quiñones, Antonio Font, Belén Martínez-Alcántara, María Ángeles Forner-Giner, Francisco Legaz, and Eduardo Primo-Millo**, *Agriculture, Ecosystems & Environment*. (Subscription may be required to view article.)

July 2013

"Modifying the Soil and Water Assessment Tool to simulate cropland carbon flux: Model development and initial evaluation." The following is the Abstract of this article: "Climate change is one of the most compelling modern issues and has important implications for almost every aspect of natural and human systems. The Soil and Water Assessment Tool (SWAT) model has been applied worldwide to support sustainable land and water management in a changing climate. However, the inadequacies of the existing carbon algorithm in SWAT limit its application in assessing impacts of human activities on CO_2 emission, one important source of GHGs that traps heat in the earth system and results in global warming. In this research, [the authors] incorporate a revised version of the CENTURY carbon model into SWAT to describe dynamics of soil organic matter (SOM)-residue and simulate land–atmosphere carbon exchange. [The authors] test this new SWAT-C model with daily eddy covariance (EC) observations of net ecosystem exchange (NEE) and evapotranspiration (ET) and annual crop yield at six sites across the U.S. Midwest. Results show that SWAT-C simulates well multi-year average NEE and ET across the spatially distributed sites and capture the majority of temporal variation of these two variables at a daily time scale at each site. [The authors] analyses also reveal that performance of SWAT-C is influenced by multiple factors, such as crop management practices (irrigated vs. rainfed), completeness and accuracy of input data, crop species, and initialization of state variables. Overall, the new SWAT-C demonstrates favorable performance for simulating land–atmosphere carbon exchange across agricultural sites with different soils, climate, and management practices. SWAT-C is expected to serve as a useful tool for including carbon flux into consideration in sustainable watershed management under a changing climate. [The authors] also note that extensive assessment of SWAT-C with field observations is required for further improving the model and understanding potential uncertainties of applying it across large regions with complex landscapes." **Xuesong Zhang, R. César Izaurralde, Jeffrey G. Arnold, Jimmy R. Williams, and Raghavan Srinivasan**, *Science of The Total Environment*. (Subscription may be required to view article.)

August 2013

"Extreme CO_2 disturbance and the resilience of soil microbial communities." The following is the Abstract of this article: "[CCS] technology has the potential to inadvertently release large quantities of CO_2 through geologic substrates and into surrounding soils and ecosystems. Such a disturbance has the potential to not only alter the structure and function of plant and animal communities, but also soils, soil microbial communities, and the biogeochemical processes they mediate. At Mammoth Mountain, [the authors] assessed the soil microbial community response to CO_2 disturbance (derived from volcanic 'cold' CO_2) that resulted in localized tree kill; soil CO_2 concentrations in [the authors'] study area ranged from 0.6 [percent] to 60 [percent]. [The authors'] objectives were to examine how microbial communities and their activities are restructured by extreme CO_2 disturbance, and assess the response of major microbial taxa to the reintroduction of limited plant communities following an extensive period (15–20 years) with no plants. [The authors] found that CO_2-induced tree kill reduced soil carbon (C) availability along [the authors'] sampling transect. In response, soil microbial biomass decreased by an order of magnitude from healthy forest to impacted areas. Soil microorganisms were most sensitive to changes in soil organic C, which explained almost 60 [percent] of the variation for microbial biomass C (MBC) along the CO_2 gradient. [The authors] employed phospholipid fatty acid analysis and quantitative PCR (qPCR) to determine compositional changes among microbial communities in affected areas and found

substantial reductions in microbial biomass linked to the loss of soil fungi. In contrast, archaeal populations responded positively to the CO_2 disturbance, presumably due to reduced competition of bacteria and fungi, and perhaps unique adaptations to energy stress. Enzyme activities important in the cycling of soil C, nitrogen (N), and phosphorus (P) declined with increasing CO_2, though specific activities (per unit MBC) remained stable or increased suggesting functional redundancy among restructured communities. [The authors] conclude that both the direct (microaerobiosis) and indirect (loss of plant C inputs) effects of elevated soil CO_2 flux have significant impacts on the composition and overall structural trajectory of soil microbial populations within disturbed areas." **Jack W. McFarland, Mark P. Waldrop, and Monica Haw**, *Soil Biology and Biochemistry*. (Subscription may be required to view article.)

Trading

September 2012

***RGGI News Release*, "RGGI Auction Sells 24.5 Million CO_2 Allowances."** The states participating in the Regional Greenhouse Gas Initiative (RGGI) announced that 24,589,000 CO_2 allowances were sold in their 17th auction, held Wednesday, September 5. The auction generated $47.4 million for reinvestment by the RGGI states in energy efficiency, clean and renewable energy, direct bill assistance, and other consumer benefit programs across the region. Bids for the CO_2 allowances ranged from $1.93 to $6.51 per allowance, with a clearing price of $1.93, the minimum reserve price for the auction. Allowances sold represent 65 percent of the 37,949,558 allowances offered for sale. The RGGI states are conducting a comprehensive program review to ensure RGGI's continued success. The next RGGI auction is scheduled for December 5, 2012. September 7, 2012, http://www.rggi.org/docs/Auctions/17/PR090712_Auction17.pdf.

***UPI.com*, "Australia and EU to Link Emissions Trading."** The Australian government announced that Australia's carbon pricing scheme will link with the European Union's (EU) emissions trading plan. In the EU's plan, businesses emitting 25,000 tons of CO_2 (or the equivalent in other GHGs) are charged $24 per ton. In 2015, Australia's plan was to convert to an emissions trading scheme with a floating price starting at a floor of $15; the floor price will now be eliminated and the plan will be linked with the EU's, whose emissions trading scheme stands at approximately $10 per ton. The link will initially be "one way," allowing Australian businesses to buy permits from the EU scheme; "two-way" trade will begin in 2018. August 28, 2012, http://www.upi.com/Business_News/Energy-Resources/2012/08/28/Australia-and-EU-to-link-emissions-trading/UPI-20871346165904/?spt=hs&or=er.

***China Daily*, "Carbon Emission Rights Trading Scheme Launched."** Shanghai has launched a pilot carbon emission rights trading scheme to encourage carbon emission reductions among the approximately 200 local emitters participating, the city government announced. Each of the carbon market participants, which include industrial companies whose annual CO_2 emissions approach 20,000 metric tons and non-industrial enterprises whose annual emissions total 10,000 metric tons, will get a free quota for a certain base carbon emission. Those companies who fail to meet their emission cut targets will need to buy quota from the companies whose emission cuts exceed their targets. China has pledged to reduce CO_2 emissions per unit of GDP by 40 to 45 percent compared to 2005 levels by 2020. August 17, 2012, http://www.chinadaily.com.cn/china/2012-08/17/content_15682368.htm.

October 2012

***Clean Technica*, "China to Create Emission Trading System, Link to European Union,"** and ***Reuters*, "Top Emitter China Agrees to Work with EU to Cut Carbon."** The European Commission announced that China has agreed to work with the European Union (EU) to cut GHGs through a variety of projects, including the development of a Chinese emission trading system that will link with EU's

Emission Trading Scheme (ETS). Announced at an EU-China Summit on September 20, 2012, the agreement also includes $32 million in financing and technical assistance from the EU over a four-year period for three carbon-reduction projects. As part of the agreement, the EU will also help fund efforts by Chinese cities to improve their resource-use efficiency and implement sustainable waste treatment systems. China recently set targets to reduce CO_2 emissions per unit of gross domestic product 17 percent by 2015 compared to 2005 levels. September 21, 2012, http://cleantechnica.com/2012/09/21/china-will-create-emission-trading-system-link-to-european-union/, September 20, 2012, http://www.reuters.com/article/2012/09/20/uk-eu-china-carbon-idUSLNE88J00P20120920.

November 2012

***Reuters*, "South Korea Doubles 2013 Emissions Reduction Target,"** and ***BusinessGreen*, "South Korea Doubles Emissions Target for 2013."** Ahead of the launch of a new cap-and-trade scheme in 2015, the South Korean Ministry of Knowledge Economy announced that local industrial and power sectors will be required to reduce GHG emissions by three percent in 2013, compared to the 1.4 percent reduction target for 2012. The fourth largest economy in Asia, South Korea aims to cut 17.2 million metric tons of CO_2 equivalent (CO_2e) of next year's expected emissions, compared to the 8 million metric tons of CO_2 reduction of this year's levels. The doubling of the emissions target is designed to boost competitiveness and help South Korean businesses prepare for the introduction of the national emissions trading scheme, which was approved by lawmakers in May and will start in January 2015. Emitters that fail to meet their reduction targets next year will face fines that will be leveled in 2014. According to the South Korean government, it is expected that industrial and power entities will account for approximately 97 percent of the country's total emissions in 2013, which is expected to be around 589.8 million metric tons of CO_2 equivalent. October 15, 2012, http://www.reuters.com/article/2012/10/15/us-korea-emissions-idUSBRE89E03Z20121015, and October 15, 2012, http://m.businessgreen.com/bg/news/2216985/south-korea-doubles-emissions-target-for-2013.

"Relating R&D and investment policies to [carbon capture and storage] market diffusion through two-factor learning." The following is the Abstract of this article: "[Carbon capture and storage] has the potential to play a major role in the stabilization of anthropogenic [GHGs]. To develop the capture technology from its current demonstration phase towards commercial maturity, significant funding is directed to [carbon capture and storage], such as the EU's €4.5 bn NER300 fund. However, [little is known] about how this funding relates to market diffusion of [carbon capture and storage]. This paper addresses that question. [The authors] initially review past learning effects from both capacity installations and R&D efforts for a similar technology using the concept of two-factor learning. [The authors] apply the obtained learning-by-doing and learning-by-searching rates to [carbon capture and storage] in the electricity market model HECTOR, which simulates 19 European countries hourly until 2040, to understand the impact of learning and associated policies on [carbon capture and storage] market diffusion. [The authors] evaluate the effectiveness of policies addressing learning-by-doing and learning-by-searching by relating the policy budget to the realized [carbon capture and storage] capacity and find that, at lower policy cost, both methods are about equally effective. At higher spending levels, policies promoting learning-by-doing are more effective. Overall, policy effectiveness increases in low CO_2 price scenarios, but the CO_2 price still remains the key prerequisite for the economic competitiveness, even with major policy support." **Richard Lohwasser and Reinhard Madlener**, *Energy Policy*, Available online October 31, 2012, doi.org/10.1016/j.enpol.2012.09.061, http://www.sciencedirect.com/science/article/pii/S0301421512008439. (Subscription may be required.)

December 2012

***Los Angeles Times*, "California's First Carbon-Credit Auction Raises $290 Million."** The California Air Resources Board announced that the state's first auction of GHG emission credits generated nearly

$290 million. All 23.1 million allowances available for 2013 sold for $10.09 each (the minimum was $10), generating $233.3 million; of the nearly 40 million credits available for 2015, the state sold approximately 14 percent, generating an additional $55.8 million. Some of the money generated will be used for energy efficiency and other projects. The result of the Global Warming Solutions Act (AB 32; passed in 2006), the cap-and-trade program aims to reduce California's production of GHGs, including CO_2, to 1990 levels (approximately 17 percent lower than current amounts) by 2020. More than 350 industrial businesses in California participated in the auction, representing approximately 600 facilities throughout the state, including utilities, food processors, and oil refineries; the program will cover distributors of natural gas and other fuels beginning in 2015. Under the program, emitters initially get 90 percent of their needed credits free; if they plan to emit GHGs above allotted levels, they are required to buy more emission credits, which start at a minimum price of $10 for the right to emit 1 metric ton of GHGs. November 20, 2012, http://www.latimes.com/business/la-fi-pollution-credits-20121120,0,1417750.story.

***RGGI News Release*, "RGGI Auction Sells 19.7 Million CO_2 Allowances at $1.93."** The nine RGGI-participating states announced the results of their CO_2 allowances auction held on December 5, 2012. The results indicate 19,774,000 CO_2 allowances were sold at the 18th auction, generating $38.1 million for reinvestment by the RGGI states. Bids for the CO_2 allowances ranged from $1.93 to $5.14 per allowance, with a clearing price of $1.93; the allowances sold represent 53 percent of the 37,563,083 allowances offered for sale. The auction proceeds will be used to fund a variety of consumer benefit initiatives, including investments in energy efficiency, clean and renewable energy, direct bill assistance, and GHG abatement and climate change adaptation. The next RGGI auction (19th) is scheduled for March 13, 2013. December 7, 2012, http://www.rggi.org/docs/Auctions/18/PR120712_Auction18.pdf.

"RFID-enabled carbon offsetting and trading." The following is the Abstract of this article: "This paper presents a novel approach to carbon credit trading with pervasive computing technologies, particularly RFID (or barcode) technology. It introduces RFID tags as certificates for the rights to claim carbon credits in carbon offsetting and trading. It enables buyers, including end-consumers, that buy products with carbon credits to hold and claim these credits unlike existing carbon offsetting schemes. It also supports the simple intuitive trading of carbon credits by trading RFID tags coupled to the credits. The approach was constructed and evaluated with real customers and real carbon credits in a real supply chain. It can also be used to encourage industries and homes to reduce [GHG] emissions." **Ichiro Satoh**, *Pervasive and Mobile Computing*, Available online October 15, 2012, doi:10.1016/j.pmcj.2012.09.003, http://www.sciencedirect.com/science/article/pii/S1574119212001149. (Subscription may be required.)

"Carbon price forecasting with a novel hybrid ARIMA and least squares support vector machines methodology." The following is the Abstract of this article: "In general, due to inherently high complexity, carbon prices simultaneously contain linear and nonlinear patterns. Although the traditional autoregressive integrated moving average (ARIMA) model has been one of the most popular linear models in time series forecasting, the ARIMA model cannot capture nonlinear patterns. The least squares support vector machine (LSSVM), a novel neural network technique, has been successfully applied in solving nonlinear regression estimation problems. Therefore, [the authors] propose a novel hybrid methodology that exploits the unique strength of the ARIMA and LSSVM models in forecasting carbon prices. Additionally, particle swarm optimization (PSO) is used to find the optimal parameters of LSSVM in order to improve the prediction accuracy. For verification and testing, two main future carbon prices under the [European Union Emissions Trading Scheme (EU ETS)] were used to examine the forecasting ability of the proposed hybrid methodology. The empirical results obtained demonstrate the appeal of the proposed hybrid methodology for carbon price forecasting." **Bangzhu Zhu and Yiming Wei**, *Omega*, Available June 2013, doi.org/10.1016/j.omega.2012.06.005, http://www.sciencedirect.com/science/article/pii/S0305048312001004. (Subscription may be required.)

January 2013

***Commodities Now*, "Carbon Market Activity Highest on Record."** According to Bloomberg New Energy Finance, carbon market transaction volumes across the world grew by 26 percent in 2012 to approximately 10.7 billion metric tons, which is equivalent to approximately one-third of the world's total emissions of CO_2. Trading activity has increased by approximately 25 percent each year since 2010 and trading in the last quarter of 2012 increased 70 percent compared to the average of the three previous quarters (2012 Q4 accounted for 36 percent of the total annual volume). The increase in trading activity in the European Union Emission Trading Scheme (EU ETS) was caused by increased use of auctioning to distribute allowances and increased volatility resulting from the European Commission's attempts to support prices in the EU ETS by withholding allowances from the market. The increase in trading of UN offsets was attributable to the rush to acquire these credits before the end of the year and to take advantage of low prices. Bloomberg New Energy Finance expects the value of the market to return to approximately $105 billion in 2013 (a similar level to 2009 and 2010). January 3, 2013, http://www.commodities-now.com/news/environmental-markets/13450-carbon-market-activity-highest-on-record.html.

***Business Green*, "California Carbon Trading Scheme Gets Underway."** California's emissions cap-and-trade scheme officially went into effect on January 1, 2013. The trading scheme establishes a statewide limit on total emissions of 162.8 million metric tons of CO_2 and imposes emission allowances on approximately 350 companies generating more than 25,000 metric tons of CO_2 a year. Each of the companies covered by the scheme must carry allowances. The majority of the allowances will be provided to companies for free, but some allowances will be auctioned. Any firm that exceeds the emissions cap would be required to purchase additional allowances. The scheme is central to California's plans to reduce GHG emissions to 1990 levels by the end of the decade. January 3, 2013, http://www.eco-business.com/news/california-carbon-trading-scheme-gets-underway/http://www.eco-business.com/news/california-carbon-trading-scheme-gets-underway/.

"CCS projects as Kyoto Protocol CDM activities." The following is the Abstract of this article: "The December 2011 decision by the meetings of the UNFCCC in Durban, South Africa, to adopt modalities and procedures for [CO_2] capture and geological storage as clean development mechanism (CDM) project activities under the Kyoto Protocol was the culmination of many years of international negotiation. The Durban CCS decision establishes a practical international standard for managing CCS projects that ensures a high level of environmental protection. It is an important official recognition by the UNFCCC that CCS is a technology capable of achieving deep cuts in [GHG] emissions in developing countries and sets an important precedent for the inclusion of CCS projects within emerging international markets and other financing and technology support mechanisms outside of the CDM. This paper analyses the Durban CCS decision and the implications for project proposals." **Tim Dixon, Gregory Leamon, Paul Zakkour, and Luke Warren**, presented at the 11th Greenhouse Gas Control Technologies conference held at the Kyoto International Conference Center, Japan, November 18-22, 2012, https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270035&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPool%5Coffice27%5Cdocs%5Cpdf%5Cghgt%2D11Final00641%2Epdf. (Subscription may be required.)

February 2013

"Georgia's Largest Power Plant to Trade Carbon Credits." Enguri Hydro Power Plant, Georgia's largest power plant, will sell carbon credits earned from a European Bank for Reconstruction and Development (EBRD)-financed energy efficiency project. The $70 million investment was used to upgrade and increase the plant's operational capacity. The project has now been registered under the Kyoto Protocols' Clean Development Mechanism (CDM) and is estimated to generate more than 5.8 million carbon credits over the 10-year crediting period. These credits can now be sold on global carbon

markets to businesses and governments that are close to exceeding their GHG emission quotas. The Enguri Hydro Power Plant is located on the Enguri River and provides a large portion of Georgia's domestic power supply. The rehabilitation of the Enguri Hydro Power Plant is the fourth CDM registered project located in Georgia. From *European Bank for Reconstruction and Development Press Release* on January 31, 2013.

"RGGI States Propose Lowering Regional CO_2 Emissions Cap 45 [Percent], Implementing a More Flexible Cost-Control Mechanism." After a two-year program review, the states participating in RGGI released an updated RGGI Model Rule and Program Review Recommendations Summary. The Updated Model Rule will guide the RGGI states as they follow state-specific statutory and regulatory processes to propose updates to their CO_2 Budget Trading Programs. The comprehensive list of improvements made to the RGGI program is available via the hyperlink above. From *RGGI Press Release* on February 7, 2013.

"CCS in Carbon Markets." The following is the Abstract of this article: "CCS technologies constitute an important component of the decarbonization efforts that are needed to keep the temperature increase to below [2°C]. According to the IEA estimates, CCS could contribute one-fifth of the total energy sector emission reductions globally through 2050. Analysis by the IEA and other institutions show that both short and long-term policy interventions are needed to provide sufficient incentives to the private sector to invest in CCS. However, it is understood that eventually technology neutral policy instruments, such as carbon price, would be able to provide sufficient incentives for CCS to be selected as a GHG emission mitigation option. Currently there are two main types of mechanisms to price carbon emissions: CO_2 taxes and GHG emission trading schemes. Both are aimed at reducing CO_2 emissions by making the cost of emitting prohibitive. Carbon taxes set a fixed price on carbon; thus under a tax, the carbon price is certain while the ultimate level of emission reductions remains uncertain. Emission trading schemes inversely set caps on emissions, but carbon price fluctuates depending on availability of emission reduction options and their costs. Emission trading schemes imply certainty of achieved emission reductions (unless they are based on intensity-based caps, in this case relative emission reductions are known but not absolute levels) but leave carbon prices uncertain. While experience shows that carbon taxes can drive CCS, given the availability of other favorable conditions at the same time, emission trading schemes so far have not been successful with facilitating CCS development, largely due to the low level of CO_2 prices. A further relevant issue is the emergence of international carbon market mechanisms under the [United Nations Framework Convention on Climate Change (UNFCCC)] process. While some of these carbon market mechanisms may help CCS, they all have particular challenges to overcome. It is likely that technology-specific support policies will be needed for CCS in short to mid-term, before carbon pricing mechanisms, although at much higher levels than currently observed, can alone drive CCS technologies into the market." **Ellina Levina and Juho Lipponen**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"Role of CCS in New International Climate Regime." The following is from the Abstract of this article: "This paper examines the role of CCS in a new post-2012 international climate regime. Instead of the traditional 450ppm equilibrium stabilization of [the Intergovernmental Panel on Climate Change (IPCC)], a new scenario based on zero-emission and overshoot schemes was proposed recently. The scientific examinations demonstrated that the [so-called] Z650 scenario could avoid long-term risks while meeting [short-term] need of relatively large emissions. A numerical experiment of global energy system optimization shows the technical feasibility of the Z650 scenario not only globally but also regionally. The obtained time series total primary energy mixes suggest that the consumption of fossil energy will peak at 2030, and the clean energies, especially the renewable energy will play an essential role during the second half of the century. The resulted regional emission curves reflect the differences of financial and technical capability among areas. The industrialized countries will reduce their emissions by 50 [percent] in 2050 compared with 2005 levels, while the emissions of developing countries will increase by 10 [percent] at the same time. The cost-effective analysis based on the simulation results of the energy

model shows that the Z650 scenario is economically rational. Compared with the reference case, the additional investments in Z650 scenario could be covered by the fuel savings during the following 40 years (2010-[2050]) both globally and regionally. However, the comparison between the projection results and the national initiatives of major countries indicates that the policy measurements should be considered to promote the low carbon technology deployment and transfer. For this purpose, the existing CDM system should be enhanced on one hand, and a simpler and more efficient international scheme should be developed on the other hand." **Fengjun Duan, Tetsuo Yuhara, Hiroshi Ujita, Kazuhiro Tsuzuki, and Toshikazu Shindou**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

March 2013

"California Holds Second Auction of Carbon Credits." The California Air Resources Board held its second auction on February 19, 2013, selling more than 22 million CO_2 emissions allowance. The minimum bid price for the auction was $10.71 per ton. The state agency's first auction was held in November 2012 and raised $290 million. Along with the cap-and-trade market, the auction is a centerpiece of AB 32, California's legislation to address potential climate change. California has placed a ceiling on the total amount of CO_2 that can be released by industries each year; the ceiling, or cap, declines each year. Most allowances are available to companies for free; however, if additional allowances are needed, they can be purchased through the state's auction or on the open market. From *The Sacramento Bee* on February 20, 2013.

April 2013

"[RGGI] Auction Notice for CO_2 Allowance Auction 20 on 6/5/13." The states participating in the Regional Greenhouse Gas Initiative (RGGI) 2013 auctions released the Auction Notice and application materials for their 20th quarterly CO_2 allowance auction scheduled for June 5, 2013. The Auction Notice for CO_2 Allowance Auction 20 provides potential auction participants with the information needed to submit a Qualification Application and indicate their intent to bid. As indicated in the Auction Notice for CO_2 Allowance Auction 20, the states will offer for sale 38,782,076 CO_2 allowances. The states will use a reserve price of $1.98 for the June auction. From *RGGI News Release* on April 8, 2013.

"A modified GHG intensity indicator: Toward a sustainable global economy based on a carbon border tax emissions trading." The following is the Abstract of this article: "It will be difficult to gain the agreement of all the actors on any proposal for climate change management, if universality and fairness are not considered. In this work, a universal measure of emissions to be applied at the international level is proposed, based on a modification of the Greenhouse Gas Intensity (GHG-INT) measure. It is hoped that the generality and low administrative cost of this measure, which [the authors] call the Modified Greenhouse Gas Intensity measure (MGHG-INT), will eliminate any need to classify nations. The core of the MGHG-INT is what [the authors] call the IHDI-adjusted Gross Domestic Product (IDHIGDP), based on the Inequality-adjusted Human Development Index (IHDI). The IDHIGDP makes it possible to propose universal measures, such as MGHG-INT. [The authors] also propose a carbon border tax applicable at national borders, based on MGHG-INT and IDHIGDP. This carbon tax is supported by a proposed global ETS. The proposed carbon tax is analyzed in a short-term scenario, where it is shown that it can result in a significant reduction in global emissions while keeping the economy growing at a positive rate. In addition to annual GHG emissions, cumulative GHG emissions over two decades are considered with almost the same results." **Reza Farrahi Moghaddam, Fereydoun Farrahi Moghaddam, and Mohamed Cheriet**, *Energy Policy*. (Subscription may be required to view article.)

"Emissions trading and international competition: The impact of labor market rigidity on technology adoption and output." The following is the Abstract of this article: "Emission trading systems have been proposed in different regions to reduce polluting emissions and are in use in the

European Union for [CO_2] emissions. One of the objectives of these systems is to encourage firms to adopt advanced abatement technologies. However, permits also create an incentive to reduce output, which may be seen as negative by policy makers. [The authors] analyze the impact of a rigid [labor] market on these two outcomes, showing the conditions necessary to avoid reductions in production while keeping the incentives to improve abatement technologies. The analysis is done for oligopolistic firms engaged in international rivalry." **Alejandro Caparrós, Jean-Christophe Péreau, and Tarik Tazdaït**, *Energy Policy*. (Subscription may be required to view article.)

"Emission trading schemes – avenues for unified accounting practices." The following is the Abstract of this article: "Emission trading has emerged as a preferred mechanism to address the global challenge of climate change. Crafting an effective [GHG] accounting and disclosure program is fundamental to the design of an emission trading scheme. This paper reviews emission trading schemes that are currently administered under various regulatory and voluntary regimes. In particular, [the authors] look at how these emission trading schemes differ when addressing risk and assurance within their monitoring and disclosure programs. One important finding is that significant variations in terms of assurance engagement, spatial scope and level of compliance exist. It is concluded that harmonization of these approaches is desirable if an effective and functional global emission trading scheme is to be implemented." **Noim Uddin and Pernille Holtedahl**, *Journal of Cleaner Production*. (Subscription may be required to view article.)

May 2013

"Emission trading and international competition: The impact of labor market rigidity on technology adoption and output." The following is the Abstract of this article: "Emission trading systems have been proposed in different regions to reduce polluting emissions and are in use in the European Union for [CO_2] emissions. One of the objectives of these systems is to encourage firms to adopt advanced abatement technologies. However, permits also create an incentive to reduce output, which may be seen as negative by policy makers. [The authors] analyze the impact of a rigid [labor] market on these two outcomes, showing the conditions necessary to avoid reductions in production while keeping the incentives to improve abatement technologies. The analysis is done for oligopolistic firms engaged in international rivalry." **Alejandro Caparrós, Jean-Christophe Péreau, and Tarik Tazdail**, *Energy Policy*. (Subscription may be required to view article.)

"A modified GHG intensity indicator: Toward a sustainable global economy based on a carbon border tax and emissions trading." The following is the Abstract of this article: "It will be difficult to gain the agreement of all the actors on any proposal for climate change management, if universality and fairness are not considered. In this work, a universal measure of emissions to be applied at the international level is proposed, based on a modification of the Greenhouse Gas Intensity (GHG-INT) measure. It is hoped that the generality and low administrative cost of this measure, which [the authors] call the Modified Greenhouse Gas Intensity measure (MGHG-INT), will eliminate any need to classify nations. The core of the MGHG-INT is what [the authors] call the IHDI-adjusted Gross Domestic Product (IDHIGDP), based on the Inequality-adjusted Human Development Index (IHDI). The IDHIGDP makes it possible to propose universal measures, such as MGHG-INT. [The authors] also propose a carbon border tax applicable at national borders, based on MGHG-INT and IDHIGDP. This carbon tax is supported by a proposed global Emissions Trading System (ETS). The proposed carbon tax is analyzed in a short-term scenario, where it is shown that it can result in a significant reduction in global emissions while keeping the economy growing at a positive rate. In addition to annual GHG emissions, cumulative GHG emissions over two decades are considered with almost the same results." **Reza Farrahi Moghaddam, Fereydoun Farrahi Moghaddam, and Mohamed Cheriet**, *Energy Policy*. (Subscription may be required to view article.)

June 2013

"South Korean Parliament Approves Carbon Trading System." The National Assembly of South Korea passed a bill to establish a cap-and-trade system to cut GHG emissions. The market-based program will require companies that exceed the emission quotas to buy permits from those that emit less. The bill calls for emissions trading to commence in 2015. According to the Global Legislators Organization, carbon markets in Korea, Australia, and China may be linked with the European Union's (EU) emissions trading system (ETS) as early as 2020. At the 2009 United Nations Climate Summit, South Korea pledged to cut GHG emissions by 30 percent from forecast levels by 2020. Click here to view a White Paper produced by Bloomberg New Energy Finance. From *Bloomberg* on May 3, 2013.

"California's Third Carbon Auction Raises $280 Million." According to results released by the California Air Resources Board, California's third carbon allowance auction raised more than $280 million. Carbon credits for this year sold for $14 a ton; allowances for 2016 sold for the minimum $10.71 a ton. The state-run auctions, part of California's cap-and-trade market, require more than 400 big industrial emitters to cap their emissions at certain levels; if that cap is exceeded, they are then required to buy credits from the state or other market participants. From *The Sacramento Bee* on May 21, 2013.

"38.7 Million CO_2 Allowances Sold at 20th RGGI Auction." A total of 38,782,076 CO_2 allowances were sold at a clearing price of $3.21 at the 20th Regional Greenhouse Gas Initiative (RGGI) auction, held on June 5, 2013. The auction generated $124.4 million for reinvestment by the nine Northeastern and Mid-Atlantic states that participate in RGGI. Bids for the CO_2 allowances ranged from $1.98 to $5.55 per allowance; 100 percent of the allowances offered for sale by the nine states were sold. This is the second RGGI CO_2 allowance auction held since the RGGI states released the "Updated Model Rule" and "Program Review Recommendations Summary" in February 2013, guiding the RGGI states as they follow state-specific statutory and regulatory processes to propose updates to their CO_2 Budget Trading Programs. More information is available in the "Market Monitor Report for Auction 20." From *RGGI Press Release* on June 7, 2013.

"Planning carbon emission trading for Beijing's electric power systems under dual uncertainties." The following is the Abstract of this article: "In this study, a full-infinite interval-stochastic mixed-integer programming (FIMP) method is developed for planning carbon emission trading (CET) under dual uncertainties. FIMP has advantages in uncertainty reflection and policy analysis, particularly when the input parameters are provided as crisp and functional intervals as well as probabilistic distributions. The developed FIMP is applied to a real case study for managing CO_2 emissions with trading scheme of Beijing's electric power system (EPS). Electric power industry is one of the major sources of CO_2 emission in China. It is essential to accumulate relevant experience to provide a reliable basis for establishing a regional or national CET market, so as to prepare for docking with the international market. This is the first attempt to introduce CET scheme into Beijing's EPS to mitigate CO_2 emissions. The solutions for energy supply, electricity generation, carbon-quota allocation, and capacity expansion are obtained. They cannot only be used for formulating CO_2-reduction policies and assessing the associated economic implications in purchasing emission permits or bearing economic penalties, but also facilitate analyzing various policies when pre-regulated electricity-generation plans and pre-defined CO_2-emission schemes are violated." **Y. Zhu, Y.P. Li, and G.H. Huang**, *Renewable and Sustainable Energy Reviews*. (Subscription may be required to view article.)

July 2013

"CO_2 Emissions from Electricity Generation and Imports in the Regional Greenhouse Gas Initiative: 2011 Monitoring Report." This RGGI report is the third in a series of annual monitoring reports called for in the 2005 RGGI MOU. The report summarizes data for electricity generation,

electricity imports, and related CO_2 emissions in the 10 states participating in the RGGI control period from 2005 through 2011.

"The impact of electricity demand reduction policies on the EU-ETS: Modelling electricity and carbon prices and the effect on industrial competitiveness." The following is the Abstract of this article: "The European electricity market is linked to a carbon market with a fixed cap that limits [GHG] emissions. At the same time, a number of energy efficiency policy instruments in the EU aim at reducing the electricity consumption. This article explores the interactions between the EU's carbon market on the one hand and instruments specifically targeted towards energy end-use efficiency on the other hand. [The authors'] theoretical analysis shows how electricity demand reduction triggered by energy efficiency policy instruments affects the emission trading scheme. Without adjustments of the fixed cap, decreasing electricity demand (relative to business-as-usual) reduces the carbon price without reducing total emissions. With lower carbon prices, costly low emission processes will be substituted by cheaper high emitting processes. Possible electricity and carbon price effects of electricity demand reduction scenarios under various carbon caps are quantified with a long-term electricity market simulation model. The results show that electricity efficiency policies allow for a significant reduction of the carbon cap. Compared to the 2005 emission level, 30 percent emission reductions can be achieved by 2020 within the emission trading scheme with similar or even lower costs for the industrial sector than were expected when the cap was initially set for a 21 percent emission reduction." **Johannes Thema, Felix Suerkemper, Katharina Grave, and Adrian Amelung**, *Energy Policy*. (Subscription may be required to view article.)

August 2013

"UN Takes Steps to Boost Demand for Carbon Market Credits." The United Nations (UN) is opening a regional collaboration center in Grenada with to accelerate the development of carbon markets in the Caribbean. The office will help identify projects and opportunities for local governments, non-governmental organizations (NGOs), and other businesses interested in the Clean Development Mechanism (CDM). This is the third regional collaboration center established by the United Nations Framework Convention on Climate Change (UNFCCC) – the first was in Lomé, Togo, and the second was in Kampala, Uganda. From *RTCC.org* on July 26, 2013.

"EWSI Launches Carbon Trading Software for E-Waste Industry." E-Waste Systems, Inc. (EWSI) is launching software to identify and quantify the energy use of electronics to aid companies in reducing energy consumption and facilitate carbon trading. According to EWSI, the eWaste Carbon Credit technology brings carbon credit trading ability to the e-waste industry. The software is integrated with VGG's SMARTWeb system – an energy reporting and carbon accounting tool offered to large GHG emitters to reduce their energy and operating costs, validate their emissions, document their reductions, and support carbon trading. According to the 2007 IEEE International Symposium on Electronics and the Environment, emissions from electronic goods imported to the United States increased 300 percent from 1997 to 2004. From *Environmental Leader* on August 5, 2013.

"Towards a comprehensive system of methodological considerations for cities' climate targets." The following is the Abstract of this article: "Climate targets for cities abound. However, what these targets really imply is dependent on a number of decisions regarding system boundaries and methods of calculation. In order to understand and compare cities' climate targets, there is a need for a generic and comprehensive framework of key methodological considerations. This paper identifies eight key methodological considerations for the different choices that can be made when setting targets for GHG emissions in a city and arranges them in four categories: temporal scope of target, object for target setting, unit of target, and range of target. To explore how target setting is carried out in practice, the climate targets of eight European cities were analyzed. The results showed that these targets cover only a limited part of what could be included. Moreover, the cities showed quite limited awareness of what is,

or could be, include in the targets. This makes comparison and benchmarking between cities difficult." **Anna Kramers, Josefin Wangel, Stefan Johansson, Mattias Hojer, Goran Finnveden, and Nils Brandt**, *Energy Policy*. (Subscription may be required to view article.)

"Taxing International Emissions Trading." The following is the Abstract of this article: "[The authors] investigate the efficiency and effectiveness consequences of emissions trading taxation. A theoretical partial equilibrium model is developed, showing that permits taxation distorts the equilibrium price and abatement efforts. Potentially counterintuitive conclusions concerning the tax revenue are also derived. A [Computable General Equilibrium (CGE)] model complements theoretical results, suggesting that the change in the equilibrium permits price brought about by taxation can be significant. Finally, [the authors] conclude that policy design based on cost effectiveness might lead to wrong conclusions: the socially desirable design of emissions trading taxation requires homogenous tax rates applied to net sellers and no rebate rates allowed for net buyers." **Valeria Costantini, Alessio D'Amato, Chiara Martini, Maria Cristina Tommasino, Edilio Valentini, and Mariangela Zoli, *Energy Economics*. (Subscription may be required to view article.)

"Frameworks for pricing greenhouse gas emissions and the policy objectives they promote." The following is the Abstract of this article: "Four cost-effective frameworks for pricing [GHG] emissions currently receive widespread attention: cap-and-trade, emission fees, and hybrid cap-and-trade approaches that include upper or lower limits on permit prices (price ceilings or floors). This paper develops a fifth framework that uses an emission fee with an upper limit on the quantity of emissions—a quantity ceiling—and compares the impact of each framework on emission prices and quantities. Cap-and-trade with a price ceiling minimizes price increases for emitting activities in all cases whereas an emission fee with a quantity ceiling maximizes emissions reductions. Thus, the choice of framework influences policy outcomes because each framework is more or less suited to particular policy goals. Whether pursuing one potential policy goal serves society's interests best depends on the eventual consequences of climate damage and emissions pricing, which are uncertain when policy choices are made. Policy updating over time may reduce but likely cannot entirely eliminate the differences in outcome that arise due to framework choice. Therefore, the 'best' framework for emissions pricing depends on subjective preferences regarding the relative importance of different policy objectives, most notably whether one is more risk averse to climate damages or emissions price increases." **Paul A.T. Higgins, *Energy Policy*. (Subscription may be required to view article.)

Recent Publications

September 2012

"Understanding how individuals perceive carbon dioxide: Implications for acceptance of carbon dioxide capture and storage." The following is the Executive Summary of this document: "CCS presents one potential technological solution for mitigating the atmospheric emission of CO_2. However, CCS is a relatively new technology with associated uncertainties and perceived risks. For this reason, a growing body of research now focuses on public perceptions and potential for societal acceptance of CCS technology. Almost all explanations of CCS technology make reference to [CO_2], with an assumption that the general public understands CO_2. It has become apparent that the general public's knowledge and understanding of CO_2's properties influences how they engage with CO_2 emitting industries and CCS technologies. However, surprisingly little research has investigated public perceptions, knowledge, and understanding of CO_2. This investigation attempts to fill that gap. This report describes an investigation of how citizens of three countries – Japan, Australia, and the Netherlands – perceive CO_2. Furthermore, it attempts to relate individual perceptions of CO_2 to perceptions of CCS, and to determine how information provision about the underlying properties and characteristics of CO_2 influences individual attitudes towards low carbon energy options, particularly CCS. In brief, the research had four ultimate aims. It aimed to: [1] Explore the public's knowledge and

understanding of the properties of CO_2; [2]·Examine the influence of that knowledge on their perceptions of CO_2 and CCS; [3] Investigate how information provision about the underlying properties and characteristics of CO_2 influences individual attitudes towards CCS; and [4] Identify if any differences between countries exist in relation to values and beliefs, knowledge of CO_2's properties, and CCS perceptions. The research employed both qualitative and quantitative methods designed to complement each other. The qualitative component consisted of interviews and focus groups aimed at exploring public knowledge of CO_2 across each of the countries. They also provided an opportunity to explore how participants reacted when provided with information about CO_2 and CCS. Using a grounded theory approach, common themes and attributes identified in the qualitative component informed the development of a large scale survey, which was piloted and then rolled out in each country." The full CSIRO report is available at: http://cdn.globalccsinstitute.com/sites/default/files/publications/42501/perceptionsofco2reportfinalversion200612.pdf.

"Global Industrial CCS Technology Roadmap: Sectoral Assessment: Source-to-Sink Matching Final Report." The following is from the Executive Summary of this document: "The aim of this study was to perform a 'source-to-sink' matching exercise on five selected industrial sectors in non-[Organization for Economic Cooperation and Development (OECD)] countries, in order to determine the potential for industrial CCS deployment. This assessment was completed within the greater context of the [United Nations Industrial Development Organization (UNIDO)] 'Global Technology Roadmap for CCS in Industry' assessment. As such, this study serves as a basis for identifying some key tasks that will need to be undertaken if industrial CCS deployment is to advance to a level that is necessary for achieving global GHG emission reduction targets by 2050. The analysis performed here, which uses a qualitative source-to-sink matching approach to pair industrial CO_2 sources with geological formations seen as potentially holding sufficient CO_2 storage capacity, focuses on [11] non-OECD regions throughout the world. In terms of emission source inventory, this study is based on the emission source information available from the [International Energy Agency Greenhouse Gas R&D Program (IEAGHG)] CO_2 database, which is currently the most comprehensive, publicly available database and which also provides the geographical location data needed for this study." To download the report, go to: http://www.globalccsinstitute.com/publications/global-industrial-ccs-technology-roadmap-sectoral-assessment-source-sink-matching-final.

"Integrity of wellbore cement in CO_2 storage wells: State of the art review." The following is from the Executive Summary of this document: "Wells are the key technology for both storing CO_2 and monitoring its reservoir migration. However new and existing wells could also represent a risk to storage assurance by potentially providing [release] pathways. Well construction involves the use of cement for two main functions; to cement well casing in place and to plug wells that are abandoned. CO_2 could [release] from abandoned wells by flowing through a degraded, damaged or incomplete plug or outside the casing, between the casing and the formation. While one outcome is that CO_2 could migrate directly to surface via the well there is also the potential for CO_2 to migrate to other formations which may not have appropriate geology to prevent subsequent [release] or may contain other resources. There are three main pathways for CO_2 [release] between the casing and the formation; the interface between the cement and the formation, within the cement itself or the interface between the cement and well casing. While poor cementing practices during well completion may represent an important opportunity for the creation of migration pathways, there is also potential that cement degradation over long time periods could create pathways in otherwise soundly cemented wells. The focus of the current report is on the previous work related to the potential for cement to degrade to the extent that storage assurance is compromised rather than on completion practices." The full document is available at: http://www.globalccsinstitute.com/publications/integrity-wellbore-cement-co2-storage-wells-state-art-review.

October 2012

"The Global Value of Coal." The following is from the Executive Summary of this document: "The *Copenhagen Accord* (2009) identified two crucial challenges at the global level: first, the need for the nations of the world to meet the growing challenge of climate change and 'cooperate in achieving the peaking of global and national emissions as soon as possible'; and second, the need to 'bear in mind that social and economic development and poverty eradication are the first and overriding priorities of developing countries.' The objective of the current document is to delineate the past, current and potential contributions of coal in meeting both challenges. The discussion focuses on the global value of coal and the opportunities clean coal technologies present to continue and expand [utilization] of this vast energy resource, thereby allowing coal to continue to play a significant role in the world's socio-economic and environmental goals. Climate objectives and the eradication of poverty are complementary, not conflicting, goals. They are compatible and represent an achievable future for all societies. The challenges are real and substantial. Over 1.4 billion people are totally without electricity and at least another two billion have highly constrained access to power. At the same time, calls to reduce emissions by 80 [percent] by 2050 face the powerful headwind of rising energy demand due to economic growth, increases in population and an ever greater proportion of people living in cities. The world needs much more energy, particularly electricity, yet at the same time must significantly reduce GHG emissions, including those of CO_2. This report is founded on the premise that increased coal-based generation efficiencies, coupled with CCS, can help the world meet the goals of a significant reduction in CO_2 emissions amid sustained economic growth, the eradication of poverty and elimination of energy deprivation." To read the full document, prepared by the International Energy Agency (IEA) Coal Industry Advisory Board (CIAB), go to: http://www.iea.org/publications/insights/global_value_of_coal-1.pdf.

"The Global Status of CCS: 2012." The following is from the Executive Summary of this document: "Addressing climate change requires broad-scale action within the global community. Effective action is needed now to [decarbonize] energy consumption during this century; no single technology, or even class of technologies, can achieve this outcome. To achieve GHG emission reduction targets limiting a global average temperature rise to no more than 2°C, IEA estimates that energy-related emissions must reduce very substantially. Large-scale investments in several technologies are required in order to meet this target, with CCS contributing 7 Gt of the required 42 Gt emission reduction in a least cost scenario. If CCS were to be excluded as a technology option in the electricity sector, IEA states that investment costs over the period to 2050 would increase by 40 [percent]. CCS is a vital component of a portfolio of low-carbon technologies, as it is able to reduce CO_2 emissions substantially from both the energy sector and other industries. The Global CCS Institute's *Global Status of CCS: 2012* report identifies the status of CCS, the developments that have occurred in the past year, and the challenges that must be addressed in order for climate change to be managed effectively and efficiently." The full Global CCS Institute document is available at: http://www.globalccsinstitute.com/publications/global-status-ccs-2012.

"Central North Sea – CO_2 Storage Hub: Enabling CCS deployment in the UK and Europe." The following is from this document: "CCS is widely [recognized] as a vital technology which will play a significant role in the generation of low carbon electricity. CCS has the potential to reduce the carbon emissions of fossil fuelled power stations by as much as 90 [percent] as well as offering the only realistic solution to heavy industrial emitters such as steel mills, petrochemical refineries and cement manufacturing plants. Projects which can combine capture of emissions from power generation as well industrial emitters will enable the development of CO_2 transport infrastructure which can act to safeguard existing employment in carbon-intensive industries within the UK and EU. CCS development zones can also attract new energy intensive industries to locate into an area with an established network of CO_2 pipelines. That means low marginal costs to connect into a guaranteed network for transportation and storage of captured CO_2. Recent studies examining the [levelized] cost of electricity have consistently demonstrated that CCS will be competitive with renewable generation technologies such as offshore wind. CCS provides a low-carbon solution to the issue of intermittency which is inevitable with wind power, thereby helping to address the need for energy security in a future which will see a growth in the

percentage of power generation from renewable sources. Fossil fuels will be part of the energy and industry system for many decades to come. CCS is the only viable option for abating those CO_2 emissions. The creation of a CCS industry in the UK will provide opportunities for economic growth through the retention of many thousands of high-value jobs, creation of thousands of new jobs, increased manufacturing activity, as well as retention of the UK's world leading oil & gas supply chain for home investment and billions of pounds in export services." The full report is available at: http://www.scottish-enterprise.presscentre.com/imagelibrary/downloadMedia.ashx?MediaDetailsID=989.

"Leading By Example: Using Information and Communication Technologies to Achieve Federal Sustainability Goals." The following is the Executive Summary of this document: "As the [Nation's] largest landlord, fleet operator, and purchaser of goods and services, the [Federal] government has the opportunity, if not the responsibility, to lead by example in moving [the United States] in a more sustainable direction. Recent initiatives across the [Federal] government have demonstrated that the expanded use of information and communications technologies (ICT) can spur significant reductions in energy consumption and [GHGs], while at the same time achieve substantial cost savings and improve productivity. Recent technological developments have created new energy saving opportunities in the areas of smart buildings, smart transportation, and travel substitution. Additional opportunities exist related to mobility and collaboration tools. Led by the General Services Administration (GSA) and the Department of Defense (DOD), these government-wide efforts are changing the way [Federal] departments and agencies operate. They represent the intersection of two critically important forces driving agency [behavior] today. Increasingly stringent budget constraints are pushing agencies to take a hard look at ways they can reduce costs and enhance efficiencies. At the same time, new Executive Orders and Congressional actions are mandating that agencies alter their practices to become more sustainable. These two forces have come together to create new opportunities for the government to change in important ways that produce multiple benefits for individual agencies and for the public they serve." To view the entire Center for Climate and Energy Solutions (C2ES) Report, go to: http://www.c2es.org/publications/leading-by-example-federal-sustainability-and-ict?utm_source=Center+for+Climate+and+Energy+Solutions+newsletter+list&utm_campaign=dd4b8608e1-September_2012_Newsletter&utm_medium=email.

"Literature Review of Tracer Partition Coefficients." The following is from the Introduction of this document: "Predicting and understanding the [behavior] of CO_2 is challenging due to its complex phase [behavior] (i.e. CO_2 can exist in the subsurface as a liquid, gas, supercritical fluid or a solute in water depending on the physical/chemical conditions) and the wide range of possible trapping mechanisms (i.e. residual, solubility, structural and mineral). Commonly proposed storage scenarios involve pumping CO_2 into reservoir rock formations at depths greater than 800 [meters], where the pressure/temperature typically exceeds the critical point of [CO_2] (7.38 MPa, 31.1°C). Chemical tracers represent a complimentary reservoir [characterization] and monitoring tool to alternative approaches such as geophysical measurements (e.g. time lapse seismic) and have been used extensively worldwide at CCS sites. The majority of tracer applications within CCS are related to either understanding the subsurface movement of [CO_2], quantifying the trapping capacity or determining containment and [release] rates for monitoring and verification programs. Chemical stability, cost effectiveness, ease of detection, toxicity, injection/sampling protocols and subsurface [behavior], together dictate the choice of tracer for a particular application or scenario." The full Commonwealth Scientific Industrial Research Organization (CSIRO) report is available at: http://cdn.globalccsinstitute.com/sites/default/files/publications/45416/literaturereviewoftracerpartitioncoefficients.pdf.

November 2012

"Initial Risk Analysis and Decision Making Framework." The following is the Introduction of this document: "Commercialization of new carbon capture simulation initiative (CCSI) technology will include two key elements of risk management, namely, technical risk (will process and plant performance be

effective, safe, and reliable) and enterprise risk (can project losses and costs be controlled within the constraints of market demand to maintain profitability and investor confidence). Both of these elements of risk are incorporated into the risk analysis subtask. Thus far, this subtask has developed a prototype demonstration tool that quantifies risk based on the expected profitability of expenditures when retrofitting carbon capture technology on a stylized 650 MW pulverized coal electric power generator. The prototype is based on the selection of specific technical and financial factors believed to be important determinants of the expected profitability of carbon capture, subject to uncertainty. The uncertainty surrounding the technical performance and financial variables selected thus far is propagated in a model that calculates the expected profitability of investments in carbon capture and measures risk in terms of variability in expected net returns from these investments. Given the preliminary nature of the results of this prototype, additional work is required to expand the scope of the model to include additional risk factors, additional information on extant and proposed risk factors, the results of a qualitative risk factor elicitation process, and feedback from utilities and other interested parties involved in the carbon capture project. Additional information on proposed distributions of these risk factors will be integrated into a commercial implementation framework for the purpose of a comparative technology investment analysis." The document is available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20932.pdf.

"Geologic Evaluation of the Tucson Basin for Carbon Dioxide [Storage] Potential." The following is from the Introduction of this document: "DOE, including its [NETL] and West Coast Regional Carbon Sequestration Partnership (WESTCARB), have established national programs to evaluate the technical feasibility of long-term subsurface geologic storage of CO_2 produced by industrial activity. The WESTCARB is a consortium of seven western U.S. [states] and one Canadian Province that is one of seven regional North American partnerships established to evaluate technical aspects of high-volume CO_2 capture and [storage]. Collaborative WESTCARB research programs have included more than 90 public agencies, private companies, and non-profit organizations. The Arizona Geological Survey (AZGS) began work in 2010 on 'WESTCARB Phase III – Arizona Geological Characterization.' As part of 'WESTCARB Phase III,' the AZGS is evaluating the potential for CO_2 [storage] in geologic formations that are below a level of 800 meters (m) (2,625 feet [ft]) depth below land surface (bls). This evaluation is directed at porous and permeable geologic formations with impermeable sealing strata in Cenozoic sedimentary basins in the Basin and Range Province, and Paleozoic sedimentary formations of the Colorado Plateau. An initial screening of Cenozoic sedimentary basins with significant depth and volume below the 800 m (2,625 ft) bls level resulted in 10 candidate basins from a total of 88 basins. This report represents ongoing WESTCARB assessment of CO_2 storage potential in the Tucson basin, one of 10 Cenozoic basins in Arizona identified during the preliminary evaluation, and is part of Tasks 2 and 3 of Arizona WESTCARB Phase III. Task 2 consists primarily of characterizing basin structure, stratigraphy, lithology, and the nature of seals or a [caprock]. This task also includes determining the storage capacity of permeable sediments below 800 m (2,625 ft) depth. Task 3 is to determine if, and at what depth, saline groundwater approaches 10,000 milligrams per liter (mg/L) of total dissolved solids (TDS), characterized in a separate salinity study. This concentration represents the threshold above which water is considered non-potable and unsuitable as drinking water. Based on the extent of permeable strata underlying impermeable strata, saturated with saline groundwater above 10,000 mg/L, the CO_2 storage volume below 800 m (2,625 ft) can be revised from earlier estimates." The entire document is available at: http://repository.azgs.az.gov/uri_gin/azgs/dlio/1479.

"Coal – Energy for Sustainable Development." The following is a summary of this document: "Coal is an essential resource for meeting the challenges facing the modern world. It plays a major role in delivering electricity across the globe, is fundamental in the creation of steel and concrete, and provides energy for transport. [The World Coal Association (WCA)] has published 'Coal – Energy for Sustainable Development,' which highlights the vital role coal has in delivering energy to the 1.3 billion people who lack access to it as well as coal's role in building sustainable communities. This section looks at the challenges of providing greater access to energy worldwide, the role played by coal and how access to

energy is essential to sustainable development." The full report is available at: http://www.worldcoal.org/resources/wca-publications/.

"World Energy Outlook 2012." The following is a summary of this publication: "[WEO-2012] presents authoritative projections of energy trends through to 2035 and insights into what they mean for energy security, environmental sustainability and economic development. Oil, coal, natural gas, renewables and nuclear power are all covered, together with an update on climate change issues. Global energy demand, production, trade, investment and [CO_2] emissions are broken down by region or country, by fuel and by sector." The full version is available for purchase at: http://www.iea.org/W/bookshop/add.aspx?id=433%20.

"CO_2 Emissions from Fuel Combustion." The following is a summary of this document: "In recognition of fundamental changes in the way governments approach energy-related environmental issues, the [International Energy Agency (IEA)] has prepared this publication on CO_2 emissions from fuel combustion. This annual publication was first published in 1997 and has become an essential tool for analysts and policy makers. The data in this book are designed to assist in understanding the evolution of the emissions of CO_2 from 1971 to 2010 for more than 140 countries and regions by sector and by fuel. Emissions were calculated using IEA energy databases and the default methods and emission factors from the Revised 1996 [Intergovernmental Panel on Climate Change (IPCC)] Guidelines for National Greenhouse Gas Inventories." The complete International Energy Agency (IEA) document is available at: http://www.iea.org/w/bookshop/add.aspx?id=618.

December 2012

"Carbon Capture and Storage: [Mobilizing] private sector finance for CCS in the UK." The following is from the Introduction of this document: "This report presents the findings of a joint project by the Energy Technologies Institute and the Ecofin Research Foundation to examine the conditions for [mobilizing] private sector financing of [CCS] in the UK. It is based on structured interviews with capital providers, project developers and other key stakeholders. The UK has adopted ambitious targets to reduce [GHG] emissions by 80 [percent] by 2050. Achieving these targets will be hugely challenging in engineering and economic terms. Many future energy system scenarios envisage a key role for CCS in enabling the UK to deliver its emissions targets at an affordable cost. CCS is the process of capturing and securely storing [CO_2] instead of emitting it into the atmosphere." To download the full report, go to: http://eti.co.uk/downloads/literature/Ecofin_CCS_Report.pdf.

"Perspectives on Carbon Capture and Storage." The following is from the Introduction of this document: "Climate change is a pressing environmental problem that threatens human health, security and prosperity. The world's scientists have concluded that 'warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.' Anthropogenic emissions of [GHGs] are responsible for the bulk of these trends… Climate change is not only an environmental problem, but also a public health, national security and prosperity problem… In order for global average temperatures to remain within bounds that may avoid the dangerous impacts of climate change, global CO_2 emissions would need to peak within the next decade, and decrease at the very least by 50-85 [percent] compared to year 2000 levels by mid-century. The more [the needed reductions are delayed], the higher the degree of warming that the planet is locked into. The continued increase of [GHGs] as a result of human activities poses a structural challenge to global energy systems and economies. Fortunately, a number of technologies are available to mitigate emissions, although not as yet deployed at the scale necessary. These include increasing efficiency and reducing demand in all energy-consuming sectors, switching to renewable and lower carbon energy sources, increasing carbon uptake in forests and soils, and [CCS]." This ENGO Network on CCS document is available at: http://www.engonetwork.org/engo_perspectives_on_ccs_digital_version.pdf.

"Carbon Capture and Storage Regulatory Review for Trinidad and Tobago." The following is from the Introduction of this document: "The Inter-American Development Bank (IDB) has provided a grant to Trinidad and Tobago to assist with the consideration of the impact of climate change into national policies and institutions. The grant program is titled "Mainstreaming of Climate Change into National Development and Capacity Building for Participation in Carbon Markets" (the Program). As part of the Program, the Government is undertaking a study to examine the feasibility of a CCS project in Trinidad and Tobago. Through this study, it is hoped that the Government and other stakeholders will better understand the potential role CCS could play in Trinidad and Tobago. The Global CCS Institute is supportive of the initiative and is pleased to contribute to the Program through the "Carbon Capture and Storage Regulatory Review for Trinidad and Tobago" (the Review). The Review considers the existing legal and regulatory framework as it pertains to CCS in Trinidad and Tobago. The major sources of CO_2 emissions in Trinidad and Tobago are the energy and manufacturing sectors. The "National Climate Change Policy 2011" indicates that the CO_2 emission levels for Trinidad and Tobago for 2008 was 28.37 [metric tons] of CO_2 per capita, the highest in the region. Given that the country is the leading producer of oil and gas in the Caribbean as well as being the largest producer of methanol and the largest trader of ammonia this figure is not surprising." To read the complete review, please visit: http://cdn.globalccsinstitute.com/sites/default/files/publications/54126/ccs-regulatory-review-trinidad-tobago.pdf.

"Climate change, impacts and vulnerability in Europe 2012." The following is from the Executive Summary of this document: "The United Nations Framework Convention on Climate Change (UNFCCC) has agreed to limit the increase in global mean temperature since pre-industrial times to less than 2°C, in order to prevent the most severe impacts of climate change. Current global actions to reduce [GHG] emissions ('mitigation') are insufficient to constrain the temperature increase to 2°C, and global warming could be well above 2°C by 2100. Even if the 2°C limit is kept, substantial impacts on society, human health and ecosystems are projected to occur. Adaptation to and mitigation of climate change are therefore both needed. The European Commission has initiated various actions to integrate and mainstream adaptation into EU sectoral policies following the publication of the White Paper on adaptation to climate change in 2009. Furthermore, many countries in Europe have already adopted national adaptation strategies and some have followed up with specific action plans. The European Commission plans publishing its European Adaptation Strategy in 2013, which will include further proposals for adaptation actions across the EU. This report aims at providing a strong knowledge base for the development and implementation of adaptation strategies and actions at both national and EU levels. The indicators presented here are also accessible via the [European Environment Agency (EEA)] indicator management system and the European Climate Adaptation Platform (Climate-ADAPT). Early in 2013 the EEA will publish a dedicated report on adaptation, which will assess actions to adapt to climate change at European, national and sub-national levels." The complete report is available for download at: http://bookshop.europa.eu/en/climate-change-impacts-and-vulnerability-in-europe-2012-pbTHAL12012/;pgid=y8dIS7GUWMdSR0EAlMEUUsWb0000UZ7LPTrH;sid=UuYkAgarTUkkC1YTga-6pWSOH4U6cAF4VDU=?CatalogCategoryID=h2YKABstrXcAAAEjXJEY4e5L. (Purchase may be required.)

January 2013

"2012 United States Carbon Utilization and Storage Atlas." The following is the Foreword of this document: "[DOE/NETL] is proud to release the fourth edition of the United States Carbon Utilization and Storage Atlas (Atlas IV). Production of Atlas IV is the result of collaboration among carbon storage experts from local, State, and Federal agencies, as well as industry and academia. Atlas IV provides a coordinated update of CCUS potential across the United States and other portions of North America. The primary purpose of Atlas IV is to update the CO_2 storage potential for the United States and to provide updated information on the RCSPs field activities and new information on the [ARRA-funded] Site Characterization projects. In addition, Atlas IV outlines DOE's Carbon Storage Program, DOE's CCUS collaborations, worldwide CCUS projects, and CCUS 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 CCUS technologies from RCSPs. A key aspect of CCUS deals with the amount of carbon storage potential available to effectively help reduce GHG emissions. As demonstrated in Atlas IV, CCUS holds great promise as part of a portfolio of technologies that enables the United States and the rest of the world to effectively address climate change while meeting the energy demands of an ever increasing global population. Atlas IV includes the most current and best available estimates of potential CO_2 storage resource determined by a methodology applied consistently across all of the RCSPs. A CO_2 storage resource estimate is defined as the fraction of pore volume of porous and permeable sedimentary rocks available for CO_2 storage and accessible to injected CO_2 via drilled and completed wellbores. Carbon dioxide storage resource assessments do not include economic or regulatory constraints; only physical constraints are applied to define the accessible part of the subsurface. Economic and regulatory constraints are included in geologic CO_2 capacity estimates.
The data in Atlas IV is current as of November 2012. It will be updated every two years as new data are acquired and methodologies for CO_2 storage estimates improve. Furthermore, it is expected that, through the ongoing work of the RCSPs, data quality and conceptual understanding of the CCUS process will improve, resulting in more refined CO_2 storage resource estimates." The full Atlas is available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIV/Atlas-IV-2012.pdf.

"Carbon Capture and Storage (CCS) for Coal-Fired Plants – Opportunity Assessment and Key Country Analysis to 2025." The following is the Summary of this document: "This report provides the retrofit potential and new market potential for the global CCS market in terms of revenues and capacity. It also discusses the key drivers and restraints impacting the market. The report provides an in depth analysis of key global CCS markets– the US, Canada, the UK, Germany, Poland, Australia, China and Japan. It provides the retrofit potential and new market potential for CCS and the regulations in each of these countries. The report also provides an overview of key players in global CCS market." The full report is available for purchase at: http://www.reportlinker.com/p01057651-summary/Carbon-Capture-and-Storage-CCS-for-Coal-Fired-Plants-Opportunity-Assessment-and-Key-Country-Analysis-to.html.

"Development of a measurement, monitoring and verification technical framework for geological storage of CO_2 in Australia: Feedback report." The following is from the Introduction of this document: "Primary objectives of this report are to: (1) provide feedback on the input and discussions involving selected stakeholders regarding issues associated with the development of a nationally consistent [measurement, monitoring, and verification (MMV)] technical framework in Australia, and (2) present options for addressing the identified key issues and potential implications for the development of a national MMV technical framework. The report is structured as follows: summary of the key findings of the literature review; summary of the key findings of the stakeholder engagement activities on the issues and challenges for a national framework; options for addressing the key issues associated with the development of a national MMV technical framework; conclusions on the level of support and how to progress for the development of a national MMV technical framework; the Consolidated Literature Review is included in Appendix A; and a list of stakeholder organizations that attended the workshop, participated in interviews, and responded to questionnaires is included in Appendix B." The report is available for download at: http://www.globalccsinstitute.com/publications/development-measurement-monitoring-and-verification-technical-framework-geological.

February 2013

"Making the business case for CCS." The following is the Introduction of this document: "A considerable number of companies and investors around the world have ambitions to create [large-scale] power plants with CCS. To do so on a sustainable model requires them to obtain a suitable return on their investment in order to accommodate the risks inherent in the technology. But CCS faces a key hurdle that, without sufficient intervention, is preventing development of CCS facilities and the emergence of a new industry. The cost of CCS facilities is not sufficiently covered by electricity sales

revenue at current wholesale power prices anywhere in the world, nor is it covered by the ability to earn income from avoiding or reducing CO_2 emissions. CCS investors, therefore, need to carefully build a suitable business case sufficient to meet the fundamental challenge of the mismatch between costs and revenues. 2Co Energy Limited (2Co) has written this knowledge product to share its real-life CCS business case for its CCS project in the UK, the Don Valley Power Project (DVPP), with the members of the Global CCS Institute. By sharing its business case in this way, 2Co hopes to provide practical information that can be of use to members of the Institute as they develop their own business cases for CCS around the world. The report covers the following: [1] A brief overview of 2Co and its CCS project in the UK, DVPP. [2] A summary of existing business case-related knowledge products previously published for the Institute by other CCS projects, [summarizing] the factors of most importance to their business cases. [3] A description of the market and regulatory context for CCS faced by DVPP and other projects in the UK. [4] A discussion of the financing challenge that 2Co faces and the resulting financing strategy. [5] The resulting business plan, including revenue and cost profiles, sensitivities and prospects for future cost reduction. [6] A description of the key risks to the project and mitigation plans."

"Toward a common method of cost estimation for CO_2 capture and storage at fossil fuel power plants." The following is the Abstract of this document: "There are significant differences in the methods employed by various organizations to estimate the cost of CCS systems for fossil fuel power plants. Such differences often are not readily apparent in publicly reported CCS cost estimates. As a consequence, there is a significant degree of misunderstanding, confusion, and misrepresentation of CCS cost information, especially among audiences not familiar with the details of CCS costing. Given the international importance of CCS as an option for climate change mitigation, efforts to improve and systematize the estimation and communication of CCS costs are especially urgent and timely. This paper recommends a path forward to achieve that goal."

"Developing a risk program for a carbon capture and storage project: A case study of Project Pioneer." The following is a summary of this document: "CCS projects could be considered a special type of oil and gas capital project. The standard approach used for risk management of oil and gas capital projects is applicable to CCS projects. Also the uniqueness of CCS projects as well as the characteristics of a particular project should influence the design of the Risk Management System (RMS). Both general CCS challenges and features specific to Project Pioneer were taken into account when shaping the project risk management system that is described in this report."

"GETICA CCS Demo Project: Financial scenarios report." The following is a summary of this document: "Given that electricity generation in Romania is primarily based on coal, implementing CCS would greatly reduce CO_2 emissions while keeping coal-fired power plants operational. This financial scenarios report describes the optimum solution to financing a large-scale CCS project in Romania. It considered the challenges of finding and securing financing sources for the project. The existing financing sources, at EU and national level, were [analyzed] in terms of financing structure of the project, project eligibility, origin of financing (public/private), availability of funding, availability in time, and degree of certainty. Three scenarios were created, based on the prospected funding sources for CCS projects. A qualitative assessment was performed and, based on this assessment, the optimum scenario was chosen for the GETICA CCS Demonstration project."

March 2013

"The Global Status of CCS: Update, January 2013." The following is a summary of this document: "This update [summarizes] the current status of large–scale integrated CCS projects (LSIPs) worldwide and outlines the major developments that have occurred since the Institute's Global Status of CCS: 2012 report was published in October 2012. In brief, at the end of January 2013 the Institute identified that the number of LSIPs around the world had decreased from 75 to 72, with two Dutch projects put on hold and one in the United States cancelled. One project in Canada made a positive final investment decision, bringing the total number of projects operating or under construction to 17. Globally, eight operational

projects are preventing 23 million [metric tons] of CO_2 per year from reaching the atmosphere. This is expected to increase to 37 million [metric tons] of CO_2 a year by 2015, by which time a further nine projects under construction—up from eight reported in the October 2012 Status Report—will be operating. In a significant setback to CCS demonstration targets in Europe, no CCS projects were awarded funding under the first round of the European Commission's NER300 competition."

"CO_2 Storage Atlas: Norwegian Sea." The following is a summary of this document: "The Norwegian Sea may be able to store 5.5 gigatons of CO_2. This is more than 100 times Norway's total CO_2 discharge in 2012. The CO_2 Storage Atlas of the Norwegian Sea has been prepared by the Norwegian Petroleum Directorate, at the request of the Ministry of Petroleum and Energy. The studied areas are in opened parts of the Norwegian Continental Shelf (NCS). The main objectives have been to identify the safe and effective areas for long-term storage of CO_2 and to avoid possible negative interference with ongoing and future petroleum activity. This study is based on detailed work on all relevant geological formations and hydrocarbon fields in the Norwegian Sea. The work is based on several studies as well as data from more than 40 years of petroleum activity on the Norwegian Continental Shelf. A new geological study of the coastal-near [formations] in the Norwegian Sea, is included. A study of the CO_2 storage potential in relevant dry-drilled structures and mapped structures in the area is provided, together with a summary of the CO_2 storage potential in oil and gas fields. [Carbon dioxide] storage in [EOR] projects is also discussed. The methodology applied for estimating storage capacity is based on previous assessments, but the storage efficiency factor has been assessed individually for each [formation] based on simplified reservoir simulation cases. The assessed [formations] have been ranked according to guidelines developed for the CO_2 Storage Atlas of the Norwegian part of the North Sea (2011)."

"Communications for carbon capture and storage: Identifying the benefits, managing risk and maintaining the trust of stakeholders." The following is a summary of this document: "This report reviews the communication approaches of five CCS projects and explores the common challenges and themes they have faced. It is not designed to be a 'template for success' or a 'how-to' guide because all projects are different and all sites have specific issues. It does, however, attempt to draw out communication strategies that have proven to be successful for some projects as they have attempted to earn and maintain stakeholders' trust and suggests measures which, project developers in general and CCS communicators in particular, might adopt if they are to mitigate the risk of failure on the engagement front."

"A deployment strategy for effective geophysical remote sensing of CO_2 sequestration: Final report." The following is a summary of this document: "The report examines alternative geophysical methods to time-lapse seismic that might be deployed to monitor commercial volumes of stored CO_2. It uses simple geological models for the South Perth and Gippsland basins to simulate the resolution of various techniques or combinations of techniques. Topics covered include lowering noise levels in data processing workflows, estimate noise in a time-lapse sense for shallow well receivers as well as ambient noise imaging for ocean bottom receivers. Whilst no alternative method or combination of methods appears to have the sensitivity to adequately replace a time-lapse seismic approach, the added information could greatly improve the resolution and sensitivity of time-lapse geophysical methods alone."

April 2013

"Carbon Capture and Storage (CCS) for Coal-Fired Plants – Opportunity Assessment and Key Country Analysis to 2025." The following is a summary of this document: "This report provides the retrofit potential and new market potential for the global CCS market in terms of revenues and capacity. It also discusses the key drivers and restraints impacting the market. The report provides an in depth analysis of key global CCS markets – the [United States], Canada, the UK, Germany, Poland, Australia, China and Japan. It provides the retrofit potential and new market potential for CCS and the regulations in each of these countries. The report also provides an overview of key players in global CCS market."

"Permitting process: Special report on getting a CCS project permitted." The following is a summary of this document: "The ROAD-project is the first of its kind in The Netherlands and applying for all of the necessary permits was one of the most challenging aspects of the project. CCS projects indeed face a complex and time consuming permitting process. The permitting process for the ROAD-project is described and evaluated in this report; with all relevant legislation and regulations described and all permits discussed. Special attention is given to the storage permitting process because this proved the most unprecedented. The EU CCS Directive, providing the legislative framework for the storage permit, and the key issues arising from this Directive was also extensively assessed. This report aims to help similar projects (CCS projects using post-combustion capture technology, transporting CO_2 by pipelines and storing CO_2 in depleted gas reservoirs) identify the important considerations for a successful permitting process."

"The Industrial Base for Carbon Dioxide Storage: Status and Prospects." The following is a summary of this document: "CCS is the process of capturing CO_2 prior to its being emitted into the atmosphere, then either using it in a commercial application or storing it in geological formations for hundreds to thousands of years. If policies aimed at large reductions of CO_2 emissions from industrial sources and power plants are enacted, more CCS will be needed. RAND researchers explored the ability of the industrial base supporting the transportation and storage of CO_2 to expand, assessing the industrial base for transportation and injection for CO_2 for both geologic storage and enhanced oil recovery. They also identified and quantified the activities, equipment, and labor required for transporting CO_2 to an injection site, using it in oil recovery, and storing it in a geologic formation. RAND developed four scenarios for future CCS development and determined that under most of them, significant expansion of geologic storage capacity is required after 2025, and that based on current activities, it appears that the industrial base supporting the development of geologic storage has the ability to meet increased needs for CO_2 storage."

May 2013

"Quantification of Risk Profiles for Atmosphere and Groundwater." The following is the Executive Summary of this document: "This report summarizes National Risk Assessment Partnership (NRAP) efforts to develop an approach to quantify risk profiles for atmospheres and [formations] at a CO_2 storage site. [The authors] have used a science-based prediction approach for computation of time-dependent profiles for [release] risks at a CO_2 storage site. The approach requires prediction of a storage site performance over long time. [The authors] used an Integrated Assessment Model (IAM) in order to implement a system modeling approach for predicting long term site behavior. The systems modeling approach treats a storage site as a system made up of sub-systems such as storage reservoir, overlying seal, wellbores, faults or other transport pathways, and shallow permeable zones including groundwater systems, etc. The behavior of each of the components in the storage-site system is predicted using reduced-order models (ROMs) based on detailed process-level simulations. Different approaches were used to develop ROMs. A look-up table approach, which directly incorporated reservoir simulation results, was used for the storage reservoir; a high-resolution look-up table developed using Lawrence Livermore National Laboratory's (LLNL) PSUADE (Problem Solving environment for Uncertainty Analysis and Design Exploration) package and based on Los Alamos National Laboratory's (LANL) FEHM (Finite Element Heat and Mass transport code) simulation results was used for [release] through cemented wellbores; a look-up table, which directly incorporated simulation results performed using Lawrence Berkeley National Laboratory's (LBNL) TOUGH2 (Transport Of Unsaturated Groundwater and Heat simulator) was used for [release] through open wellbores; high-order polynomial ROMs developed using LLNL's PSUADE package and based on detailed numerical simulations using LANL's FEHM code and Pacific Northwest National Laboratory's (PNNL) STOMP (Subsurface Transport Over Multiple Phases) code were used for shallow [formations]. The IAM was used for first-generation risk profile calculation was built using LANL's CO_2-PENS (CO_2-Predicting Engineered Natural Systems) system model."

"CO_2 Capture Project Annual Report 2012." The following is from the Introduction of this document: "There has been intense activity in 2012 across all [CO_2 Capture Project (CCP)] Teams – Capture, Storage, Policy & Incentives and Communications. The Capture Team continues to work to develop a suite of economically viable next generation technologies – focusing on oil refinery, oil production and power generation scenarios. Last year saw the CCP hold an oxy-firing test at a pilot-scale Fluid Catalytic Cracking (FCC) unit at a Petrobras research facility in Parana state, Brazil. This demonstration has indicated the technical viability of retrofitting an FCC unit to enable CO_2 capture through oxy-firing. It has underlined oxy-firing technology as the preferred route for FCC CO_2 capture and is a crucial achievement for the CCP and its member companies, who have closely collaborated to bring this to fruition. The team also made progress in developing a range of other capture technology tests and studies that will be delivered in 2013, while greater clarity was achieved around the baseline cost implications of the three main capture technologies. It has also been an important year for the Storage Team, which has continued its work on addressing key issues for industry and regulators through a mix of experiment, analysis, modeling and field trials. The team guided a number of important monitoring field trials to completion with the successful deployment of innovative Modular Borehole Monitoring technology at Citronelle Dome in the [United States], and further results from a satellite monitoring program at Decatur, Illinois. The team's work on contingencies, contributing to the understanding of detection and remediation of unexpected CO_2 or brine migration has also progressed well. This work has the potential to be a key input to help assure stakeholders that storage can be performed safely and securely. The Policy & Incentives Team has continued to further contribute to an understanding of government and institutional policies influencing the development of CCS. Its 2012 CCS Regulatory Study has given valuable insight into the evolution of legal frameworks in key jurisdictions and into how project managers and regulators are finding pathways for regulatory approvals."

"Making the case for funding carbon capture and storage in developing countries." The following is a summary of this document: "This report was developed for the Fourth Clean Energy Ministerial [(CEM)] meeting held in New Delhi [April 17-18, 2013]. It provides an update on recommendations made to Ministers in the preceding report 'Funding Carbon Capture and Storage in Developing Countries' tabled at the 2012 CEM in London. It includes a 'Template Business Case' that identifies the links between funding for CCS and development impacts, which may be a useful reference document for donor countries considering funding CCS in developing countries."

"European chemistry for growth: Unlocking a competitive, low carbon and energy efficient future." The following is the Introduction of this document: "The European chemical industry is an essential industry manufacturing products used in the majority of everyday goods. The industry adds value to the economy and creates direct employment for 1.2 million people. Looking towards 2050, the European chemical industry has the potential to continue as an innovative industry contributing to new and currently unknown solutions to [fulfill] human needs. The chemical industry uses fossil and renewable resources both as feedstock to make products and as a source of energy to generate heat, steam and electricity. It accounts for roughly one third of the combined energy and feedstock use of the European industry. Its energy and feedstock basis is largely fossil fuel based and as such contributes to the increasing level of [GHGs] in the atmosphere and to climate change. At the same time, the European chemical industry is a vital solution provider to create a more energy efficient and low carbon economy. It contributes to energy efficient solutions in almost all sectors of the economy, and the demand for products of the chemical industry will continue to grow. The challenge for the European chemical industry is to satisfy the demand growth for chemical products with highly efficient European production while reducing CO_2 and other GHG emissions. For this to happen, the European chemical industry needs to be competitive in a global market place, which is challenging due to differences in feedstock and energy prices as well as climate policies and their ambition levels across the world. Globally, energy use continues to increase and to limit the most harmful impacts of climate change on society, global action is required to improve energy efficiency and to transform the energy system towards a lower GHG emissions intensity. Currently, the debate in Europe is focused on how to develop its energy and climate

policies in the coming decades given the current absence of a global agreement on GHG emissions reduction and the uncertain outlook on reaching such an agreement in the years to come."

"Looking at the Potential of Carbon Sequestration." The following is from the description of this document: "This report envisages on the key issue of making carbon [storage] an economically competent and financially viable strategy which links the community in the long run by incentivizing sustained socio-economic activity in conjunction with the environment. The report looks at carbon [storage] projects as a means of promoting sustainable forestry practices as well as conserving the interest of the land stakeholders in implementation of these projects…The report uses the Bolivia – Noelle Kempff Climate Action model and several other projects as case studies of a large scale carbon project at work in a developing country. The efforts of some countries and the innovative initiative taken by them in achieving carbon [storage] ahead of the world order and also ensuring the goal of weaving the community in economic activity with the environment thereby removing one of the most basic reasons for degradation of forest cover. The report is a complete guide to understanding and identifying the true potential of Carbon [Storage] for a clean sustainable future for mankind." (Subscription may be required to view document.)

June 2013

"Comparison of Publicly Available Methods for Development of Geologic Storage Estimates for Carbon Dioxide in Saline Formations." The following is from the Executive Summary of this NETL-published document: "Prospective CO_2 storage resource estimates for application to saline formations at the national, regional, and basin scale are required to assess the potential for CCS technologies to reduce CO_2 emissions. Both private and public entities worldwide rely on CO_2 storage resource estimates for broad energy-related government policy and business decisions. As prospective estimates, they embody inherent uncertainties arising from simplifying assumptions and data limitations pertaining to subsurface geology. Carbon storage resource estimates provide important bounds for energy planning at the national and regional levels. Several methods have been developed to provide storage-resource estimates, originating with efforts as early as 1993. This study compares estimates that several commonly used methods produce when applied to common data sets to assess the impact that the choice of method has on the results."

"CCS Cost Reduction Taskforce: Final Report." The following is from the Executive Summary of this document: "This Final Report builds on the Interim Report of November 2012 which focused on identifying the opportunities for cost reduction across the CCS chain to achieve cost competitive CCS in the 2020s. The Final Report presents to [the UK] Government what the Task Force has identified as Agreed Actions and recommended Next Steps to achieve these cost reductions and develop the CCS industry in the UK… The Key Conclusion of the Interim Report of the UK CCS Cost Reduction Task Force (CRTF) remains intact. This is: 'UK gas and coal power stations equipped with carbon capture, transport and storage have clear potential to be cost competitive with other forms of low-carbon power generation, delivering electricity at a [levelized] cost approaching [~$155]/MWh by the early 2020s, and at a cost significantly below [~$155]/MWh soon thereafter.' The contents of the Interim Report of the CRTF remain largely unchanged. The work of the CRTF over the last four months, and this Final Report, have built on the Interim Report findings by: [1] converting the Interim Report Candidate Actions into Agreed Actions; and [2] laying out the Next Steps which should be followed to develop the CCS industry in the UK, to enable the roll-out of follow-on projects after the DECC Commercialisation Programme projects and ultimately to deliver cost-effective CCS in the UK."

"Carbon Capture and Storage – Global Strategic Business Report." The following is from the Summary of this document: "CCS is a valuable tool in the drive to minimize [GHG] emissions. The rationale for opting for CCS comes from the fact that the current large dependence on fossil fuels would continue to exist for several years to come, due in part to a wide installed base in the fossil fuel industry

and early stages of renewables. The sheer magnitude of existing fossil-fuel based energy infrastructure makes it difficult for complete replacement by sustainable and eco-friendly alternative energy sources that can serve the global energy needs. The situation creates demand for technologies that allow use of fossil fuels as a source of energy while reducing CO_2 emissions. [CCS] is one such low-carbon technology that promises to achieve a part of this goal by reducing CO_2 emissions across various sectors. While a few large-scale integrated projects (LSIPs) are already operational, several more such projects are in various stages of development worldwide. Furthermore, the technology also finds use in industries that depend on biomass for its energy needs, where capture and storage of CO_2 would assist in net CO_2 reduction from the atmosphere. Use of CCS along with other emission gas reducing strategies is critical for achieving emission targets set for the decades to come to prevent large-scale changes to earth's climate. EOR remains a major driver of CCS projects. The overall progress of CCS projects worldwide is currently limited due to factors such as associated high costs, nascent stage of the technology, weaker economic environment and public opposition in some countries. Funding, an important aspect of the technology's deployment due to its huge associated costs, mainly comes from governments. The sluggish progress in global CCS deployment is hampering private sector investment, which in turn is hindering technology development in the industry."

"Future Electricity Part 1: Power from Fossil Fuels." The following is from the Executive Summary of this document: "The [UK] Government's approach in pursuing fossil fuels with [CCS] as one of three key low carbon options for the power sector is consistent with available evidence. Whilst there is strong support for [CCS] through the current demonstration [program], it is unlikely to result in significant levels of fossil fuels with [CCS] being deployed by 2030, which models consistently indicate will be needed to achieve the 2050 target cost effectively. More rapid and widespread deployment of [CCS] may be achievable by supporting industrial applications, and focusing on the development of shared transport and storage infrastructure, alongside existing plans for power sector demonstration and deployment. There is strong evidence of the value of developing [CCS] in future. Electricity supply will likely need to increase substantially between 2030 and 2050 as additional sectors such as heating and possibly transport are largely electrified. Doing so without abated fossil fuels would significantly increase reliance on renewable and nuclear deployment, which is likely to be more expensive and politically challenging. [CCS] could be at least as important in cost-effective [decarbonization] outside the power sector. It is the only known option to [decarbonizes] many industrial processes, could provide alternative low carbon energy vectors such as hydrogen for use in powering transport and could deliver negative emissions in conjunction with biomass combustion. Overall, it is estimated that without [CCS], total energy system costs could be [~$47-63 billion] higher per year by 2050."

"Effects of a Carbon Tax on the Economy and the Environment." The following is the Summary of this document: "Lawmakers could increase [Federal] revenues and encourage reductions in emissions of CO_2 by establishing a carbon tax, which would either tax those emissions directly or tax fuels that release CO_2 when they are burned (fossil fuels, such as coal, oil, and natural gas). Emissions of CO_2 and other [GHGs] accumulate in the atmosphere and contribute to climate change—a long-term and potentially very costly global problem. The effects of a carbon tax on the U.S. economy would depend on how the revenues from the tax were used. Options include using the revenues to reduce budget deficits, to decrease existing marginal tax rates (the rates on an additional dollar of income), or to offset the costs that a carbon tax would impose on certain groups of people. This study examines how a carbon tax, combined with those alternative uses of the revenues, might affect the economy and the environment."

"Redrawing the Energy-Climate Map." The following is from the Introduction of this document: "Climate change is a defining challenge of our time. The scientific evidence of its occurrence, its derivation from human activities and its potentially devastating effects accumulate. Sea levels have risen by 15-20 [centimeters], on average, over the last century and this increase has accelerated over the last decade. Oceans are warming and becoming more acidic, and the rate of ice-sheet loss is increasing. The Arctic provides a particularly clear illustration, with the area of ice covering the Arctic Ocean in the summer diminishing by half over the last 30 years to a record low level in 2012. There has also been an

increase in the frequency and intensity of heat waves, resulting in more of the world being affected by droughts, harming agricultural production. Global awareness of the phenomenon of climate change is increasing and political action is underway to try and tackle the underlying causes, both at national and international levels. Governments agreed at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties in Cancun, Mexico in 2010 (COP-16) that the average global temperature increase, compared with pre-industrial levels, must be held below 2°C, and that this means [GHG] emissions must be reduced. A deadline was set at COP-18 in Doha, Yatar in 2012 for agreeing and enacting a new global climate agreement to come into effect in 2020. But although overcoming the challenge of climate change will be a long-term endeavour, urgent action is also required, well before 2020, in order to keep open a realistic opportunity for an efficient and effective international agreement from that date."

July 2013

"IEA 2013 CCS Technology Roadmap." The following is from the Introduction of this document: "Between 2009 when the first IEA *Carbon Capture and Storage (CCS)* roadmap was published, and 2013, the need for CCS has not diminished: the urgency of its deployment has in fact grown. There have been many developments and significant gains in CCS technology and the enabling policy frameworks. However, given today's level of fossil fuel [utilization], and that a carbon price as a key driver for CCS remains missing, the deployment of CCS is running far below the trajectory required to limit long-term global average temperature increases to 2°C. The goal of this updated CCS roadmap is to describe and [analyze] actions needed to accelerate CCS deployment to levels that would allow it to fulfill its CO_2 emissions reduction potential. The IEA is revising the 2009 roadmap to reflect developments in CCS that have occurred over the last four years and to develop a plan of action that fully reflects the current context. This roadmap provides a brief status report on CCS technologies, outlines a vision for CCS deployment between 2013 and 2050 consistent with limiting the average global temperature increase to 2°C, and suggests actions that need to be taken to facilitate this envisaged deployment, particularly between 2013 and 2020. [The authors] believe that the recommended near-term actions are of vital importance to the deployment of CCS not only to limit average global temperature increase to 2°C, but for any scenario designed to achieve [stabilization] of global temperature changes at 4°C or below."

"ICO_2N Perspectives on the GHG Impact of Storing CO_2 through Enhanced Oil Recovery." The following is from the Summary of this document: "ICO_2N commissioned the Pembina Institute, a Canadian environmental think tank, to analyze the GHG impact of storing CO_2 through the process of EOR. The analysis looked at CO_2 emissions associated with operating an EOR site as well as those associated with the oil that is produced. Stakeholders have differing perspectives on how to view the GHG impact of CO_2-EOR and this work is an attempt to quantify five different scenarios. Using actual operational data, the intent of the study was not to legitimize any one viewpoint but rather to bring quantitative data into the discussion. The analysis considered the CO_2 emissions of five scenarios representing differing viewpoints; it did not include the upstream activities associated with the capture and transport of CO_2… When downstream production of EOR is taken into account there is a 0.5 [metric ton] increase in emissions for every [metric ton] of CO_2 brought to site. However, when assuming full displacement of competing sources of crude oil, storing CO_2 through EOR has a net GHG benefit of 1.175 TCO_2e reduced for an oil sands barrel and 0.834 TCO_2e for an average barrel…"

"**State of Play on CO_2 Geological Storage in 28 European Countries**." The following is from the Introduction of this document: "The current state of play on CO_2 geological storage in the CGS Europe countries is [summarized] in this report. More detailed country-specific information is provided in Annex I. In this report, a brief overview of the CO_2 storage options, potentials and capacities in Europe is provided in Chapter 2. Structure and organization of research funding related to CO_2 storage on a national level are outlined in Chapters 3 and 5 of the current report. Research topics addressed by the CGS Europe partners and other research institutions in the CGS Europe countries are introduced in Chapter 4, followed by a summary of current pilot, demo and test sites (Chapter 7) and an overview of the current

state of transposition of the EU Directive on the geological storage of CO_2 in the CGS Europe countries (Chapter 8). Information on a national level is complemented by an overview of ongoing EU-funded research projects related to CO_2 storage and a summary of activities of the European Energy Research Alliance in Chapter 6."

"Carbon Capture Through Innovative Commercial Structuring in the Canadian Oil Sands." The following is from the Introduction of this document: "Economic capture and use of CO_2 is the primary limiting challenge for meaningful large industrial GHG emission reduction. The capital investment in carbon capture facilities is high and the required purification and compression is energy intensive. Use of immature capture technology and requirement for extensive plant integration can be a significant operating and investment risk for industrial facilities. The North West Sturgeon Refinery (NWSR) project has been developed to take advantage of the rising supply of bitumen from the oil sands of northern Alberta and the need for refining conversion capacity to produce low carbon fuels with reduced GHG emissions. Since its inception the project has incorporated gasification technology to economically co-produce hydrogen for the refining process and pure CO_2 that will generate a modest revenue stream from sales into an EOR scheme. The fully integrated project will capture, use for EOR and geologically [store] over 1.2 million [metric tons] per year of 99 percent pure, dry CO_2, the equivalent to removing approximately 225,000 vehicles from the road. The CO_2 from the NWSR will also be the anchor supply for the Alberta Carbon Trunk Line (ACTL), an open access CO_2 pipeline being developed by Enhance Energy Inc. The ACTL has public funding which will support the development of a common CO_2 handling infrastructure for EOR in Alberta."

"**Moving CCS Forward in Europe**." The following is from the Introduction of this document: "Back in 2007, the European Council agreed to pursue an aggressive effort to support the demonstration of CCS. The aim was to secure up to 12 commercial–scale projects by 2015, covering the range of technologies and geological storage options. Sitting alongside the European Union's (EU) wider ambitions on climate and energy policy, this intent firmly positioned Europe at the heart of expanding international efforts on CCS. But now, in mid-2013, the EU is still without any new commercial– scale CCS projects under construction. Two different funding mechanisms have failed to secure projects able to take positive final investment decisions. The previous momentum that [favored] CCS has been lost. But why has this happened, and what can be done about it? This paper looks at why CCS still matters for Europe, and how a more positive outlook can be encouraged. First, [the authors] review Europe's previous efforts on CCS, considering how policy measures have fared in the context of increasingly challenging economic and political conditions. This section, authored by E3G, then looks at how CCS could be reconsidered moving forward, with a focus on how a positive vision could be advanced to win back political support and inform policy choices. Second, with a number of potential policy options currently under consideration, [the authors] set out some initial ideas from the Bellona Foundation on how EU-wide and Member State policy incentives could work together to accelerate action on CCS over the coming years. Third, [the authors] consider the case of Norway—a country that is not a member of the EU, but which has also had leadership aspirations for CCS and now confronts similar challenges in bringing projects to reality. This section, authored by ZERO, also considers how Norway and the EU might be able to cooperate further in future."

"**Transport and storage economics of CCS networks in the Netherlands**." The following is a summary of this document: "A team from the Rotterdam Climate Initiative, CATO-2 (the Dutch national R&D [program] on CCS) and the Clinton Climate Initiative, developed a financial model to assess the economics of alternative CO_2 transport and storage options in the North Sea, based on common user infrastructure. The purpose of the financial model that is available on the Global CCS Institute website is to introduce a simple planning tool relating to the transport and storage components of an integrated CCS project using readily available, non-confidential data. A steering group of major emitters with advanced plans for CCS projects in the Netherlands and Belgium guided the project. Although the report [focuses] on potential projects in the Netherlands (Rotterdam and Eemshaven) and Belgium (Antwerp) in

the short to medium term, the analysis and lessons could be useful to other regions considering CO_2 network solutions."

August 2013

"Global Action to Advance Carbon Capture and Storage: A Focus on Industrial Applications." The following in from the Summary and Recommended Global Action chapter of this publication: "Energy-intensive industries account for a significant part of global CO_2 emissions. Industrial sectors such as cement, iron and steel, chemicals and refining represent one-fifth of total global CO_2 emissions, and the amount of CO_2 they produce is likely to grow over the coming decades. CCS in industrial applications refers to the prevention of CO_2 emissions through the capture, transport and storage or use of CO_2 from these sectors. Analysis by the International Energy Agency shows that CCS in industrial applications could represent around half of the emission reductions achieved through CCS by 2050. CCS is the only option to decarbonize many industrial sectors. CCS is currently the only large-scale mitigation option available to cut the emissions intensity of production by over 50 [percent] in these sectors. Further energy efficiency improvements, while urgently needed, have limited potential to reduce CO_2 emissions, partly due to the non-energy related emissions from many industrial processes. As a result, it may not be possible to decarbonize industrial sectors without CCS. Failure to make the case for CCS in industrial applications and to undertake the actions needed for deployment poses a significant threat to the world's capacity to tackle climate change. In addition, economies where CCS is available may be better placed to host and benefit from industrial production in the future. Developing and deploying CCS in energy-intensive industries is of critical importance. CCS in industrial applications requires more attention from policy makers. Deploying a control method such as CCS requires policy action; it is not something that a market will deliver if left alone…"

"Pioneer's Sequestration Research and Proposed MMV [Program]." The following is a summary of this document: "This report represents the work and results accomplished during the initial phase of work done on Project Pioneer, with respect to [storing] CO_2 in a deep geological formation. This report will also discuss some early geological studies (one of which preceded the inception of Pioneer), the drilling and testing of the evaluation well, as well as the detailed geological and reservoir models and the risk analysis that enabled the Project to develop a [storage] and [measurement, monitoring, and verification (MMV)] program complete with a cost estimate and schedule."

"European Commission CCS Consultation paper: Global CCS Institute submission." The following is from the Executive Summary of this document: "Under the Energy Roadmap 2050, the European Commission (EC) envisions the broad scale deployment of CCS technologies in Europe from 2030 onwards. However, in response to challenges in successfully establishing any large-scale demonstration projects in the European Union (EU), the EC has released a Consultative Communication (the Consultation) seeking advice on how to reinvigorate the CCS demonstration program, with a view to achieving earlier deployment of CCS. The Global Carbon Capture and Storage Institute (the Institute) considers CCS to be the single most promising set of technologies capable of bridging the dual objectives of cost effective large-scale abatement and security of supply in a carbon constrained environment. The Institute acknowledges challenges will arise in undertaking initial commercial-scale demonstration activities for such a transformational clean energy solution, particularly with regard to permitting the initial projects as well as bringing the local community along with the project. It is important to [recognize] that, to a very large extent, the proposals examined in the Consultation will take effect in the medium to long term. While long-term signals are important in giving visibility to project proponents, there is an urgent need to address the short-term funding issues (both CAPEX and OPEX) facing projects here and now. It is clear that the way CCS is currently promoted in Europe needs enhancing and the Institute agrees with the EC assessment that the 'available funding is not sufficient' to support an effective demonstration program. This submission explains the Institute's preferred approach to supporting CCS in Europe and makes [several recommendations]."

"Predicting CO_2 injectivity properties for application at CCS sites." The following is from the Executive Summary of this ANLEC R&D document: "This project aims to investigate the injectivity of potential Australian carbon storage reservoirs, and to provide some understanding of their capacity to store CO_2. A parallel work-flow is developed to allow the efficient movement of a core sample through the four laboratory test stages. Berea sandstone core is used to commence tests as a standard calibration example due to its well-documented characteristics in the international literature. Three other cores are tested afterwards, namely Otway (Waarre-C), Pinjarra-1 (Lesueur) and Harvey-1 (Lesueur). Geomechanical tests and CT scanning are performed and the results provide new insights into the injectivity of CO_2."

Legislative

September 2012

***DNV Press Release,* "New Certification Framework for CO_2 Storage."** DNV's new framework builds on preceding guidelines for CO_2 storage and is organized as two documents. The first document, "Recommended Practice (RP) J203," is for the selection, qualification, and management of geological storage sites. This document is available at: http://exchange.dnv.com/publishing/Codes/download.asp?url=2012-04/rp-j203.pdf. RP J203 outlines generic workflows reflective of a site-specific and risk-based approach that should contribute to enhanced traceability and efficiency across projects. The second document, "DNV Service Specification (DSS) 402," defines the following statements and certificates that may be issued in project development: Statement of Feasibility, Statement of Endorsement, Certificate of Fitness for Storage, and Certificate of Fitness for Closure. This document is available at: http://exchange.dnv.com/publishing/Codes/download.asp?url=2012-06/dss-402.pdf. RP-J203 is consistent with the ISO31000 international standard for risk management. According to officials, the new framework fills a gap by providing a common international method for CO_2 storage site selection, risk assessment, monitoring, and verification. August 29, 2012, http://www.dnv.com/news_events/news/2012/newcertificationframeworkforco2storage.asp.

October 2012

***Oil & Gas Journal*, "Senators Offer Bill to Boost Use of Carbon Dioxide in EOR."** On September 20, 2012, U.S. Senators Jay Rockefeller, Kent Conrad, and Mike Enzi introduced a bill to expand the use of CO_2 for EOR, modifying a Federal tax incentive that provides a $10/metric ton credit for CO_2 used in EOR and a $20/metric ton credit for CO_2 placed directly into secure geologic storage. The bill, S.3581, would adopt recommendations made in February by the National Enhanced Oil Recovery Initiative (NEORI) to modestly improve the Federal tax code section 45Q sequestration provision, which is authorized to provide credits for up to 75 million metric tons of CO_2. According to NEORI, the change would make modest and functional improvements in the tax code provision at little or no additional cost, and would also help several CO_2-EOR projects secure private financing and operate commercially. To track "S.3581: A bill to amend the Internal Revenue Code of 1986 to modify the credit for carbon dioxide sequestration," visit: http://www.govtrack.us/congress/bills/112/s3581. To view NEORI's 45Q modifications, go to: http://neori.org/publications/neori-45q/. September 21, 2012, http://www.ogj.com/articles/2012/09/senators-offer-bill-to-boost-use-of-carbon-dioxide-in-eor.html.

November 2012

"Public concepts of [carbon capture and storage]: Understanding of the Dutch general public and its reflection in the media." The following is the Abstract of this article: "This study aims to increase understanding of the public view on [carbon capture and storage] and energy innovations in the

Netherlands. The study is based on the premise that to understand the public's concerns and to predict their future opinion, it is necessary to know how people arrive at their evaluations about [carbon capture and storage]. The study described in this paper aimed to enhance insight into currently held beliefs and awareness among the general public about [carbon capture and storage] and CO_2 as well as to investigate the role of the media as a vehicle for knowledge transfer. To meet the first aim, [the authors] interviewed 15 lay people to identify commonly held beliefs. Next, [the authors] investigated the prevalence of these beliefs by administering a questionnaire among 401 respondents. To meet the second aim, [the authors] analyzed the 430 articles mentioning [carbon capture and storage] in all major Dutch newspapers from mid-2009 to mid-2010 and investigated respondents' media use and exposure to recent media events about [carbon capture and storage]. The survey revealed several beliefs that were shared by a large group of respondents, some of which were factually incorrect. The media analysis did not yield evidence that national newspapers reinforce or create particular misperceptions such as found in the survey." **Marjolein de Best-Waldhober, Suzanne Brunsting, and Mia Paukovic**, *International Journal of Greenhouse Gas Control*, Available online November 2012, doi.org/10.1016/j.ijggc.2012.08.016, http://www.sciencedirect.com/science/article/pii/S1750583612002125. (Subscription may be required.)

"**Argument map for carbon capture and storage."** The following is the Abstract of this article: "[Carbon capture and storage] can contribute to the deep CO_2 cuts which are necessary to achieve climate change targets. There is, however, a strong public debate whether [carbon capture and storage] should be implemented. In this article [the authors] give an overview of the arguments for and against based on the opinion of Dutch stakeholders. [Carbon capture and storage] is an umbrella term for a wide range of different configurations of separate technologies. Some arguments are applicable in general for all [carbon capture and storage] chains; some are only valid for a particular configuration. In this paper [the authors] will discuss these arguments in the context of the background of different [carbon capture and storage] configurations. The argument that [carbon capture and storage] costs a lot of extra energy, for instance, is valid for the power sector, not for gas treatment. A good understanding of the [carbon capture and storage] debate and the arguments used may help with developing a better energy policy and may give direction to future research and technology development." **Sander van Egmond and Marko P. Hekkert**, *International Journal of Greenhouse Gas Control*, Available online November 2012, doi.org/10.1016/j.ijggc.2012.08.010, http://www.sciencedirect.com/science/article/pii/S1750583612001958. (Subscription may be required.)

December 2012

***GHG Monitor News*, "California State Senator Reintroduces CCS Legislation."** California Senator Michael Rubio reintroduced legislation aimed at clarifying subsurface pore space ownership and filling regulatory gaps for the permitting of CCS projects in California. The bill states that subsurface pore space ownership in California lies with the surface landowner; reasserts a previous provision from AB 32 that requires the state Air Resources Board to adopt final protocols for CCS projects by 2016; ensures that CCS and enhanced oil recovery (EOR) projects aimed at storing CO_2 are considered eligible emissions reduction technologies under AB 32; and clarifies the authority of the California Department of Conservation's Division of Oil, Gas and Geothermal Resources and the State Fire Marshal to regulate CO_2 injection for EOR and intrastate pipelines, respectively. SB 34 is available for viewing at: http://www.leginfo.ca.gov/pub/13-14/bill/sen/sb_0001-0050/sb_34_bill_20121203_introduced.pdf. The bill contains several points from the earlier policy recommendations of the California CCS Review Panel. This group was commissioned by several state agencies to focus on the challenges the CCS industry faces in California. The earlier policy recommendations are available at: http://climatechange.ca.gov/carbon_capture_review_panel/documents/2011-01-14_CSS_Panel_Recommendations.pdf. December 7, 2012, http://ghgnews.com/index.cfm/california-state-senator-reintroduces-ccs-legislation/.

***United Kingdom Department of Energy & Climate Change Press Release*, "An Energy Bill to Power Low-Carbon Economic Growth, Protect Consumers, and Keep the Lights On."** A bill to promote low-carbon economic growth in the United Kingdom was introduced to Parliament on November 29, 2012. The bill aims to reform the design of the electricity market to promote construction of low-carbon energy infrastructure and low-carbon manufacturing supply chains. In particular, the bill provides support for technologies like CCS by allowing the government to negotiate rates with power plants installed with CCS and other low-carbon technologies. The operators would then sell the electricity to consumers and the government would pay the difference between the market price and negotiated rates. This structure would alleviate some of the operational costs that affect technologies like CCS and their long-term development. November 29, 2012, http://www.decc.gov.uk/en/content/cms/news/pn12_151/pn12_151.aspx.

January 2013

***U.S. Senator Bernie Sanders News Release*, "Congress Must Act on Global Warming: Sanders Cites Record U.S. Heat in 2012."** U.S. Senator Bernie Sanders (I-Vt.) said that he plans to introduce legislation to address potential climate change. The legislation would include a transparent fee on GHG emissions and call for investment in efficiency, sustainable energy, advanced transportation infrastructure, and clean energy R&D. The legislation also would end fossil fuel subsidies and tax breaks. The plan follows an early announcement by the National Climatic Data Center that the annual U.S. temperature in 2012 was 55.32 degrees Fahrenheit, one degree warmer than the old record set in 1998. January 9, 2013, http://www.sanders.senate.gov/newsroom/news/?id=98fbf36e-0ac2-4702-b6ef-08a2c3a0a5d5.

February 2013

"[Wyoming] State Primacy on Greenhouse Gas Regulation**."** The Wyoming Senate Minerals Committee has approved House Bill 63. The bill proposes the transfer of regulatory authority for companies that release CO_2 and other GHGs from the U.S. Environmental Protection Agency (EPA) to the Wyoming Department of Environmental Quality. House Bill 36, which follows the repeal of a Wyoming state law last year that prohibited the regulation of GHGs, will advance to the Senate floor. From *Casper Star-Tribune Online* on February 1, 2013.

March 2013

"Sanders, Boxer Propose Climate Change Bills." U.S. Senator Bernie Sanders, chairman of the Senate Committee on Environment and Public Works, and U.S. Senator Barbara Boxer introduced comprehensive legislation that proposes a fee on carbon emissions to fund investments in energy efficiency and sustainable energy technologies. Under the legislation, rebates would be provided to consumers to offset efforts to raise prices by oil, coal, or gas companies. The proposal was drafted as two measures: the Climate Protection Act and the Sustainable Energy Act. A summary of the legislation is also available. From *U.S. Senator Bernie Sanders News Release* on February 14, 2013.

April 2013

"Wash. State Climate Change Bill Signed into Law." A bill that would study the best ways to reduce GHGs was signed into law by Washington Governor Jay Inslee. Under the measure, a newly created working group of legislators and other leaders would recommend actions based on an independent consultant's evaluation of Washington state's efforts to reduce CO_2 emissions. Strategies that are considered most effective, while providing the greatest environmental benefit in relation to the investment would be prioritized. The measure is expected to help the state reach its GHG-reduction target based on

a 2008 state law calling for a return to 1990 emissions levels by 2020. From *The Seattle Times* on April 2, 2013.

May 2013

"New Bill Would Expand Tax Benefits to CCS, Clean Energy Projects." On April 24, 2013, a group of lawmakers reintroduced the "Master Limited Partnership Parity Act" that would provide access to a corporate tax structure, which is traditionally reserved for fossil fuel products, to CCS and other clean energy projects. An expanded version of a measure introduced to the Senate in 2012, the legislation was brought forward to both chambers of the U.S. Congress to spur new private investment. The goal is for the bill to widen the scope of eligible energy technologies to include CCS and other clean energy technologies. According to the legislation, CCS and coal gasification projects that store at least 75 percent of their CO_2 emissions would be eligible for the tax structure. From *GHG Monitor* on April 26, 2013.

"Shaheen-Portman Energy Efficiency Bill Passes Senate Energy Committee with Strong Support." The energy efficiency and job creation strategy proposed by two U.S. Senators passed the U.S. Senate Committee on Energy and Natural Resources by a vote of 19-3. The legislation offers a framework to promote the transition to a more energy-efficient economy, while increasing economic growth and private sector job creation. The bill uses a variety of tools to reduce barriers for private sector energy users and drive adoption of efficiency technologies by energy consumers. From *U.S. Senator Jeanne Shaheen Press Release* on May 8, 2013.

June 2013

"Understanding barriers to commercial-scale carbon capture and sequestration in the United States: An empirical assessment." The following is the Abstract of this article: "Although a potentially useful climate change mitigation tool, CCS efforts in the United States remain mired in demonstration and development. Prior studies suggest numerous reasons for this stagnation. This article empirically assesses those claims. Using an anonymous opinion survey completed by 229 CCS experts, [the authors] identified four primary barriers to CCS commercialization: (1) cost and cost recovery, (2) lack of a price signal or financial incentive, (3) long-term liability risks, and (4) lack of a comprehensive regulatory regime. These results give empirical weight to previous studies suggesting that CCS cost (and cost recovery) and liability risks are primary barriers to the technology. However, the need for comprehensive rather than piecemeal CCS regulation represents an emerging concern not previously singled out in the literature. [The authors'] results clearly show that the CCS community sees fragmented regulation as one of the most significant barriers to CCS deployment. Specifically, industry is united in its preference for a [Federal] regulatory floor that is subject to state-level administration and sensitive to local conditions. Likewise, CCS experts share broad confidence in the technology's readiness, despite continued calls for commercial-scale demonstration projects before CCS is widely deployed." **Lincoln L. Davies, Kirsten Uchitel, and John Ruple**, *Energy Policy*. (Subscription may be required to view article.)

"Public climate-change skepticism, energy preferences and political participation." The following is the Abstract of this article: "Many studies have shown a general decline of public concern about climate change or vice versa a rise in public climate-change skepticism, in particular in the U.S. and other Anglo-Saxon countries. There is a vivid debate on whether this is a global phenomenon, on which factors explain the decline, and on the broader societal implications of these trends in the context of the transformation toward a low-carbon society. [The authors] add to this literature by presenting the results of a recent general population survey in Germany in which [the authors] looked for systematic linkages between public climate-change skepticism on one hand, and energy preferences and political participation on the other. Germany is an interesting testbed as it is currently involved in a large-scale restructuring of its system of energy supply toward renewable energy sources (the 'Energiewende'). [The

authors'] results indicate that climate-change skepticism has not diffused widely in Germany, but that it correlates with less support of renewable energy sources. However, skepticism correlates negatively with political participation, and there is no strong political outlet for public climate-change skepticism in Germany. Alternative potential barriers for the successful implementation of the 'Energiewende' are also discussed." **Anita Engels, Otto Hüther, Mike Schäfer, and Hermann Held**, *Global Environmental Change*. (Subscription may be required to view article.)

July 2013

"Liechtenstein Extends Carbon Dioxide Tax." The Liechtenstein Government adopted a bill revising the Principality's Carbon Dioxide Act (CO_2 Act) to align the legislation with Switzerland's revised CO_2 Act. The legislation calls for a CO_2 levy imposed on fossil fuel to be extended until 2020. The revised CO_2 Act maintains the incentive fee on fossil fuels (CO_2 levy) introduced in 2008 and increases the levy with interim targets. The revised act also introduces two measures aimed at transport and importers of petrol and diesel to compensate for a portion of emissions by investing in climate protection projects in Switzerland. From *Tax-News.com* on July 9, 2013.

"State Lawmakers Push 1st-in-U.S. Carbon Tax." Massachusetts lawmakers are seeking to pass legislation that would tax carbon at $5 per metric ton. The legislation would increase taxes on gasoline as determined by the Department of Revenue and add new taxes to consumers of heating oil and firewood. The tax revenue under their proposal would be given back to taxpayers through a tax exemption and other measures. The bill would raise in the range of $350 million to $500 million, although tax breaks in the bill would cause the state government to retain $100 million to fund public transit and other programs. From *WBJournal.com* on July 18, 2013.

August 2013

"Governor Martin Governor Martin O'Malley Hosts Maryland Climate Change Summit, Releases Final Greenhouse Gas Reduction Act Plan." Maryland Governor Martin O'Malley hosted a climate change summit to highlight the release of Maryland's Greenhouse Gas Reduction Act, which will help the state reach its goal of reducing GHG emissions 25 percent by 2020. The plan is a framework to strengthen current programs with new technologies and policies over the next seven years, resulting in a reduction in GHG emissions and economic benefits. Key programs in the Greenhouse Gas Reduction Act include: Maryland Renewable Energy Portfolio Standard (RPS) (establishes a market for new sources of renewable electricity generation); EmPOWER Maryland (designed to reduce both Maryland's per capita total electricity consumption and peak load demand by 15 percent by 2015); Zero Waste (aims to ensure all products in Maryland can be reused, recycled, or composted); Maryland Clean Cars Program (regulates CO_2 emissions from motor vehicles); and the Regional Greenhouse Gas Initiative (RGGI). RGGI is a regional cap-and-trade initiative among nine northeast states to reduce CO_2 emissions from fossil fuel-fired power plants to support energy efficiency programs and enhance EmPOWER and RPS. The plan is projected to create 37,000 additional jobs. More information can be found at Maryland's Greenhouse Gas Reduction Act Plan. From *Governor Martin O'Malley Press Release* on July 25, 2013.

Announcements

September 2012

Carbon Storage R&D Project Review Meeting Presentations Available. NETL has released the conference proceedings from the Carbon Storage R&D Project Review Meeting held on August 21-23,

2012, in Pittsburgh, Pennsylvania. All presentations from the plenary and parallel sessions can be downloaded from: http://www.netl.doe.gov/publications/proceedings/12/carbon_storage/index.html.

NETL Releases Accomplishments Document. DOE/NETL has released a new document, titled, "Carbon Storage Program 2010-2011 Accomplishments," which highlights the accomplishments of the Carbon Storage Program during the 2010 and 2011 calendar years. 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-Program-2010-2011-Accomplishments.pdf.

United States, Canada Announce Next Phase of U.S.-Canada Clean Energy Dialogue. On June 21, 2012, DOE and Environment Canada released the U.S.-Canada Clean Energy Dialogue (CED) Action Plan II, renewing their commitment to collaborate on CCS technologies, build more efficient electrical grids, and advance clean energy R&D. The CED was established in 2009 to encourage the development of clean energy technologies to reduce greenhouse gases (GHGs) and address potential climate change. To view Action Plan II, click: http://energy.gov/articles/united-states-canada-announce-next-phase-us-canada-clean-energy-dialogue.

CarbonKids Resources. The Commonwealth Scientific and Industrial Research Organization (CSIRO) has developed an educational program called "CarbonKids," which combines the latest in climate science with education in sustainability. CarbonKids aims to provide primary and secondary schools with resources enabling them to encourage their community to address climate change. The materials are available at: http://www.csiro.au/CarbonKids and http://www.csiro.au/en/Portals/Education/Teachers/Classroom-activities/CarbonKids/Carbon-Kids/Resources.aspx.

Short Educational Videos on CCS Technology. Victoria's (Australia) Department of Primary Industries has developed a short film to provide an introduction to CCS technology for educational purposes. Transcripts of each segment are also available for download. The videos (full version and segments) and transcripts are available at: http://www.dpi.vic.gov.au/earth-resources/community-information/carbon-capture-and-storage-videos.

October 2012

HDS International Announces Grant of U.S. Patent for Carbon Capture and Reutilization. The U.S. Patent and Trademark Office has granted patent no. 8,197,587, "Method for Eliminating Carbon Dioxide from Waste Gases," according to HDS International, a green technology company. The invention preserves the advantages of prior methods for eliminating CO_2 from waste gases while providing new advantages not found in currently available methods and overcomes many disadvantages of such currently available methods. To view the press release, go to: http://www.hdsicorp.com/2012%2009%2028%20HDSI%20Announces%20Waste%20Gas%20Patent%20(a).pdf.

November 2012

DOE Announces Milestones for MGSC Project. DOE announced that MGSC has made progress on construction of the Illinois Industrial Carbon Capture and Storage project's storage facility and opened the National Sequestration Education Center to the public. The Illinois project will be able to store 1 million tons of CO_2 per year once fully operational in 2013, and will also help demonstrate the feasibility

and reduce the cost of clean coal and CCUS technologies. For more information, visit: http://www.fossil.energy.gov/news/techlines/2012/12044-Sequestration_Education_Center_Ope.html.

NETL Researchers Chosen as Science & Engineering Ambassadors. Four NETL researchers have been chosen as Science & Engineering Ambassadors, with the goal of increasing public understanding and engagement with energy issues. Chosen from NETL's Office of Research and Development (ORD), the four researchers will serve as interpreters and communicators of scientific research to the non-technical public. For more information, visit: http://www.fossil.energy.gov/news/techlines/2012/12050-NETL_Researchers_Chosen_as_Energy_.html.

December 2012

CSLF Recognizes Three DOE CCUS Projects. The Carbon Sequestration Leadership Forum (CSLF) recognized three DOE projects as important advancements toward commercialization and large-scale deployment of carbon capture, utilization, and storage (CCUS) technologies. The three DOE projects are (1) the Illinois Basin Decatur Project, a large-scale CCUS demonstration project being conducted by the Midwest Geological Sequestration Consortium (MGSC); (2) Air Products & Chemicals, Inc., an ARRA-funded, large-scale industrial CCUS project; and (3) the Illinois Industrial Carbon Capture and Storage Project, another ARRA-funded, large-scale industrial CCUS project. More information is available at: http://www.fossil.energy.gov/news/techlines/2012/12051-CSLF_Praises_DOE_Carbon_Storage_Pr.html.

MGSC Completes First Year of CO_2 Injection Operations. The Illinois Basin-Decatur Project has completed the first year of injecting CO_2 from an industrial plant at a large-scale test site in Illinois. The project uses CO_2 from an industrial source and injects it into the Mount Simon Sandstone saline formation approximately 7,000 feet below the surface. Injection operations began November 17, 2011, with an average injection rate of 1,000 metric tons (1,100 tons) per day; after approximately one year, a total of 317,000 metric tons (350,000 tons) of CO_2 have been injected – about one-third of the planned 1 million metric ton (1.1 million ton) injection volume. To learn more, visit: http://www.fossil.energy.gov/news/techlines/2012/12056-Carbon_Storage_Partner_Completes_F.html.

Geologic CO_2Storage Standard Developed. CSA Group and the International Performance Assessment Center for Geologic Storage of Carbon Dioxide (IPAC-CO_2) have announced the CSA Z741 Geologic Storage of Carbon Dioxide Standard, the world's first bi-national CCS standard for geologic CO_2 storage for Canada and the United States. The standard establishes requirements and recommendations for the safe, long-term geological storage of CO_2 in a way that minimizes risks to the environment and human health. To view the standard, go to: http://ipac-co2.com/uploads/File/PDFs/CSA%20IPAC-CO2%20CCS%20Standard%202012%20Final%20News%20Release%20v1%20copy.pdf.

CO_2 Capture Membranes Developed in DOE-Funded Project. Researchers from Ohio State University have developed a new hybrid membrane that combines the separation performance of inorganic membranes with the cost-effectiveness of polymer membranes. Further information can be viewed at: http://www.fossil.energy.gov/news/techlines/2012/12053-OSU_Develops_Novel_Composite_Membr.html.

RGGI Releases Q3 2012 Secondary Market Report. According to the Regional Greenhouse Gas Initiative's (RGGI) "Report on the Secondary Market for RGGI CO_2 Allowances: Third Quarter 2012," 92 percent of RGGI's CO_2 allowances are held by compliance entities and their affiliates. The report found that RGGI CO_2 allowance prices were stable in the third quarter of 2012, ranging from $1.93 to $1.95, which is consistent with the Auction 17 clearing price of $1.93. The complete report is available at: http://www.rggi.org/docs/Market/MM_Secondary_Market_Report_2012_Q3.pdf.

New Home for CCS Legal Resources Website. The UCL Carbon Capture Legal Program, which has developed and hosted a legal resources website designed to provide accessible and objection information on CCS law developments and policy, will now be managed by the Global Carbon Capture and Storage Institute (GCCSI). The material is now available at: http://www.globalccsinstitute.com/networks/cclp.

January 2013

DOE Approves Field Test for Promising Carbon Capture Technology. DOE has approved a post-combustion membrane technology to advance to a large-scale field test. The technology successfully demonstrated the separation and capture of 90 percent of the CO_2 from a pulverized coal plant. Membrane Technology and Research Inc. (MTR) will next begin fabricating a 1-megawatt (MW) system capable of meeting DOE's program goals of capturing more than 90 percent of CO_2 from flue gas with a less than 35 percent increase in cost of electricity. The 1-MW system will be tested at DOE's National Carbon Capture Center (NCCC) in Wilsonville, Alabama. For more information, visit: http://www.fossil.energy.gov/news/techlines/2012/12057-DOE_Approves_Carbon_Capture_Field_.html.

Factbook – Bringing Carbon Capture and Storage to Market. A factbook based on the September 2012 SBC Energy Institute report, titled, "Bringing Carbon Capture and Storage to Market," has been released, summarizing the status of existing technologies and the main research and development (R&D) priorities. In addition, the factbook also analyzes the economics of the main large-scale demonstration and deployment projects and gives the SBC Energy Institute's view of the future of CCS technologies and projects. To download the document, go to: http://www.globalccsinstitute.com/publications/factbook-bringing-carbon-capture-and-storage-market.

Short Course at SPE Americas. The Society of Petroleum Engineers (SPE) is offering a one-day short course, titled, "GHG and CCS Regulatory and Legal Framework," on March 17, 2013, at the Hilton Galveston Island Resort in Galveston, Texas. In addition to reviewing the evolving regulatory and legal frameworks that will govern GHGs and the CCS industry, the course will also cover topics such as the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, current international climate negotiations, surface and subsurface property rights issues for geologic storage, and remaining gaps in legislation and regulation. More information is available at: http://www.spe.org/training/courses/RLF.php.

openCCS: A Collaboratively Developed Handbook for Delivering CCS Projects. The Global CCS Institute (GCCSI) has released "openCCS," a platform for sharing methodologies, best practices, and lessons learned from experience with each component of an integrated CCS project. GCCSI's goal is for openCCS to improve over time through the contributions of CCS practitioners on topics such as: recommended project schedules, activities, and work breakdown structures; definitional pages to explain core CCS concepts; technical papers, methods, and guidelines; and aggregations of useful pages on other sites. To learn more, go to: http://www.globalccsinstitute.com/openccs. A slideshow overview of openCCS is available at: http://www.slideshare.net/globalccs/introduction-to-openccs-15612962.

February 2013

NETL's Carbon Capture, Utilization, and Storage Database – Version 4. NETL has released the fourth version of the CCUS Database, which includes active, proposed, canceled, and terminated CCUS projects worldwide. Information in the database regarding technologies being developed for capture, evaluation of sites for CO_2 storage, estimation of project costs, and anticipated dates of completion is sourced from publically available information. The CCUS Database provides the public with information regarding efforts by various industries, public groups, and governments towards development and eventual deployment of CCUS technology. As of November 2012, the database contained 268 CCUS

projects worldwide. The 268 projects include 68 capture, 61 storage, and 139 for capture and storage in more than 30 countries across 6 continents. While most of the projects are still in the planning and development stage, or have recently been proposed, 37 are actively capturing and injecting CO_2. Users can download the CCUS database as a Google Earth layer or download a copy in Microsoft Excel file format.

DOE Releases Carbon Utilization and Storage Atlas. DOE's 2012 United States Carbon Utilization and Storage Atlas (Atlas IV) states that the United States has at least 2,400 billion metric tons of potential CO_2 storage resource in saline formations, oil and gas reservoirs, and unmineable coal. Atlas IV was created by FE's NETL with input from DOE's seven Regional Carbon Sequestration Partnerships (RCSPs) and ARRA-funded site characterization projects. Click here to access the NATCARB Viewer.

RGGI States Initiate Bidding Process for Auction 19. The states participating in the Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice and application materials for their 19th quarterly CO_2 allowance auction scheduled for March 13, 2013. The Auction Notice for CO_2 Allowance Auction 19 provides potential auction participants with the information needed to submit a Qualification Application and indicate their intent to bid in Auction 19. The states will offer 37,835,405 CO_2 allowances for sale with a reserve price of $1.98 for the March auction.

March 2013

Breakthrough Large-Scale Industrial Project Begins Carbon Capture and Utilization. A CCS project at Air Products and Chemicals hydrogen production facility in Port Arthur, Texas, has begun capturing CO_2 and piping it to an oilfield for use in EOR. The project is expected to capture approximately 1 million metric tons of CO_2 per year that would otherwise be released in the atmosphere, as well as recover 1.6 to 3.1 million additional barrels of domestic oil annually.

New Set of Computational Tools and Models Expected to Help Enable Rapid Development and Deployment of Carbon Capture Technologies. A new suite of 21 computational tools and models to help enable rapid development and deployment of new carbon capture technologies has been developed and made available by the Carbon Capture Simulation Initiative (CCSI), a public-private partnership led by NETL. The toolset is expected to make it easier for U.S. utilities to meet carbon capture requirements if/when they are enacted and help technology companies doing business in countries where controls are already in place.

NETL Research Results in New U.S. Patents. Researchers at DOE's NETL received nine patents in 2012 for innovations that address the Nation's energy challenges. The patents include an integrated process for removing pollutants from fossil-fuel combustion systems; a metallurgical melting process to produce defective-free metal ingots; catalysts that make it easier to reform hydrocarbon fuels; stainless steel compositions and heat treatment processes to enhance stainless steel durability; a method to measure the circulation rate of coal solids in gasification reactors; and a process to separate and purify CO_2. Deployment of these technologies will enhance energy efficiency, improve metallurgical processes, and allow for better emissions monitoring and control.

RGGI Auction 19 Results. The nine states participating in the Regional Greenhouse Gas Initiative (RGGI) announced that 37,835,405 CO_2 allowances were sold at the 19th auction, held Wednesday, March 13, 2013, at a clearing price of $2.80. The auction generated $105.9 million for reinvestment in a variety of consumer benefit initiatives, including energy efficiency, renewable energy, direct bill assistance, greenhouse gas (GHG) abatement, and climate change adaptation programs. Allowances sold represent 100 percent of the allowances offered for sale. Bids for the CO_2 allowances ranged from $1.98 to $5.03 per allowance. The next RGGI auction is scheduled for June 5, 2013.

April 2013

CCEMC Grand Challenge: Innovative Carbon Uses: Converting GHGs into Valuable Carbon-Based Products. NineSigma, representing the Climate Change and Emissions Management Corporation (CCEMC), invites proposals for technologies that will convert CO_2 arising from greenhouse gases (GHGs) into valuable, carbon-based products. The goal of the challenge is to reduce GHG emissions by fostering the development of technologies that create new, carbon-based, value-added products and markets. The challenge is a multi-stage event, with opportunities for additional funding upon advancement to each successive stage. Responses are due by July 15, 2013.

May 2013

New Fossil Energy Website. DOE's FE website has been updated and moved to the Energy.gov platform. It is now accessible by clicking here. Feedback can be provided through email, Facebook, or Twitter.

Korea Carbon Capture and Sequestration R&D Center Request for Proposal. The Korea Carbon Capture and Sequestration R&D Center (KCRC), an institution supported by the Ministry of Science, ICT, and Future Planning (MSIP) in South Korea, is seeking proposals for the implementation of the "Korea CCS 2020 Project" and to develop CCS technologies.

GHG Reporting Database Launched. The Climate Registry launched the GHG Reporting Database, a free online tool that compares Federal, regional, and state GHG reporting requirements. The database is designed to help organizations navigate GHG regulations, which include the Federal Greenhouse Gas Reporting Program (GHGRP), California's Mandatory Reporting Regulation (MRR), and Regional Greenhouse Gas Initiative (RGGI) requirements. The database allows users to search by keyword, conduct side-by-side program comparisons, and search for variation in requirements between specific reporting programs or U.S. Environmental Protection Agency (EPA) sub-part.

Energy Innovation Projects Announced across Canada. Canada announced 55 new projects aimed at producing and using energy in a cleaner, more efficient manner. Fifteen projects will be pre-commercialization demonstration projects to test the feasibility of various technologies and 40 projects will be research and development (R&D) projects to address knowledge gaps and bring technologies from the conceptual stage to the ready-to-be-tested stage of development. The projects will be focus on research in the following areas: energy efficiency, clean electricity and renewables, bioenergy, electrification of transportation, and unconventional oil and gas.

June 2013

Breakthrough Industrial CCS Project Begins Full-Scale Operations. The Air Products and Chemicals hydrogen production facilities in Port Arthur, Texas, have successfully begun capturing CO_2 and using it for enhanced oil recovery (EOR). At full-scale operation, more than 90 percent of the CO_2 from the product stream of two methane steam reformers (approximately 1 million metric tons of CO_2 per year) will be delivered for storage and EOR, leading to an estimated annual increase in oil production of 1.6 to 3.1 million barrels from the West Hastings oil field. The approximately $431 million project, supported by $284 million from DOE, included retrofitting the plants with an innovative system that separates CO_2 from the steam reformer product gas during hydrogen production, followed by compression and drying processes.

Carbon Storage Atlas, Employee Newsletter Earn International Communications Awards. DOE's Office of Fossil Energy (FE) and NETL won two prestigious 2013 Blue Pencil & Gold Screen Awards presented by the National Association of Government Communicators (NAGC). NETL earned first place

honors in the "Technical or Statistical Report" category for the United States 2012 Carbon Utilization and Storage Atlas (Atlas IV); NETL also won the top award last year for the previous version of the Atlas. FE's internal employee newsletter, inTouch, was also recognized for communications excellence.

July 2013

CCS Browser: A Guide to CCS. The CCS Browser was created by the CO_2 Capture Project to help individuals learn more about CCS, including how the CCS process works, how CO_2 is securely stored, the techniques used to ensure safe CCS operations, and the differences that CCS can achieve.

President's Plan to Fight Climate Change. The White House announced a series of executive actions to reduce carbon emissions, prepare the United States for the impacts of climate change, and lead international efforts to address global climate change.

RGGI States Initiate Bidding Process for Auction 21. The states participating in the Regional Greenhouse Gas Initiative's (RGGI) 2013 auctions released the Auction Notice and application materials for the 21st quarterly CO_2 allowance auction scheduled for September 4, 2013. The Auction Notice for CO_2 Allowance Auction 21 provides potential auction participants with the information needed to submit a Qualification Application and indicate intent to bid. The states will offer for sale 38,409,043 CO_2 allowances at a reserve price of $1.98.

August 2013

"**MRCSP Begins Field Tests in Michigan**." The Midwest Regional Carbon Sequestration Partnership (MRCSP), one of DOE's RCSPs, has begun a large-scale CO_2 field project designed to inject and monitor at least 1 million metric tons of CO_2 into a series of oil fields that are in different stages of their production life cycles. The CO_2 will be injected into the geologic structures known as the northern Niagaran pinnacle reef trend.

"**Research Without Borders: NETL Pens MOU with Brazilian Coal Association**." DOE's NETL and the Brazilian Coal Association (BCA) signed a Memorandum of Understanding (MOU) on carbon capture and storage (CCS) in Florianópolis, Brazil. Under the MOU, both parties will work together to assess the potential of CCS in fossil fuel-based systems over the next five years, as well as the development of clean coal technologies applicable to Brazilian coals.

DOE's NETL Releases Revised Editions of Best Practice Manuals (BPMs). NETL released revised editions of the following Best Practice Manuals (BPMs): "Public Outreach and Education for Carbon Storage Projects"; "Risk Analysis and Simulation for Geologic Storage of CO_2"; "Site Screening, Site Selection, and Initial Characterization for Storage of CO_2 in Deep Geologic Formations"; and "Carbon Storage Systems and Well Management Activities." The BPMs are available via the Carbon Storage Program Reference Shelf.

Webinar on Proposed Government-Provided Incentives to Promote the Capture and Use of CO_2 for EOR: Options for Incentivizing. A Global CCS Institute (GCCSI) webinar was held on June 26 to discuss how additional large-scale projects are needed to advance CCS. The participants discussed how capture costs and incentives influence new projects and existing large-scale projects.

Western Climate Initiative, Inc., Upgrades Compliance Instrument Tracking System Service (CITSS). The Western Climate Initiative, Inc., is upgrading its Compliance Instrument Tracking System Service (CITSS) to provide cap-and-trade program participants with improved features and more detailed account information. CITSS version 3.0 provides expanded functionality and information, including facility

information (entity management/account consolidation), corporate association management, limited exemption and holding limit management, and enhanced reporting features.

CCS Browser: A Guide to CCS. The CCS Browser was created by the CO_2 Capture Project to help individuals learn more about CCS, including how the CCS process works, how CO_2 is securely stored, techniques used to ensure safe CCS operations, and the differences that CCS can achieve.

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DOE's Carbon Storage Program