Office of Fossil Energy

Carbon Sequestration Newsletter

July 2012

What's Inside?

Introduction

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

Highlights

***U.S. Department of Energy News Release*, "United States, Canada Announce Next Phase of U.S.-Canada Clean Energy Dialogue."**

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

***Fossil Energy Techline*, "New DOE 'Best Practices' Manual Features Top Strategies for Carbon Storage Wells."**

DOE's National Energy Technology Laboratory (NETL) released its latest best practices manual (BPM), titled, "Carbon Storage Systems and Well Management Activities." The BPM covers the planning, permitting, design, drilling, implementation, and decommissioning of CO_2 storage wells. The manual builds on lessons learned through NETL research, the experiences of the Regional Carbon Sequestration Partnerships' (RCSPs) carbon capture, utilization, and storage (CCUS) field tests, and the acquired knowledge of industries that have been actively drilling wells for more than 100 years. In addition, the BPM provides an overview of the well-management activities associated with CCUS projects, beginning with pre-injection planning and continuing through post-injection operations; it provides a roadmap and resource for lessons learned about well-management issues and what project planners and operators can expect as a project progresses. The manual discusses the types of experts needed for a successful CCUS project team and informs the general public about

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Highlights (Continued)

the approach that project developers undertake to ensure human and environmental safety as they design, drill, maintain, and close these wells. (**See Recent Publications section for the Executive Summary and a link to the "Carbon Storage Systems and Well Management Activities" BPM.**) The BPM is available at http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf. June 7, 2012, http://www.fossil.energy.gov/news/techlines/2012/12025-NETL_Issues_Best_Practices_Manual.html.

***Fossil Energy Techline*, "NETL Publications Earn National Communications Awards."**

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

Sequestration in the News

***Skyonic News Release*, "Skyonic Raises $9 Million and Signs Northwater Capital, ConocoPhillips, BP and PVS as New Investors."**

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

Sequestration in the News (Continued)

***Carbon Capture Journal*, "DNV - Improving CO_2 Pipeline Design."**

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

***2Co Energy News Release*, "BOC Takes Stake in 2Co Energy's Don Valley CCS Power Project."**

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

***The Guardian*, "World's First CCS [Release] Experiment Completed in Sea Off Scotland."**

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

***Bloomberg News*, "Shell Gets Conditional Alberta Approval for Carbon-Capture Plan."**

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

***PennEnergy*, "Alstom Advances CO_2 Capture Program at Mongstad in Norway."**

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

Announcements

2012 NETL Carbon Storage R&D Project Review Meeting.

The DOE Carbon Storage R&D Project Review Meeting will be held at the Sheraton Station Square Hotel in Pittsburgh, Pennsylvania, on August 21-23, 2012. More than 120 DOE-sponsored projects will be presented, covering DOE's carbon storage infrastructure and core R&D projects. In addition, DOE's RCSP Initiative and the American Recovery and Reinvestment Act (ARRA) Site Characterization projects will be featured. Presentations will focus on regulatory issues, government-industry collaborations, and large-scale international storage efforts. An interactive reception/poster session will also be held. More information is available at: http://netldev.netl.doe.gov/events/carbon-storage-project-review.

ANNOUNCEMENTS (CONTINUED)

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

2012 MGSC Annual Meeting and Workshop.
The Midwest Geological Sequestration Consortium (MGSC) Annual Meeting and Workshop will be held September 17-19, 2012, at the I Hotel and Conference Center in Champaign, Illinois. The agenda includes a full day of presentations on the Illinois Basin Decatur Project (IBDP), covering all aspects of MGSC Phase II research activities; a Sequestration Training and Education Program (STEP)-sponsored workshop; and an optional tour of the IBDP site. For more information, visit the MGSC website at: http://www.sequestration.org/.

33rd IEAEOR Symposium.
Hosted by the Petroleum Technology Research Center (PTRC), the International Energy Association Enhanced Oil Recovery (IEA-EOR) Research Program's 33rd Annual Symposium and Workshop will be held in Regina, Saskatchewan, on August 26-30, 2012. In addition to two days of conference activities, a one-day workshop focused on CO_2-EOR is included. The conference concludes with a field trip to SaskPower's Boundary Dam Power Plant and Cenovus Energy's Weyburn field CO_2 injection facility. Abstracts are being accepted through May 15, 2012. For more information, visit the conference website at: http://www.iea-eor2012.com/.

SCIENCE

"Induced Seismicity Potential in Energy Technologies (2012)."

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

***msnbc.com*, "Melting Sea Ice Could Decimate Emperor Penguins."**

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

POLICY

"What about coal? Interactions between climate policies and the global steam coal market until 2030."

The following is the Abstract of this article: "Because of economic growth and a strong increase in global energy demand the demand for fossil fuels and therefore also [GHG] emissions are increasing, although climate policy should lead to the opposite effect. The coal market is of special relevance as coal is available in many countries and often the first choice to meet energy demand. In this paper [the authors] assess possible interactions between climate policies and the global steam coal market. Possible market adjustments between demand regions through market effects are investigated with a numerical model of the global steam coal market: the 'COALMOD-World' model. This equilibrium model computes future trade flows, infrastructure investments and prices until 2030. [The authors] investigate three specific designs of climate policy: a unilateral European climate policy, an Indonesian export-limiting policy and a fast-roll out of CCS in the broader context of climate policy and market constraints.

Policy (Continued)

[The authors] find that market adjustment effects in the coal market can have significant positive and negative impacts on the effectiveness of climate policies." **C. Haftendorn, C. Kemfert, and F. Holz**, *Energy Policy*, Available online June 27, 2012, doi:10.1016/j.enpol.2012.05.032, http://www.sciencedirect.com/science/article/pii/S0301421512004442. (Subscription may be required.)

Geology

"Tracers – Past, Present and Future Applications in CO_2 Geosequestration."

The following is the Abstract of this article: "Chemical tracers have been used in various CCS projects worldwide primarily to provide information regarding subsurface migration of CO_2 and to verify CO_2 containment. Understanding the movement and interactions of CO_2 in the subsurface is a challenging task considering the variety of states in which it exists (i.e. gas, liquid, supercritical, dissolved in water) and the range of possible storage mechanisms (i.e. residual or capillary trapping, dissolved in water, structural trapping or incorporation into minerals). This paper critically reviews several chemical tracer applications and case studies for CCS projects. In many instances, there are parallels (e.g. tracer classes and applications) between tracers in the oil and gas industry and in CCS. It has been shown that chemical tracers can complement geophysical measurements (e.g. seismic) in understanding the formation [behavior] of CO_2. Although tracers have been successfully used in many CCS projects, some fundamental information, for example partitioning and adsorption, about the [behavior] of tracers is still lacking and this can be an issue when interpreting tracer data (e.g. determining leakage rates). In this paper the deployment and recovery of chemical tracers and their use on various CCS projects are described." **Matthew Myers, Linda Stalker, Bobby Pejcic, and Andrew Ross**, *Applied Geochemistry*, Available online June 15, 2012, doi:10.1016/j.apgeochem.2012.06.001, http://www.sciencedirect.com/science/article/pii/S0883292712001485?v=s5. (Subscription may be required.)

"Reaction of Water-Saturated Supercritical CO_2 with Forsterite: Evidence for Magnesite Formation at Low Temperatures."

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

"Monitoring groundwater flow and chemical and isotopic composition at a demonstration site for carbon dioxide storage in a depleted natural gas reservoir."

The following is the Abstract of this article: "Between March 2008 and August 2009, 65,445 tonnes of ~75 mol% CO_2 gas were injected in a depleted natural gas reservoir approximately 2000 m below surface at the Otway project site in Victoria, Australia. Groundwater flow and composition were monitored biannually in two overlying [formations] between June 2006 and March 2011, spanning the pre-, syn- and post-injection periods. The shallower (~0–100 m), unconfined, porous and karstic [formation] of the Port Campbell Limestone and the deeper (~600–900 m), confined and porous [formation] of the Dilwyn Formation contain valuable fresh to brackish water resources. Groundwater levels in either [formation] have not been affected by the drilling, pumping and injection activities that were taking place, or by the rainfall increase during the project. In terms of groundwater composition, the Port Campbell Limestone groundwater is brackish (electrical conductivity = 801–3900 $\mu S\ cm^{-1}$), cool (temperature = 12.9–22.5°C), and near-neutral (pH = 6.62–7.45), whilst the Dilwyn [formation] groundwater is fresher (electrical conductivity = 505–1473 $\mu S\ cm^{-1}$), warmer (temperature = 42.5–48.5°C), and more alkaline (pH = 7.43–9.35). Carbonate dissolution, evapotranspiration and cation exchange control the composition of the groundwaters. Comparing the chemical and isotopic composition of the groundwaters collected before, during and after injection shows no statistically significant changes; even if they were statistically significant, they are mostly not consistent with those expected if CO_2 addition had taken place. The monitoring program reveals no impact on the groundwater resources attributable to the C storage demonstration project." **Patrice de Caritat, Allison Hortle, Mark Raistrick, Charlotte Stalvies, and Charles Jenkins**, *Applied Geochemistry*, Available online May 16, 2012, doi:10.1016/j.apgeochem.2012.05.005, http://www.sciencedirect.com/science/article/pii/S0883292712001230. (Subscription may be required.)

"Experimental study of crossover from capillary to viscous fingering for supercritical CO_2 – water displacement in a homogeneous pore network."

The following is the Abstract of this article: "Carbon [storage] in saline [formations] involves displacing brine from the pore space by supercritical CO_2 $scCO_2$). The displacement process is unstable due

Geology (Continued)

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

Technology

"NEMS-CCUS: A Model and Framework for Comprehensive Assessment of CCUS and Infrastructure."

The following is the Abstract of this article: "NETL has funded development of a NEMS-CCUS (National Energy Modeling System) Model that enables modeling of CO_2 pipelines and pipeline networks across the [48] contiguous states. An existing NEMS-based analysis used by NETL to assess CCUS for existing coal-fired power plants was updated to include CO_2 capture from both existing coal-fired and new gas- and coal-fired plants, factor in plant specific variations in the costs of CO_2 capture and include regional variations in the costs of the transmission and storage of CO_2. Pipeline networks in the updated model are configured endogenously to be optimally consistent with the latest capacity and cost data for the U.S. storage resource base. The model enables analysis of various source, [formation], and pipeline combinations under different economic and policy scenarios. This paper presents a recent application of the model to assess the role of [CCUS] in both carbon tax and clean energy standard Cases. Documentation is presented for key parts of the model, including: (1) capture costs – an update of the original generic model that includes corrections for other site specific details such as space constraints and location, based on the AEP Conesville Unit 5 CCUS retrofit study, which originally included corrections based on capacity, heat rate, and emission control configuration; (2) [storage] capacity and costs – NATCARB and other databases are used for storage capacity and formation properties which are combined with drilling, monitoring, and other cost estimates in various cost models; (3) transmission costs – pipeline cost data and [Geographic Information Systems (GIS)] data on siting constraints are combined in a General Algebraic Modeling System (GAMS) based optimizer that configures an evolving pipeline network ; (4) NEMS integration – the GAMS GDX utility is used to interface NEMS and the GAMS based optimizer (Capture Transportation Storage Module – CTS) such that the evolving pipeline network and its associated cost adders for transmission and [storage] are consistent with the penetration of CCUS in NEMS." **Rodney Geisbrecht, Charles A. Zelek, Tim Grant, L. A. Goudarzi, K. M. Callahan, and William Babiuch**, presented at the Carbon Management Technology Conference held in Orlando, Florida, USA, February 7-9, 2012 (CMTC-150377-PP), http://www.netl.doe.gov/energy-analyses/refshelf/PubDetails.aspx?Action=View&Source=Main&PubId=431.

"Monitoring CO_2 intrusion and associated geochemical transformations in a shallow groundwater system using complex electrical methods."

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

"In Situ Measurement of Magnesium Carbonate Formation from CO_2 Using Static High-Pressure and –Temperature 13C NMR."

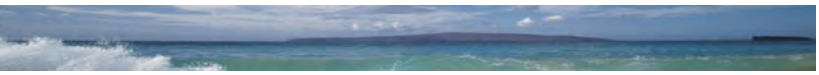
The following is the Abstract of this article: "[The authors] explore a new in situ NMR spectroscopy method that possesses the ability to monitor the chemical evolution of supercritical CO_2 in relevant conditions for geological CO_2 [storage]. As a model, [the authors] use the fast reaction of the mineral brucite, $Mg(OH)_2$, with supercritical CO_2 (88 bar) in aqueous conditions at 80 °C. The in situ conversion of CO_2 into metastable and stable carbonates is observed throughout the reaction. After more than 58 h of reaction, the sample was

Technology (Continued)

depressurized and analyzed using in situ Raman spectroscopy, where the laser was focused on the undisturbed products through the glass reaction tube. Postreaction, ex situ analysis was performed on the extracted and dried products using Raman spectroscopy, powder X-ray diffraction, and magic-angle spinning 1H-decoupled 13C NMR. These separate methods of analysis confirmed a spatial dependence of products, possibly caused by a gradient of reactant availability, pH, and/or a reaction mechanism that involves first forming hydroxy-hydrated (basic, hydrated) carbonates that convert to the end-product, anhydrous magnesite. This carbonation reaction illustrates the importance of static (unmixed) reaction systems at [storage]-like conditions." **J. Andrew Surface, Philip Skemer, Sophia E. Hayes, and Mark S. Conradi**, *Environ. Sci. Technol*., Available online June 1, 2012, doi:10.1021/es301287n, http://pubs.acs.org/doi/abs/10.1021/es301287n. (Subscription required.)

"Scoping analysis of brine extraction/re-injection for enhanced CO_2 storage."

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



Terrestrial

"Early Public Impressions of Terrestrial Carbon Capture and Storage in a Coal-Intensive State."

The following is the Abstract of this article: "While CCS is considered to be critical to achieving long-term climate-protection goals, public concerns about the CCS practice could pose significant obstacles to its deployment. This study reports findings from the first state-wide survey of public perceptions of CCS in a coal-intensive state, with an analysis of which factors predict early attitudes toward CCS. Nearly three-quarters of an Indiana sample (N=1,001) agree that storing carbon underground is a good approach to protecting the environment, despite 80 [percent] of the sample being unaware of CCS prior to participation in the two-wave survey. The majority of respondents do not hold strong opinions about CCS technology. Multivariate analyses indicate that support for CCS is predicted by a belief that humankind contributes to climate change, a preference for increased use of renewable energy, and egalitarian and individualistic worldviews, while opposition to CCS is predicted by self-identified political conservatism and by selective attitudes regarding energy and climate change. Knowledge about early impressions of CCS can help inform near-term technology decisions at state regulatory agencies, utilities, and pipeline companies, but follow-up surveys are necessary to assess how public sentiments evolve in response to image-building efforts with different positions on coal and CCS." **Sanya Carley, Rachel M. Krause, David C. Warren, John Rupp, and John Graham**, *Environ. Sci. Technol*., Available online June 7, 2012, doi:10.1021/es300698n, http://pubs.acs.org/doi/abs/10.1021/es300698n. (Subscription required.)

"Passive [Storage] of Atmospheric CO_2 through Coupled Plant-Mineral Reactions in Urban soils."

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

Trading

***RGGI News Release*, "RGGI Auction Sells 20.9 Million CO_2 Allowances."**

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

***RGGI News Release*, "Auction Notice for CO_2 Allowance Auction 17."**

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

Recent Publications

"Carbon Storage Systems and Well Management Activities."

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

"North American Carbon Storage Atlas."

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

"A Benefits Analysis of the Existing Plants Emissions and Capture (EPEC) Program."

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

"U.S.-Canada Clean Energy Dialogue Action Plan II."

The following is from the document: "Canada and the United States have a strong bilateral energy relationship. Energy fuels [Canadian and U.S.] prosperity, secures [Canadian and U.S.] future, and challenges [Canada and the United States] to reduce its effects on global climate change. The U.S.-Canada CED began in 2009 to strengthen bilateral collaboration on clean energy technologies and seek solutions for

Recent Publications (Continued)

reducing GHG emissions to accelerate the transition to a low-carbon economy. Today, [Canadian and U.S.] responses to climate change are more coordinated. [Canadian and U.S.] emission reduction targets are aligned. [Canada and the United States] are pursuing North American standards for vehicles. [Canada and the United States] continue to share a common vision of a low-carbon North American economy powered by clean energy. Action Plan II describes initiatives that CED Working Groups plan to implement under Phase II of the CED to further progress toward a low-carbon economy that enhances energy security and revitalizes [Canadian and U.S.] economies through the creation of clean energy jobs." The Action Plan is available at: http://energy.gov/sites/prod/files/CED%20Action%20Plan%20II_June%2012%202012.pdf.

"Biomass with CO_2 Capture and Storage (Bio-CCS)."

The following is from the body of this document: "In short, there is now an urgent need for carbon-negative solutions, i.e. systems that remove CO_2 from the atmosphere. Indeed, Bio-CCS – the combination of CCS with sustainable biomass conversion – is the only large-scale technology that can achieve net negative emissions (in addition to any emissions reductions achieved by replacing fossil fuels with that biomass). This has already been [recognized] at an international level, e.g. in the [Intergovernmental Panel on Climate Change's (IPCC)] Special Report on Renewable Energy Sources and Climate Change Mitigation and in the Technology Roadmap Carbon Capture and Storage in Industrial Applications jointly published by the IEA and the United Nations Industrial Development Organization (UNIDO). Bio-CCS has already entered the European policy debate: the EU Energy Roadmap 2050 not only confirms that 'For all fossil fuels, [CCS] will have to be applied from around 2030 onwards in the power sector in order to reach [decarbonization] targets,' it also [recognizes] that CCS 'combined with biomass could deliver "carbon negative" values.'" The document is available at: http://bellona.org/ccs/uploads/tx_weccontentelements/filedownload/EBTP__ZEP_Report_Bio-CCS_The_Way_Forward.pdf.

Legislative Activity

***Department of Environmental Conservation Press Release*, "DEC Adopts Ground-Breaking Power Sector Regulations to Analyze Possible Environmental Impacts and Limit CO_2 Emissions from Power Plants."**

New or expanding electric-generating facilities in New York will be required to evaluate the potential impacts on nearby environmental justice communities under new regulations adopted by the New York State Department of Environmental Conservation (DEC). The regulations require an environmental justice analysis in the siting of major electric-generating facilities. In addition, DEC also adopted regulations to limit CO_2 emissions from new electric-generating facilities and expansions at existing electric-generating facilities. The environmental justice regulations require applicants to evaluate the cumulative impact on air quality; evaluate the demographic, economic, and physical description of the community where the facility will be located, and compare and contrast to the county and adjacent communities; evaluate the environmental impacts of a proposed major electric-generating facility; and avoid, minimize, or offset any environmental impacts to the maximum extent. The CO_2 emission regulations set a CO_2 emission limit of 925 lbs/megawatt-hour (output-based limit) or 120 lbs/mmBtu (input-based limit) for most new or expanded baseload fossil fuel-fired plants; set a CO_2 emission limit of 1,450 lbs/megawatt-hour (output-based limit) or 160 lbs/mmBtu (input-based limit) for simple cycle combustion turbines; allow each facility's owner/operator to choose whether to comply with the relevant output- or input-based emission limits; provide for DEC to set case-specific CO_2 emission limits for certain power plants that fire non-fossil fuels; and require recordkeeping, monitoring, and reporting consistent with existing Federal and state regulations. The regulations were adopted by DEC as required by the Power NY Act of 2011, which was signed into law in August 2011. June 28, 2012, http://www.dec.ny.gov/press/83269.html.

Events

August 21-23, 2012, **NETL Carbon Storage R&D Project Review Meeting**, *Sheraton Station Square Hotel, Pittsburgh, Pennsylvania, USA*. Presentations will focus on regulatory issues, government-industry collaborations, and large-scale international storage efforts. An interactive reception/poster session will also be held to highlight related work being performed by ARRA-supported Regional Carbon Sequestration Training Centers, DOE National Laboratories, RCSP subcontractors, and other organizations directly participating in geologic carbon storage and characterization projects in the United States and internationally. More information is available at: http://netldev.netl.doe.gov/events/carbon-storage-project-review.

Events (Continued)

August 21-22, 2012, **International Conference on Earth Science & Climate Change**, *Hilton Chicago, Northbrook, Chicago, USA*. This conference will include research talks and presentations focused on strategies in earth science and potential climate change. Included in the scientific program is a session on the current status of carbon footprinting. For more information, visit the conference website at: http://www.omicsonline.org/earthscience2012/.

September 4-6, 2012, **Carbon Capture & Storage: A Field-Based Masterclass**, *Springfield County Hotel, Stoborough, Wareham, Dorset, UK*. This three-day course follows the path of CO_2 from extraction from ancient rocks in the subsurface, through its use, to the capture and safe storage back into the rocks. The training experience will combine classroom sessions, case studies, and field visits. For more information, download the course flyer at: http://www.ccstlm.com/content_189_.

October 15-18, 2012, **29th Annual Pittsburgh Coal Conference**, *David L. Lawrence Convention Center, Pittsburgh, Pennsylvania, USA*. This conference will focus on environmental emissions issues and technologies surrounding the continued use of coal, as well as the development of future coal-based energy plants. Among the topics to be discussed in the sessions are combustion, gasification, sustainability, carbon management, coal-derived products, coal science, clean coal demonstration and commercial projects, and coal mining and coal gas. For more information, visit the conference website at: http://www.engineering.pitt.edu/Coal_Conference/2012_Conference.aspx.

October 17-18, 2012, **ImechE Carbon Capture and Storage – Ready, Steady, Go!**, *Institution of Mechanical Engineers, London, UK*. The Institution of Mechanical Engineers' (ImechE) 6th international conference aims to prepare companies for commercial-scale CCS technologies by covering, among other topics, the latest in European Union (EU) and UK government CCS decisions, funding for CCS research and project development, CCS business development and investment opportunities, and legal and regulatory issues surrounding the development market. To download the brochure, visit the seminar's website at: http://events.imeche.org/EventView.aspx?EventID=1442.

October 21-23, 2012, **National CCS Conference**, *Burswood Entertainment Complex, Perth, Australia*. The theme of this conference, which is the major event of National CCS Week, a biennial Australian-based event focusing on CCS as an essential part of the global GHG mitigation portfolio, is "Advancing CCS: Progress and Achievements." The aim of the conference will be to facilitate knowledge-sharing and networking opportunities between CCS stakeholders and to raise awareness of CCS among the community. To learn more about the conference and Australia's National CCS Week, visit: http://www.nationalccs.com.au/information/?IntCatId=43.

November 5-9, 2012, **CLIMATE 2012**. This online climate conference will focus on the latest scientific findings on the social, economic, and political aspects of potential climate change. New projects and innovative initiatives in both industrialized and developing countries by universities, scientific institutions, government bodies, non-governmental organizations (NGOs), and other stakeholders will be covered. For more information, visit the conference website at: http://www.climate2012.de/.

November 18-22, 2012, **International Conference on Greenhouse Gas Technologies 11 (GHGT-11)**, *Kyoto International Conference Center, Japan*. This will be the second visit to Kyoto by the GHGT conference series, with more than 1,600 delegates expected to attend. Online registration is available at: http://www.ghgt.info/index.php/Content-GHGT11/ghgt-11-conference-registration.html. The call for papers has expired. Visit: http://www.ghgt.info/index.php/Content-GHGT11/ghgt-11-overview.html for more details.

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Please visit http://listserv.netl.doe.gov/mailman/listinfo/sequestration, enter your email address, and create a password. This will enable you to receive a pdf version of the Carbon Sequestration Newsletter at no cost.
To view an archive with past issues of the newsletter, see: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/subscribe.html.

To learn more about DOE's Carbon Sequestration Program, please contact John Litynski at john.litynski@netl.doe.gov, or Dawn Deel at dawn.deel@netl.doe.gov.