Carbon Sequestration Newsletter

August 2010

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

***Fossil Energy Techline*, "DOE-Sponsored Field Test Demonstrates Viability of Simultaneous CO_2 Storage and Enhanced Oil Recovery in Carbonate Reservoirs."**

The Plains CO_2 Reduction (PCOR) Partnership has conducted a field test that demonstrated using carbon dioxide (CO_2) in an enhanced oil recovery (EOR) method called "huff-and-puff" to assess the carbon storage potential of geologic formations. The PCOR Partnership collaborated with Eagle Operating, Inc. to complete the test in the Northwest McGregor Oil Field in Williams County, North Dakota. The "huff-and-puff" EOR method consists of three phases: injection, soaking, and production. During the test, 440 tons of liquid CO_2 were injected into a producing oil well in the Mission Canyon Formation, which is part of the Madison Group of Mississippian-age carbonate rocks in the western United States. The injection occurred at a depth of approximately 8,050 feet, at which CO_2 is miscible and blends with residual, in-place oil. Following two weeks of soaking, the well was placed back into operation and production more than doubled over the course of a three-month period. In addition, the test also determined that two Schlumberger technologies – a reservoir saturation tool (RST) and vertical seismic profiling (VSP) – have the potential to be effective tools for detecting and monitoring small-volume CO_2 plumes in deep carbonate reservoirs. To learn more about the PCOR Partnership, click: http://www.undeerc.org/pcor/, or visit: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html for details on the U.S. Department of Energy's (DOE) Regional Carbon Sequestration Partnership (RCSP) Program. June 28, 2010, http://www.fossil.energy.gov/news/techlines/2010/10021-Field_Test_Demonstrates_Carbon_Sto.html.

***Fossil Energy Techline*, "U.S. Partners with Canada to Renew Funding for World's Largest International CO_2 Storage Project in Depleted Oil Fields,"** and ***Natural Resources Canada Newsroom*, "Canada and U.S. Invest in Leading Carbon Capture and Storage Project."**

DOE and Natural Resources Canada (NRCan) announced they will commit $5.2 million to bring the International Energy Agency (IEA) Greenhouse Gas Weyburn-Midale CO_2 Monitoring and Storage Project to conclusion in 2011. The funding, of which DOE is providing $3 million and the Government of Canada is providing $2.2 million, will allow the final phase of the project to focus on best practices for the safe and permanent storage of CO_2 with EOR; support research to solidify the knowledge of monitoring, verification, and accounting (MVA) in depleted oil reservoirs; and demonstrate the safe storage of CO_2. Weyburn-Midale is conducted in conjunction with $2 billion of commercial CO_2 injection operations, which to date have stored 18 million tonnes of CO_2 into the Weyburn and Midale oil fields located in Saskatchewan, Canada. Approximately 40 million tonnes of CO_2 are expected to be stored over the life of the EOR operations. July 20, 2010, http://www.fossil.energy.gov/news/techlines/2010/10026-DOE_Renews_Weyburn_Funding.html, and July 20, 2010, http://www.nrcan-rncan.gc.ca/media/newcom/2010/201053-eng.php.

National Energy Technology Laboratory

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

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

One West Third Street, Suite 1400
Tulsa, OK 74103-3519

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South, Suite 201
Fairbanks, AK 99709

Sean I. Plasynski
412-386-4867
sean.plasynski@netl.doe.gov

Dawn M. Deel
304-285-4133
dawn.deel@netl.doe.gov

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681

Sequestration in the News

***Fossil Energy Techline*, "Research Projects to Convert Captured CO_2 Emissions to Useful Products."**

DOE selected six projects that will aid in the research of converting captured CO_2 emissions from power plants and industrial facilities into useful products, such as chemicals, fuels, building materials, and other commodities, to help mitigate potential climate change. The six projects have an approximate value of $5.9 million over two to three years ($4.4 million in Federal funding) and are located in North Carolina; New Jersey; Massachusetts; Rhode Island; Georgia; and Quebec, Canada. As more fossil fuel-based power plants and other CO_2-emitting industries become equipped with CO_2 emissions control technologies, it is anticipated that large volumes of captured CO_2 will become available. DOE efforts are underway to demonstrate the permanent storage of the captured CO_2 through geologic sequestration, and focus is also being placed on the potential opportunity to use the CO_2 as an inexpensive raw material and convert it to beneficial use. For more information on DOE's Carbon Sequestration Program, click: http://www.fossil.energy.gov/programs/sequestration/index.html. July 6, 2010, http://www.fossil.energy.gov/news/techlines/2010/10022-Projects_to_Convert_CO2_to_Useful_.html.

***Enbridge Media Center*, "Enbridge to join TransAlta on Project Pioneer."**

Enbridge, Inc. announced it will join TransAlta Corporation in the development of Project Pioneer by offering its past experience with pipeline construction and design to the fully integrated carbon capture and storage (CCS) project. Project Pioneer will use Alstom Canada's proprietary chilled ammonia process and be designed to capture one megatonne (Mt) of CO_2 per year from Keephills 3, a coal-fired power plant west of Edmonton, Alberta, Canada, for EOR. Project Pioneer is expected to account for at least 20 percent of the Government of Alberta's target of reducing five Mt of CO_2 emissions per year by 2015. For more information about Project Pioneer, click: http://www.projectpioneer.ca/. June 28, 2010, http://www.enbridge.com/MediaCentre/News.aspx?yearTab=en2010&id=1282702.

***CSIRO Media Release*, "$10 [Million] Project to Store CO_2 Underground in China."**

Australia's Commonwealth Scientific and Research Organization (CSIRO) is partnering with China United Corporation Limited (CUCBM) on a $9.01 million joint demonstration project that will store 2,000 tonnes of CO_2 underground in the Shanxi Province. This enhanced coalbed methane (ECBM) recovery project (the CO_2 injected into the coal seams displaces the methane) has received funding from the Chinese and Australian Governments as part of the Asia-Pacific Partnership on Clean Development and Climate. CSIRO is also currently collaborating with China by supporting the launch of a post-combustion capture pilot plant in Beijing and the first CO_2 capture project using post-combustion capture technology in China. July 7, 2010, http://www.csiro.au/news/Chinese-CO_2-underground-storage-project.html.

ANNOUNCEMENTS

AAPG Geosciences Technology Workshop.

The American Association of Petroleum Geologists (AAPG) is hosting a workshop on August 10-12, 2010, at the Colorado School of Mines in Golden, Colorado. The workshop will focus on new approaches and case studies in the geological storage and capture of CO_2. Presentations will be given representing real-life scenarios concerning geosciences technology. For more information, click: http://www.aapg.org/gtw/CarbonCapture_Sequestration/index.cfm.

CCS Review Panel Meeting.

The California CCS Review Panel will hold a meeting on Wednesday, August 18, 2010, to review policy and develop recommendations to guide legislation and regulation related to CCS in California. The panel is comprised of the California Energy Commission, California Public Utilities Commission, and California Air Resources Board. For information on the August meeting and past meetings of the California CCS Review Panel, visit: http://www.climatechange.ca.gov/carbon_capture_review_panel/meetings/.

International Interdisciplinary CCS Summer School 2010.

In collaboration with BIGCCS and SUCCESS, The Gas Technology Center NTNU-SINTEF will host this year's CCS Summer School on August 22-27, 2010, at Longyearbyen, Svalbard, Norway. The Summer School will cover the whole field of CCS and present the most recent results from the following research and development (R&D) fields: CO_2 sources, CO_2 capture, CO_2 transport, underground geological storage, costs, economic potential of CCS, regulatory regimes, and implications of CCS for greenhouse gas (GHG) inventories and accounting. To learn more, go to: http://www.ieaghg.org/index.php?/20100113166/international-interdisciplinary-ccs-summer-school-2010.html.

Online CCS Network Launched.

CO2Sense Yorkshire, a business support and market development program, has set up an online network for organizations interested in developing CCS technologies within the Yorkshire and Humber CCS cluster in the United Kingdom. For more information, visit the Yorkshire and Humber CCS Network website at: http://www.co2sense.org.uk/networks/.

Fourth Quarterly Report on the Secondary Market for RGGI Allowances Now Available.

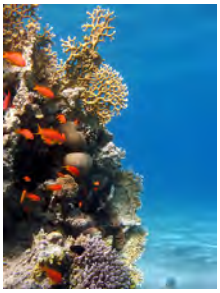
The states participating in the Regional Greenhouse Gas Initiative (RGGI) published the fourth quarterly report on the secondary market for RGGI CO_2 allowances from independent market monitor Potomac Economics. The report, which addresses the period from September 2009 to January 2010, is part of Potomac's ongoing monitoring of the RGGI auction and the secondary markets where CO_2 allowances are traded. The complete "Report on the Secondary Market for RGGI CO_2 Allowances" is available at: http://www.rggi.org/docs/MM_Secondary_Market_Report_Q4.pdf.

SCIENCE

***National Academy of Sciences News Release*, "Near-Term Emissions Decisions and Long-Term Climate Impacts: Research Council Report Released."**

The National Research Council released a study that claims choices made now concerning CO_2 emissions reductions will affect potential climate change impacts over the next few decades, as well as into the coming centuries and millennia. The study, which is sponsored by the Energy Foundation and the U.S. Environmental Protection Agency (EPA), states that since CO_2 stays in the atmosphere, it can effectively lock the Earth and future generations into a range of impacts, some of which could be severe. Furthermore, the report estimates the changes in precipitation, streamflow, wildfires, crop yields, and sea level rise that can be expected with different degrees of warming per degree Celsius. For example, one degree Celsius of global warming may result in: 5 to 10 percent less total rain in southwest North America, the Mediterranean, and southern Africa; 5 to 10 percent less streamflow in some river basins, including the Arkansas and Rio Grande; and 5 to 15 percent lower yields of some crops, including U.S. and African corn and Indian wheat. July 16, 2010, http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12877.

***Los Angeles Times*, "Oceans' Growing Carbon Dioxide Levels May Threaten Coral Reef Fish."**



According to marine ecologists, rising CO_2 levels in the ocean may confuse coral reef fish and cause them to swim toward the smell of predators rather than away from them. Published in the Proceedings of the National Academy of Sciences, the study observed larval fish in water enriched with various levels of CO_2. The majority of coral reef fish can smell nearby predators, which is a key ability for their survival due to their size. However, instead of fleeing from the predators odors,

Science (Continued)

the fish exposed to the highest levels of CO_2 in the experiment appeared to be attracted to the same odors that normally set off their neuronal alarms. Scientists then tested the fish in the ocean by making temporary one-fish habitats. They found that the fish that had spent time in the highest levels of CO_2 ventured farther away from their coral and acted more fearlessly than their counterparts in normal water by exploring without trying to hide and striking aggressively at food. In addition, the fish exposed to the higher levels of CO_2 were five to nine times more likely to die. July 6, 2010, http://www.latimes.com/news/science/la-sci-fish-20100707,0,399923.story.

Policy

***E&E News PM*, "White House Issues Draft Guidance on Agency Emissions."**

Following the issuing of Executive Order 13514 last year, the White House released draft guidance on July 15 that informs Federal agencies how to proceed with plans to achieve a target of reducing GHG emissions 28 percent over the next decade. The executive order requires agencies to establish an inventory of GHG emissions for the current fiscal year and submit it to the White House by January 31, 2010. The agencies will then work to reduce their total GHG emissions and cut the government's energy bills in the range of $8 billion to $11 billion. The draft guidance from the Council on Environmental Quality (CEQ) informs agencies how to measure emissions by focusing on land use, carbon offsets, and the burning of biomass. The draft guidance, which currently exempts biomass and biofuels from reduction targets, is available for public comment on the Federal Register along with a technical support document. The "Draft Federal Greenhouse Gas Accounting and Reporting Guidance" is available at: http://www.whitehouse.gov/sites/default/files/microsites/ceq/Draft-GHG-Accounting-and-Reporting-Guidance-6-30-10.pdf, and the draft technical support document can be viewed at: http://www.whitehouse.gov/sites/default/files/microsites/ceq/Draft-GHG-Technical-Support-Document.pdf. July 15, 2010, http://www.eenews.net/eenewspm/2010/07/15/archive/3.

***German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety Press Release*, "CCS Act an Important Step for a Future Technology."**

Germany's Federal Economics Minister and Federal Environment Minister presented a joint draft act that uses a gradual approach to set a legal framework for the demonstration and application of CCS technologies. The draft act permits testing and demonstration of storages, which will result in an evaluation of CCS technologies by 2017. In addition, the draft act sets requirements for site characterization, operator liability, protection of stakeholders, and MVA. A new provision in draft act states that storage facilities may only be licensed if the application is filed by the end of 2015, the annual storage volume per facility does not exceed 3 million tonnes, and the overall volume nationwide does not exceed 8 million tonnes of CO_2 per year. Other provisions state that precautionary measures must be taken, funds must be set aside for long-term monitoring, landowners' rights protected, and municipalities where projects take place will receive compensation. The German government will evaluate the act in 2017 by preparing a report that will determine whether CCS may be used on a larger scale. The draft act will now be reviewed and voted upon within the German government. July 14, 2010, http://www.bmu.de/english/current_press_releases/pm/46238.php.

"Determinants of the costs of carbon capture and sequestration for expanding electricity generation capacity."

The following is from the Abstract of this article: "This study models the costs of electricity generation with CCS, from generation at the power plant to carbon injection at the reservoir, examining the economic factors that affect technology choice and CCS costs at the individual plant level. The results suggest that natural gas and coal prices have profound impacts on the carbon price needed to induce CCS. To extend previous analyses [the authors] develop a 'cost region' graph that models technology choice as a function of carbon and fuel prices. Generally, the least-cost technology at low carbon prices is pulverized coal, while intermediate carbon prices favor natural gas technologies and high carbon prices favor coal gasification with capture. However, the specific carbon prices at which these transitions occur is largely determined by the price of natural gas. For instance, the CCS-justifying carbon price ranges from $27/t CO_2 at high natural gas prices to $54/t CO_2 at low natural gas prices. This result has important implications for potential climate change legislation. The capital costs of the generation and CO_2 capture plant are also highly important, while pipeline distance and criteria pollutant control are less significant." **Emily Giovanni and Kenneth R. Richards**, *Energy Policy*, Available online July 9, 2010, doi:10.1016/j.enpol.2010.05.058, http://www.sciencedirect.com/science/article/B6V2W-50GTRFY-2/2/46fa41016613b258413a2654196adde2. (Subscription may be required.)

"Real options analysis of investment in carbon capture and sequestration technology."

The following is from the Abstract of this article: "Among a comprehensive scope of mitigation measures for climate change, CCS plays a potentially significant role in [industrialized] countries. In this paper, [the authors] develop an analytical real options model that values the choice between two emissions-reduction technologies available to a coal-fired power plant. Specifically, the plant owner may decide to invest in either full CCS (FCCS) or partial CCS (PCCS) retrofits given uncertain electricity, CO_2, and coal prices. [The authors] first assess the opportunity to upgrade to each technology independently by determining the option value of installing a CCS unit as a function of CO_2 and fuel prices. Next, [the authors] value the option of investing in either FCCS or PCCS technology. If the volatilities of the prices are low enough, then the investment region is dichotomous, which implies that for a given fuel price, retrofitting to the FCCS (PCCS) technology is optimal if the CO_2 price increases (decreases) sufficiently. The numerical examples provided in this paper using current market data suggest that neither retrofit is optimal immediately. Finally, [the authors] observe that the optimal stopping boundaries are highly sensitive to CO_2 price volatility." **Somayeh Heydari, Nick Ovenden, and Afzal Siddiqui**, *Computational Management Science*,

Policy (Continued)

Available online June 16, 2010, doi:10.1007/s10287-010-0124-5, http://www.springerlink.com/content/r2hx264343864724/?p=b1325ea06ce84a3cbb841c0d1ee6ad2d&pi=8. (Subscription required.)

Geology

"Coupled hydromechanical modeling of CO_2 sequestration in deep saline aquifers."

The following is from the Abstract of this article: "Sequestration of CO_2 in deep saline aquifers has emerged as an option for reducing [GHG] emissions to the atmosphere. The large amounts of supercritical CO_2 that need to be injected into deep saline aquifers may cause large fluid pressure increases. The resulting overpressure may promote reactivation of sealed fractures or the creation of new ones in the caprock seal. This could lead to escape routes for CO_2. In order to assess the probability of such an event, [the authors] model an axisymmetric horizontal aquifer–caprock system, including hydromechanical coupling. [The authors] study the failure mechanisms, using a viscoplastic approach. Simulations illustrate that, depending on boundary conditions, the least favorable moment takes place at the beginning of injection. Initially, fluid pressure rises sharply because of a reduction in permeability due to desaturation. Once CO_2 fills the pores in the vicinity of the injection well and a capillary fringe is fully developed, the less viscous CO_2 displaces the brine and the capillary fringe laterally. The overpressure caused by the permeability reduction within the capillary fringe due to desaturation decreases with distance from the injection well. This results in a drop in fluid pressure buildup with time, which leads to a safer situation. Nevertheless, in the presence of low-permeability boundaries, fluid pressure continues to rise in the whole aquifer. This occurs when the radius of influence of the injection reaches the outer boundary. Thus, caprock integrity might be compromised in the long term." **Victor Vilarrasa, Diogo Bolster, Sebastia Olivella, and Jesus Carrera**, *International Journal of Greenhouse Gas Control*, Available online July 10, 2010, doi:10.1016/j.ijggc.2010.06.006, http://www.sciencedirect.com/science/article/B83WP-50H1HPS-1/2/2b2913fa2d68f61e5fab81ff1e57361d. (Subscription may be required.)

"Sensitivities of injection rates for single well CO_2 injection into saline aquifers."

The following is from the Abstract of this article: "This paper investigates methods to predict potential injection rates of CO_2 into a saline aquifer and analyses the sensitivities of the input parameters. Geological parameters are based on conditions at the European CO_2 Onshore Research Storage and Verification Project in Ketzin, Germany, and varied within an acceptable range. Two injection regimes for CO_2 are [analyzed]: pressure controlled injection and power plant controlled injection, where the CO_2 flux depends on the load curve of a 600 MWnet lignite power plant. The results are determined with a numerical model and compared to an analytical solution with constant pressure injection. The injection rates depend mainly on the geological setting and only slightly on technical parameters. Aquifer permeability and thickness show approximately linear sensitivity and have a dominant impact. Depth is also of high importance, but the impact is more complex and is based on geothermal temperature and hydrostatic gradient, which affect viscosity, compressibility and caprock stability. Vertical anisotropy is insensitive. The difference in the mean rate between constant pressure injection and power plant controlled injection is [eight percent]. Peak injection rates are 29 [percent] above mean injection rates, which shows that the reservoir can effectively dampen rate variations. The analytical solution predicts the highest injection rates, the lowest temporal variability and decreasing rates with injection duration. The numerical solution predicts a stronger temporal variability and the rates increase with duration. In the initial phase the differences between the methods add up to a factor of 1.45." **Bernd Wiese, Michael Nimtz, Matthias Klatt, and Michael Kühn**, *Chemie der Erde – Geochemistry*, Available online July 1, 2010, doi:10.1016/j.chemer.2010.05.009, http://www.sciencedirect.com/science/article/B7CW6-50F4622-1/2/a00b8fca747203e03e0d53f5bc58d739. (Subscription may be required.)

"Dissolution and Precipitation of Clay Minerals under Geologic CO_2 Sequestration Conditions: CO_2−Brine−Phlogopite Interactions."

The following is from the Abstract of this Article: "To ensure efficiency and sustainability of geologic CO_2 sequestration (GCS), a better understanding of the geochemical reactions at CO_2-water-rock interfaces is needed. In this work, both fluid/solid chemistry analysis and interfacial topographic studies were conducted to investigate the dissolution/precipitation on phlogopite ($KMg_3Si_3AlO_{10}(F,OH)_2$) surfaces under GCS conditions (368 K, 102 atm) in 1 M [sodium chloride (NaCl)]. Phlogopite served as a model for clay minerals in potential GCS sites. During the reaction, dissolution of phlogopite was the predominant process. Although the bulk solution was not supersaturated with respect to potential secondary mineral phases, interestingly, nanoscale precipitates formed. Atomic force microcopy (AFM) was utilized to record the evolution of the size, shape, and location of the nanoparticles. Nanoparticles first appeared on the edges of dissolution pits and then relocated to other areas as particles aggregated. Amorphous silica and kaolinite were identified as the secondary mineral phases, and qualitative and quantitative analysis of morphological changes due to phlogopite dissolution and secondary mineral precipitation are presented. The results provide new information on the evolution of morphological changes at CO_2-water-clay mineral interfaces and offer implications for understanding alterations in porosity, permeability, and wettability of pre-existing rocks in GCS sites." **Hongbo Shao, Jessica R. Ray, and Young-Shin Jun**, *Environ. Sci. Technol.*, Available online June 29, 2010, doi:10.1021/es1010169, http://pubs.acs.org/doi/abs/10.1021/es1010169. (Subscription required.)

Technology

"Impact of coal seam as interlayer on CO_2 storage in saline aquifers: A reservoir simulation study."

The following is from the Abstract of this article: "Geological storage of CO_2 is a viable option for the mitigation of [GHG] emissions. Two main

Technology (Continued)

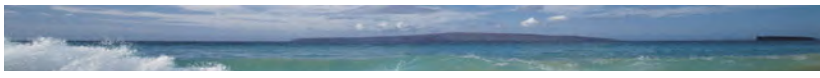
reservoir types exist; porous formations such as saline aquifers or depleted oil or gas reservoirs and, of lesser importance in terms of storage capacity, coal or shale reservoirs. These reservoirs have distinct storage mechanisms; in the porous formations the CO_2 is stored within the porosity by compression and/or dissolution in the formation fluid, whereas in coal or shale, the CO_2 is primarily stored by adsorption. Geological storage scenarios exist where these two reservoir types could be present within a geological sequence and come into contact with migrating CO_2. In order to simulate this situation simulators are required which represent the mechanisms operating for both reservoir types. One aspect of the work presented in this paper involves further development of the coal seam gas reservoir simulator, SIMED II, to include CO_2 dissolution in formation waters and a more accurate Equation of State, the Span and Wagner model, to describe CO_2 density. The modified model is first tested through a code comparison study with TOUGH2 for CO_2 storage in a saline aquifer with dissolution in formation water, which finds that the two simulators are in close agreement. The second component of this paper involved investigating the potential impact that coal seams could have on CO_2 storage in saline formations. A series of hypothetical cases are constructed to investigate the impact of coal seams as (1) a layer within the target aquifer above the injection point, (2) two layers separated by an aquifer above the injection point, (3) a layer in the target aquifer below the point of injection, and (4) a layer in the overburden. The results show that coal seams can have a significant impact on CO_2 storage and migration behavior by providing extra storage capacity and influencing the CO_2 flow path both vertically and horizontally. The potential impact of coal seams in these scenarios is related to a range of factors but key ones are the adsorption capacity and the permeability. The results also demonstrate that coal seam permeability decrease due to CO_2 adsorption induced coal swelling, although regarded as a technical obstacle to CO_2 injection in the deep unmineable coal seams to [ECBM] recovery and for CO_2 storage in coal, would further influence the CO_2 flow path, helping to reduce the upward CO_2 flow due to buoyancy and pressure. This could act to reduce CO_2 contact with cap rocks and lower the risk of CO_2 leakage." **Zhejun Pan and Luke D. Connell**, *International Journal of Greenhouse Gas Control*, Available online July 15, 2010, doi:10.1016/j.ijggc.2010.06.012, http://www.sciencedirect.com/science/article/B83WP-50J3DDW-1/2/28b1fd7cf9b2245fe80310304838c186. (Subscription may be required.)

"Single-well experimental design for studying residual trapping of supercritical carbon dioxide.

The following is from the Abstract of this article: "The objective of [this] research is to design a single-well injection-withdrawal test to evaluate residual phase trapping at potential CO_2 geological storage sites. Given the significant depths targeted for CO_2 storage and the resulting high costs associated with drilling to those depths, it is attractive to develop a single-well test that can provide data to assess reservoir properties and reduce uncertainties in the appraisal phase of site investigation. The main challenges in a single-well test design include (1) difficulty in quantifying the amount of CO_2 that has dissolved into brine or migrated away from the borehole; (2) non-uniqueness and uncertainty in the estimate of the residual gas saturation (Sgr) due to correlations among various parameters; and (3) the potential biased Sgr estimate due to unaccounted heterogeneity of the geological medium. To address each of these challenges, [the authors] propose (1) to use a physical-based model to simulation test sequence and inverse modeling to analyze data information content and to quantify uncertainty; (2) to jointly use multiple data types generated from different kinds of tests to constrain the Sgr estimate; and (3) to reduce the sensitivity of the designed tests to geological heterogeneity by conducting the same test sequence in both a water-saturated system and a system with residual gas saturation. To perform the design calculation, [the authors] build a synthetic model and conduct a formal analysis for sensitivity and uncertain quantification. Both parametric uncertainty and geological uncertainty are considered in the analysis. Results show (1) uncertainty in the estimation of Sgr can be reduced by jointly using multiple data types and repeated tests; and (2) geological uncertainty is essential and needs to be accounted for in the estimation of Sgr and its uncertainty. The proposed methodology is applied to the design of a CO_2 injection test at CO2CRC's Otway Project Site, Victoria, Australia." **Yingqi Zhang, Barry Freifeld, Stefan Finsterle, Martin Leahy, Jonathan Ennis-King, Lincoln Paterson, and Tess Dance**, *International Journal of Greenhouse Gas Control*, Available online July 13, 2010, doi:10.1016/j.ijggc.2010.06.011, http://www.sciencedirect.com/science/article/B83WP-50HN7P5-1/2/38f3e470dc23c2882895543c128286d6. (Subscription may be required.)

"Analytical solution for Joule–Thomson cooling during CO_2 geo-sequestration in depleted oil and gas reservoirs."

The following is from the Abstract of this article: "Mathematical tools are needed to screen out sites where Joule–Thomson cooling is a prohibitive factor for CO_2 geo-sequestration and to design approaches to mitigate the effect. In this paper, a simple analytical solution is developed by invoking steady-state flow and constant thermophysical properties. The analytical solution allows fast evaluation of spatiotemporal temperature fields, resulting from constant-rate CO_2 injection. The applicability of the analytical solution is demonstrated by comparison with non-isothermal simulation results from the reservoir simulator TOUGH2. Analysis confirms that for an injection rate of 3 kg s^{-1} (0.1 MT yr^{-1}) into moderately warm (>40 °C) and permeable formations (>10^{-14} m^2 (10 mD)), JTC is unlikely to be a problem for initial reservoir pressures as low as 2 MPa (290 psi)." **Simon A. Mathias, Jon G. Gluyas, Curtis M. Oldenburg, and Chin-Fu Tsang**, *International Journal of Greenhouse Gas Control*, Available online June 17, 2010, doi:10.1016/j.ijggc.2010.05.008, http://www.sciencedirect.com/science/article/B83WP-50B5WJB-1/2/a266a6b345ede2114a504a46fdd5b848. (Subscription may be required.)



Terrestrial

"Soil Carbon Accumulation During Temperate Forest Succession on Abandoned Low Productivity Agricultural Lands."

The following is from the Abstract of this Article: "Carbon

Terrestrial (Continued)

sequestration in soils that have previously been depleted of organic matter due to agriculture is an important component of global strategies to mitigate rising atmospheric CO_2 concentrations. Extensive areas of low productivity farmland have been abandoned from agriculture in eastern North America and elsewhere over the past century, and are naturally regenerating to temperate forests. [The authors] investigated the soil carbon sequestration potential of such lands by sampling adjacent mature forest and agricultural field sites, and replicated chronosequences of forest succession on Podzol, Brunisol, and Luvisol soil types that are considered 'marginal' for agriculture and have been abandoned extensively across southeastern Ontario, Canada. Total soil organic carbon and nitrogen stocks to 10 cm depth were approximately 32 [percent] and 18 [percent] lower, respectively, in agricultural fields compared to mature forests. Furthermore, carbon stocks across [the authors'] 100-year chronosequences increased most within the 0–5 cm soil depth interval, tended to increase within the 5–10 cm interval, and were unaltered within the 10–20 cm interval. Soil type had little effect on the potential magnitude or rates of soil carbon sequestration (~10 g C m^{-2} y^{-1} in the top 10 cm), perhaps because all sites shared a common vegetation successional pattern. Finally, [the authors'] investigations of the 'labile' free-light carbon and nitrogen fractions in the Brunisol soil type indicated no increases across the chronosequence, implying that soil carbon accumulation was primarily in more recalcitrant pools. [The authors'] results indicate that each of these low productivity soil types can be moderate carbon sinks for a century following agricultural abandonment, and strongly suggest that time since abandonment is more important than soil type in determining the potential magnitude of carbon sequestration within this climatic region." **Robyn L. Foote and Paul Grogan**, *Ecosystems*, Available online June 30, 2010, doi:10.1007/s10021-010-9355-0, http://www.springerlink.com/content/621k285750720481/?p=b1325ea06ce84a3cbb841c0d1ee6ad2d&pi=5. (Subscription required.)

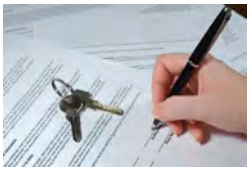
Trading

Carbon Market Update, July 21, 2010	
CCX-CFI 2010 ($/tCO$_2$)	EU ETS-EUA DEC 2010 ($/tCO$_2$)
$0.10 (Vintage 2009)	$17.92
	(Converted from € to US$)

***RGGI News Release*, "RGGI States Initiate Bidder Application Process for September 2010 CO_2 Allowance Auction."**

The 10 Northeast and Mid-Atlantic RGGI states have released the Auction Notice and application materials for the third quarterly CO_2 allowance auction of 2010. The materials provide potential auction participants with the information needed to submit a Qualification Application and indicate their intent to bid in the auction, scheduled for September 8, 2010. According to the Auction Notice, the participating states will offer 45,595,968 CO_2 allowances for the current control period (2009-2011) and 2,137,992 for the future control period (2012-2014); states will continue to use the reserve price of $1.86. This will be the ninth auction held since the debut of the RGGI auctions on September 25, 2008. To date, the participating states have auctioned more 250 million CO_2 allowances. Additional information about previous auction results is available at: http://www.rggi.org/co2-auctions/market_monitor. July 13, 2010, http://www.rggi.org/docs/Auction_9_Notice_News_Release.pdf.

"An emerging equilibrium in the EU emissions trading scheme."



The following is from the Abstract of this article: "The European Union's Emissions Trading Scheme (ETS) is the key policy instrument of the European Commission's Climate Change Program aimed at reducing [GHG] emissions to eight percent below 1990 levels by 2012. A critically important element of the EU ETS is the establishment of a market determined price for EU allowances. This article examines the extent to which several theoretically founded factors including, economic growth, energy prices and weather conditions determine the expected prices of the [EU] CO_2 allowances during the 2005 through to the 2009 period. The novel aspect of [this] study is that [the authors] examine heavily traded futures instruments that have an expiry date in Phase 2 of the EU ETS. [The authors'] study adopts both static and recursive versions of the Johansen multivariate cointegration likelihood ratio test as well as a variation on this test with a view to controlling for time varying volatility effects. [The authors'] results are indicative of a new pricing regime emerging in Phase 2 and point to a maturing market driven by the fundamentals. These results are valuable both for traders of EU allowances and for those policy makers seeking to improve the design of the [EU] ETS." **Don Bredlin and Cal Muckley**, *Energy Economics*, Available online July 6, 2010, doi:10.1016/j.eneco.2010.06.009, http://www.sciencedirect.com/science/article/B6V7G-50G698G-1/2/c891586466e081e24abd5f0e1c6eb2a8. (Subscription may be required.)

Recent Publications

Design for the WCI Regional Program.

The following is from the section, titled, "The [Western Climate Initiative (WCI)] Cap-and-Trade Program," of this document: "As part of a comprehensive strategy to reduce GHG emissions, the WCI Partner jurisdictions have recommended a market-based program that provides an incentive to limit emissions and promotes technological innovation. Cap-and-trade has proven to be a successful means of reducing air pollution. It also is considered one of the most cost-effective and reliable strategies for pricing carbon emissions and providing emitters of

Recent Publications (Continued)

GHG emissions with an incentive to limit pollution. With the trading component, cap-and-trade allows emitters to be flexible and creative in how to make needed reductions. The WCI program design includes a broad scope, encompassing nearly 90 percent of economy-wide emissions in the WCI Partner jurisdictions. The merits of pricing emissions broadly throughout the economy have been recognized in most of the recent [Federal] proposals in the [United States]. A forthcoming study by the National Research Council also recommends a broad scope, stating: 'An economy-wide carbon pricing policy would provide the most cost-effective reduction opportunities, would lower the likelihood of significant emissions leakage, and could be designed with a capacity to adapt in response to new knowledge.' Similarly, in 2009 the National Round Table on the Environment and the Economy published a report on carbon pricing in Canada, including: 'To achieve stated reduction targets at the least possible cost, all emissions must be covered as fully as possible. This requires a unified pricing policy that consciously takes into account all emissions across all sectors and all jurisdictions.'" The complete WCI document is available for download at: http://westernclimateinitiative.org/the-wci-cap-and-trade-program/program-design.

Energy Technology Perspectives 2010.

The following is from the Executive Summary of this document: "ETP 2010 feeds into this momentum by providing an IEA perspective on how low carbon energy technologies can contribute to deep CO_2 emissions reduction targets. Using a techno-economic approach that assesses costs and benefits, the book examines least-cost pathways for meeting energy policy goals while also proposing measures to overcome technical and policy barriers. Specifically, ETP 2010 examines the future fuel and technology options available for electricity generation and for the key end-use sectors of industry, buildings and transport. For the first time, this edition includes an analysis of OECD Europe, the United States, China and India, which together account for about 56 [percent] of today's global primary energy demand. It then sets out the technology transitions needed to move to a sustainable energy future, and provides a series of technology roadmaps to chart the path. Other new elements of ETP 2010 include chapters on financing, behavioral change, the diffusion of technologies amongst developed and emerging economies, and a discussion of the environmental impacts of key energy technologies." To read the IEA press release, click: http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=395. The document is available for purchase at: http://www.iea.org/w/bookshop/add.aspx?id=401.

Legislative Activity

***Senator Jay Rockefeller Press Release*, "Rockefeller, Voinovich Introduce Carbon Capture and Storage Deployment Act of 2010,"** and ***The Register-Herald*, "Legislation Promotes Carbon Capture and Storage Techniques."**

On July 14, 2010, U.S. Senators John D. Rockefeller and George V. Voinovich introduced legislation that promotes research and creates incentives to develop and deploy full-scale CCS technologies. The "Carbon Capture and Storage Deployment Act of 2010" represents a comprehensive approach to realizing widespread deployment of CCS activities. If approved, the legislation will authorize an industry-government R&D program in DOE's Office of Fossil Energy (FE) to stimulate additional CCS-related R&D. The "Pioneer Phase" of the legislation calls for the deployment of 20 gigawatts (GW) of CCS capacity; tax credits would be provided based on the amount of CO_2 captured at the facilities, providing price certainty for investors. After CCS technology is deployed on the first 10 GW of generating capacity, the next phase of deployment would require power plants permitted between bill enactment and completion of the "Pioneer Phase" to be retrofitted with CCS technologies. To view the proposed legislation, click: http://rockefeller.senate.gov/press/CCS1X9.pdf. July 14, 2010, http://rockefeller.senate.gov/press/record.cfm?id=326356&, and July 15, 2010, http://www.register-herald.com/local/x540033253/Legislation-promotes-carbon-capture-and-storage-techniques.

Events

August 10-12, 2010, **6th Australian-New Zealand Climate Change and Business Conference**, *Sydney Convention and Exhibition Centre, New South Wales, Australia*. This conference focuses on how businesses can respond to potential climate change in the face of policy uncertainty. Other topics to be discussed include: the potential for reduced emissions from key sectors, low-emissions technology, international policy, and the science behind climate change. To visit the conference website, which includes a downloadable program, visit: http://www.climateandbusiness.com/index.cfm.

EVENTS (CONTINUED)

August 10-12, 2010, **Coal Gen 2010**, *David L. Lawrence Convention Center, Pittsburgh, Pennsylvania, USA*. This three-day event covers the latest topics affecting the design, development, upgrading, operation, and maintenance of coal-fired power plants, as well as how to address challenges associated with them. For more information, visit this conference website at: http://www.coal-gen.com/index.html.

September 13-17, 2010, **2010 CO_2 Capture Technology R&D Meeting**, *Sheraton Station Square Hotel, Pittsburgh, Pennsylvania, USA*. This meeting provides a public forum to present CO_2 capture technology development status and accomplishments. Topics to be covered include post-, oxy-, and pre-combustion carbon capture technologies – including post-combustion solvent, sorbent, and membrane technologies – and CO_2 compression technologies. For registration information, visit the conference website at: http://www.netl.doe.gov/events/10conferences/co2capture/#mtg.

September 15-17, 2010, **10th International Conference on Clean Energy**, *Salamis Bay Conti Hotel, Famagusta, North Cyprus*. This conference provides a platform to discuss two topics: the depletion of fossil fuels and the resulting potential environmental problems. Other topics to be discussed include climate change, renewable energy sources, environmental impacts, and risk analysis and economics. To learn more, visit the conference website at: http://icce2010.emu.edu.tr/proceedings.html.

September 19-23, 2010, **10th International Conference on Greenhouse Gas Control Technologies**, *RAI, Amsterdam, The Netherlands*. Attendees of this conference, which is held every two years, will contribute to discussions on overcoming the barriers to implementing GHG mitigation technologies, as well as technological and policy-related developments. For more information, visit the conference website at: http://www.ghgt.info/GHGT10.html.

September 29-30, 2010, **Carbon Capture and Storage Summit**, *Capital Hilton, Washington, DC*. The 4th Annual CCS Summit will provide a forum to discuss the continuing development of commercialized CCS technologies. Topics to be discussed include: the impact of legislation on CCS; legal, regulatory, and liability issues surrounding CCS; CO_2-EOR; and the acceleration of CO_2 transport infrastructure. For a full list of topics, visit the conference website at: http://www.carboncapturesummit.com/index.html.

October 12-14, 2010, **2010 SPE Eastern Regional Meeting**, *Morgantown, West Virginia, USA*. The technical sessions at this meeting will cover topics such as CCS and gas storage; production operations, optimization, monitoring, and control; formation evaluation; and the drilling of wells. More information can be found by visiting the conference website at: http://www.spe.org/events/erm/2010/.

October 19-20, 2010, **Carbon Capture and Storage Symposium 2010**, *Chifley at Lennons, Brisbane, Queensland, Australia*. The Carbon Capture and Storage Symposium 2010 features cases studies of local and global initiatives and projects related to CCS, including policy and regulatory frameworks, business models and strategies in a low carbon economy, technical presentations on low emissions technologies, site selection, and expert-led panel discussions. Detailed information can be obtained at: http://www.carbon-capture.com.au/Event.aspx?id=329858.

October 25-26, 2010, **Coal Power Plant Fundamentals**, *The Adolphus Hotel, Dallas, Texas, USA*. This Electric Utility Consultants, Inc. (EUCI) introductory course details the basic workings of a coal-fired power plant, covering all major systems from coal handling to the switchyard. For more information, including a detailed program agenda, view the course brochure at: http://www.euci.com/pdf/1010-coal-power.pdf.

October 27-28, 2010, **Emissions Regulations and Control Technologies for Fossil-Fuel Power Plants**, *The Adolphus Hotel, Dallas, Texas, USA*. This EUCI course will provide a basic understanding of how emission control technologies reduce emissions. In addition, the Clean Air Act (CAA) will be discussed and relative CO_2 emissions standards will be reviewed. For more information, including a detailed program agenda, view the course brochure at: http://www.euci.com/pdf/1010-emisisons.pdf.

FOR SUBSCRIPTION DETAILS...

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 Sean Plasynski at sean.plasynski@netl.doe.gov, or Dawn Deel at dawn.deel@netl.doe.gov.