



Office of Fossil Energy

Carbon Sequestration Newsletter



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APRIL 2012

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storage technology barriers. The energy-efficient, high-performance supercomputer will be used to develop and deploy advanced simulation tools that are needed to quickly and reliably overcome energy technology challenges. Researchers from partnering organizations, such as the members of the NETL-Regional University Alliance (NETL-RUA), will be able to access the supercomputer via NETL's user centers in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, which will also provide advanced visualization hardware and software. For more information on the five universities that are part of the NETL-RUA, go to: <http://www.netl.doe.gov/rua/index.html>. March 29, 2012, http://www.fossil.energy.gov/news/techlines/2012/12009-NETL_Shares_Computing_Speed.html.

EPA News Release, "EPA Proposes First Carbon Pollution Standard for Future Power Plants."

On March 27, the U.S. Environmental Protection Agency (EPA) proposed the first Clean Air Act (CAA) standard for carbon emissions from new power plants. EPA's rule creates a path forward for new technologies to be deployed at future facilities that will allow companies to burn coal while emitting less carbon. The rulemaking proposed concerns new generating units that will be built in the future and does not apply to existing units already operating or units that will start construction over the next 12 months. For more information, visit: <http://epa.gov/carbonpollutionstandard/>. The proposed rule can be viewed at: <http://epa.gov/carbonpollutionstandard/pdfs/20120327proposal.pdf>. March 27, 2012, <http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceac8525735900400c27/9b4e8033d7e641d9852579ce005ae957!OpenDocument>.

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

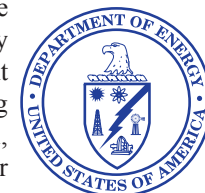
Fossil Energy Techline, "NETL Shares Computing Speed, Efficiency to Tackle Technology Barriers."

One of the world's fastest supercomputers will be installed at the Office of Fossil Energy's (FE) National Energy Technology Laboratory's (NETL) Simulation-Based Engineering User Center this summer to help develop solutions to carbon capture, utilization, and

SEQUESTRATION IN THE NEWS

Reuters, "Petrofac, UK National Grid Plan Carbon Capture Plant," and Summit Power News Release, "Summit Power, National Grid and Petrofac Team Up on DECC Carbon-Capture Program in UK."

National Grid and Petrofac announced plans to partner with Summit Power to build a 400-megawatt (MW) coal-fired power plant with carbon capture and storage (CCS) in Britain. The companies will submit the Caledonia Clean Energy Project to the United Kingdom's (UK) Department of Energy and Climate Change (DECC) for funding through the UK's CCS Delivery Competition, which is expected to re-launch a \$1.6-billion tender



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SEQUESTRATION IN THE NEWS (CONTINUED)

for CCS projects. The proposed plant would be based at the Scottish port of Grangemouth, west of Edinburgh, and capture carbon emissions from more than 90 percent of its production capacity. The captured carbon dioxide (CO₂) would then be transported via pipeline by National Grid and transferred offshore for geologic storage beneath the North Sea by CO₂DeepStore, a subsidiary of Petrofac. The location of the project site provides the benefit of being close to the North Sea for CO₂ storage, as well as for potential future enhanced oil recovery (EOR) opportunities. March 20, 2012, <http://www.reuters.com/article/2012/03/20/britain-ccs-caledonia-idUSL6E8EK80E20120320>, and March 20, 2012, <http://www.summitpower.com/in-the-news/summit-power-national-grid-and-petrofac-team-up-on-decc-carbon-capture-programme-in-uk/>.

Government of Canada News Release, "Government of Canada Invests in Carbon Capture and Storage Technology."

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

Carbon Capture Journal, "SaskPower & Hitachi to Build CCS Test Facility."

SaskPower and Hitachi Ltd. are partnering to build a test facility in southeastern Saskatchewan to capture CO₂ emissions from coal-fired thermal power plants. SaskPower and Hitachi will each contribute approximately \$30 million toward the test facility, which will be located at SaskPower's Shand Power Station. SaskPower will act as the owner/operator of the test facility and Hitachi will supply their process development team and process equipment from their Saskatoon manufacturing facility. The test facility will accommodate a wide range of test configurations; Hitachi's amine technology will be the first technology tested at the facility and SaskPower plans to evaluate a number of current and emerging carbon capture technologies over the life of the facility. Construction of the test facility will begin in late 2012 or early 2013, and is expected to be completed in the summer of 2014. March 25, 2012, <http://www.carboncapturejournal.com/displaynews.php?NewsID=918&PHPSESSID=qdrk611btpc5ilvhchlfg0fgd0>.

The Star, "Petronas, Total to Study Potential of CO₂ Field."

Petronas and Total will jointly study the development and production potential of a high CO₂ gas field offshore Sarawak called K5. Under the Heads of Agreement (HOA), Petronas' newly established research unit – the Exploration and Production Technology Center – and Total will explore the possibility of developing the field in ways that are

SEQUESTRATION IN THE NEWS (CONTINUED)

technically, commercially, and environmentally viable. The scope of the study, which is expected to begin immediately and take up to 15 months to complete, will also include the

development of CO₂ management technologies in the areas of carbon capture, transportation, and storage. Discovered in 1970, K5 is a sour gas field with up to 70 percent CO₂ content located approximately 140 miles from Bintulu. If the study finds the field to be viable, it will be the first gas field with more than 50 percent CO₂ content to be developed in Malaysia. March 29, 2012, <http://biz.thestar.com.my/news/story.asp?file=/2012/3/29/business/11005641&sec=business>.

ANNOUNCEMENTS



Call for Papers. NETL is organizing a topical conference for the upcoming American Institute of Chemical Engineers (AIChE) Annual Meeting, to be held in Pittsburgh, Pennsylvania, during the fall of 2012. This topical conference, “Accelerating Technology Development through Integrated Computation and Experimentation,” will include plenary talks by officials within the U.S. Department of Energy (DOE), as well as regional, industrial, and academic representatives speaking on the future of sustainable energy. In addition, several technical sessions will address the development of computational and experimental collaborations to accelerate technology, including gas separations, CO₂ utilization, EOR, advanced power cycles, simulations, and related topics. Electronic abstracts may be submitted by May 2, 2012, to the meeting website: <http://aiche.confex.com/aiche/2012/cfp.cgi>.

2012 NETL CO₂ Capture Technology Meeting.

NETL’s 2012 CO₂ Capture Technology Meeting will be held at the Sheraton Station Square Hotel in Pittsburgh, Pennsylvania, on July 9-12, 2012. This year’s meeting will provide a public forum to present CO₂ capture technology development status and accomplishments made under NETL’s Innovations for Existing Plants (IEP), Carbon Storage, and Demonstration Programs, as well as highlight DOE’s Advanced Research Projects Agency-Energy (ARPA-E) CO₂ capture portfolio. In addition to covering post-, oxy-, and pre-combustion technologies, the meeting will also cover solvent, membrane, chemical looping, and compression technologies. To learn more, go to: <http://netldev.netl.doe.gov/business/event-all>.

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 Regional Carbon Sequestration Partnerships (RCSPs) 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 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/business/event-all>.

33rd IEA-EOR Symposium.

Hosted by 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 CO₂-EOR is included. The conference concludes with a field trip to SaskPower’s Boundary Dam Power Plant and Cenovus Energy’s Weyburn field CO₂ injection facility. Abstracts are being accepted through May 15, 2012. For more information, visit the conference website at: <http://www.iea-eor2012.com/>.

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/>.

North American Partnership Launched.

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

ANNOUNCEMENTS (CONTINUED)

CCS Research Center Launched.

The Engineering and Physical Sciences Research Council (EPSRC) and DECC have established a CCS Research Center to support innovative research to maximize the contribution of CCS to a low-carbon energy system. Based at the University of Edinburgh, the new capture research facilities will include pilot-scale advanced testing facilities in Yorkshire, with a 1-tonne of CO₂ per day amine capture facility; a mobile testing unit to allow a range of tests to be conducted on real power station flue gases; and advanced oxy-fuel fluidized bed and chemical looping pilot facilities. For more information, visit: <http://www.carboncapturejournal.com/displaynews.php?NewsID=923&PHPSESSID=sl01kmagthng0kc0qif34s91b6>.

SCIENCE

***ScienceMag.org*, “Climate Change Sends Beetles Into Overdrive.”**

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

***MIT News Release*, “MIT Research: Study Finds Room to Store CO₂ Underground.”**

A study released by researchers at the Massachusetts Institute of Technology (MIT) suggests that the United States has the ability to store at least a century's worth of its CO₂ emissions in saline formations. In the study, the researchers modeled how the CO₂ would move through the rock, accounting for the capacity of the formations as well as the rate of injection that could be sustained over time. March 20, 2012, <http://web.mit.edu/press/2012/greenhouse-gas-in-aquifers.html>.

POLICY

***Bloomberg*, “Scotland to Fit Carbon Capture at Existing Coal Plants by 2025.”**

In a draft document on power generation plans, the Scottish government

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

“Providing adequate economic incentives for bioenergies with CO₂ capture and geological storage.”

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

“The evolving perception of risk during reservoir evaluation projects for geological storage of CO₂.”

The following is the Abstract of this article: “If [CO₂] is to be stored in geological strata other than depleted hydrocarbon reservoirs (e.g. in saline [formations]), relatively little information will typically be available about the potential reservoirs. Significant risk associated with

POLICY (CONTINUED)

such projects therefore derives from uncertainty in reservoir evaluation. This paper describes a risk elicitation exercise carried out during geological reservoir evaluation for two exemplar CCS projects. A project-specific Features, Events and Processes (FEPs) register was developed through a structured elicitation process and discussions with experts. The register was used to elicit experts' perception of risk early in each project and thereafter at regular intervals, finding that the risk was moderate or low for the majority of FEPs. Where FEPs were perceived as high risk, lack of information and uncertainty tended to be the most influential factor. The results of the risk assessments were instrumental in identifying key project activities aimed at reducing uncertainty and addressing the highest areas of risk. Using the relatively inexpensive techniques of reprocessing legacy seismic data and conducting a hydrogeological study of the region around the storage site, uncertainty was reduced and the experts' perception of risk was lowered by the new information. However the risk assessment results also showed changes occurring in the absence of new information and where experts declared no change to their perception of risk. It is therefore vital to understand the uncertainty in the risk assessment results which can clearly be affected by factors other than information related to the storage formations."

Debbie Polson, Andrew Curtis, Claudia Vivalda, *International Journal of Greenhouse Gas Control*, Available online March 28, 2012, doi:10.1016/j.ijggc.2012.02.010, <http://www.sciencedirect.com/science/article/pii/S1750583612000503>. (Subscription may be required.)

GEOLOGY

"Hydrogeochemical processes in clastic sedimentary rocks, South Korea: A natural analogue study of the role of dedolomitization in geologic carbon storage."

The following is the Abstract of this article: "For long-term mineral trapping of [stored] CO₂ in deep saline [formations], base cations such as Ca²⁺ and Mg²⁺ are essential. As a natural analogue study of geologic carbon storage in deep [formations] hosted in sedimentary formations, [the authors] examined the hydrochemistry of sulfate-rich (up to 1140 mg/l SO₄²⁻) and moderately high PCO₂ (10^{-1.1} to 10^{-2.4} atm) groundwater in a Cretaceous non-marine sedimentary basin in South Korea with the objective to elucidate water-rock interactions controlling the concentrations and behavior of base cations. Principal component analysis of the acquired hydrochemical data indicated that dissolution of carbonates (calcite and dolomite) and evaporite minerals (halite and gypsum) controls the chemical composition of groundwater, resulting in substantial increases of the concentration s of Ca²⁺, Mg²⁺, Na⁺, Cl⁻, SO₄²⁻ and total dissolved solids (TDS) in deep groundwater. Na⁺ versus Cl⁻ and Ca²⁺ versus Mg²⁺ versus HCO₃⁻ + SO₄²⁻ plots provided evidence for dissolution of halite and gypsum. Progressively increasing δ³⁴S values of dissolved SO₄²⁻ (from 15.1 to 19.2‰) with increasing sulfate concentrations indicated gypsum dissolution. Ion-ion plots (esp., Mg²⁺/Ca²⁺, Ca²⁺/SO₄²⁻ and Mg²⁺/SO₄²⁻) and saturation indices of calcite, dolomite and gypsum suggest that the groundwater chemistry (esp., the concentrations of Ca²⁺ and Mg²⁺) is controlled by dedolomitization driven by gypsum dissolution. Groundwater in the study area does not reach complete

equilibrium with respect to calcite and dolomite because of gypsum dissolution, which controls the Mg²⁺/Ca²⁺ ratios of groundwater. Continued calcite precipitation triggered by an excess Ca supply from gypsum dissolution reduces the concentrations of dissolved inorganic carbon (DIC) in groundwater. The increase of δ¹³CDIC values from -11.1 to -6.5‰ concomitantly with increasing sulfate concentration was explained via geochemical modeling by dedolomitization under the rate constant ratio of about 0.038 between dolomite and calcite. The model results agree well with the observed Mg²⁺/Ca²⁺ ratios and further suggest a potential increase of the void volume in the [formation] through dedolomitization by about 0.72 cm³/l. Based on this analogue, [the authors] suggest that dedolomitization in concert with dissolution of gypsum may constitute an important process releasing base cations for mineral trapping of injected CO₂ in non-marine clastic sedimentary strata containing carbonates and gypsum in South Korea and elsewhere." **Byoung-Young Choi, Seong-Taek Yun, Bernhard Mayer, So-Young Hong, Kyoung-Ho Kim, Ho-Young Jo**, *Chemical Geology*, Available online March 8, 2012, doi:10.1016/j.chemgeo.2012.03.002, <http://www.sciencedirect.com/science/article/pii/S0009254112001192>. (Subscription may be required.)

"Microfracturing of coal due to interaction with CO₂ under unconfined conditions."

The following is the Abstract of this article: "Laboratory experiments conducted in the past century have shown that exposure of coal to CO₂ under unconfined, hydrostatic conditions leads to reversible adsorption and swelling. However, several authors also report irreversible changes in sorption capacity, sample volume, equilibration time and brittle failure strength. Some relate these effects to the formation of microfractures, while others consider 'structural rearrangements' in the macromolecular structure of coal to be responsible. In this study, [the authors] investigate the magnitude of irreversible swelling effects and changes in equilibration time in high volatile bituminous coal (Brzeszcze, Seam 364, Poland), and attempt to explain the results in terms of the operative microphysical processes. [The authors] also assess the implications for Enhanced Coalbed Methane (ECBM) operations. [The authors'] approach involves detailed dilatometry experiments conducted on fresh, unconfined, mm-scale coal matrix cylinders at CO₂ pressures up to 100 MPa, and at 40.0°C. Exposure of [the authors'] samples to CO₂ produced reversible and irreversible strains resulting predominantly from competition between adsorption-induced swelling and elastic compression. During the first or second cycle of exposure, substantial hysteresis was observed in volumetric behavior, notably at CO₂ pressures above 35-40 MPa. After two or three upward and downward CO₂ pressure cycles, the measured strain response became fully reversible. Equilibration with CO₂ took about four times longer during the first CO₂ pressurization cycle than in subsequent CO₂ pressurization cycles. Microstructural analysis and comparison showed that microfractures formed in the coal during first exposure to CO₂. From the microstructural and mechanical data, [the authors] infer that microfracturing was responsible for enhanced CO₂ penetration into the present samples. This, in turn allowed more homogeneous access of CO₂, and caused adsorption-induced swelling of matrix material not previously accessed by CO₂. [The authors] further infer that the enhanced penetration, sorption and swelling, in turn, resulted in the observed hysteresis in dimensional response and in the decrease in equilibration time seen in subsequent exposure cycles. Since most microfractures developed parallel to the bedding,

GEOLOGY (CONTINUED)

roughly following maceral–maceral and bedding/layer interfaces, and because the largest permanent strains and strain hysteresis were measured perpendicular to the bedding, [the authors] infer that the formation of microfractures was caused by heterogeneous swelling, in combination with differential accessibility of the coal microstructure. No evidence was found that CO₂-induced plasticization of the macromolecular structure of the coal matrix played any role in the behavior observed. Simple mechanical considerations indicate that at in situ stresses corresponding to a depth of 1000–1500 m, i.e. effective stresses in the range 25–35 MPa, adsorption-induced microfractures are unlikely to form. This means that improved access of CO₂ to coal matrix material for ECBM production can probably be achieved only by inducing damage into coal seams, either by injection of solvents/solutes, or by performing active mining of the coal and/or the over- or underlying strata.” **Sander Hol, Christopher J. Spiers, Colin J. Peach**, *Fuel*, Available online March 12, 2012, doi:10.1016/j.fuel.2012.02.030, <http://www.sciencedirect.com/science/article/pii/S0016236112001536>. (Subscription may be required.)

TECHNOLOGY

“Effects of Well Spacing on Geological Storage Site Distribution Costs and Surface Footprint.”

The following is the Abstract of this article: “Geological storage studies thus far have not evaluated the scale and cost of the network of distribution pipelines that will be needed to move CO₂ from a central receiving point at a storage site to injection wells distributed about the site. Using possible injection rates for deep-saline sandstone [formations, the authors] estimate that the footprint of a [storage] site could range from <100 km² - >100,000 km², and that distribution costs could be <\$0.10/tonne - >\$10/tonne. [The authors’] findings are based on two models for determining well spacing; one which minimizes spacing in order to maximize use of the volumetric capacity of the reservoir, and a second that determines spacing to minimize sub-surface pressure interference between injection wells. The interference model, which [the authors] believe more accurately reflects reservoir dynamics, produces wider well spacings and a counterintuitive relationship whereby total injection site footprint and thus distribution cost declines with decreasing permeability for a given reservoir thickness. This implies that volumetric capacity estimates should be reexamined to include well spacing constraints, since wells will need to be spaced further apart than void space calculations might suggest. [The authors] conclude that site selection criteria should include thick, low-permeability reservoirs to minimize distribution costs and site footprint.” **Jordan Kaelin Eccles, Lincoln Pratson, and Munish Kumar Chandel**, *Environmental Science & Technology*, Available online March 21, 2012, doi:10.1021/es203553e, <http://pubs.acs.org/doi/abs/10.1021/es203553e?prevSearch=carbon%2Bsequestration&searchHistoryKey=>. (Subscription required.)

“Parameters influencing the flow performance of natural cleat systems in deep coal seams experiencing carbon dioxide injection and sequestration.”

The following is the Abstract of this article: “Carbon dioxide [storage] in deep, unmineable coal seams may provide an immediate and economically feasible solution for mitigation of anthropogenic CO₂ emissions. Coal contains natural cleats, which largely control fluid movement in coal seams. This study uses experimental and numerical methods to investigate the variables (i.e. injection pressure, injection depth, and coal temperature) that will influence cleat performance in the CO₂ [storage] process for black coal. The steady-state downstream pressure (and pressure differential from the injection value) that develops during undrained triaxial tests performed on fractured black coal, without deviatoric load, is taken as a measure of cleat performance. The results of tests show that increasing injection pressure has a significant detrimental effect on cleat performance, in accord with greater adsorption-induced swelling (and cleat closure) with higher injection pressure. Testing also shows that increasing injection depth has a moderate (negative) effect on cleat performance and that temperature has a minor (positive) effect on cleat performance. The experimental results were used to validate a numerical model produced using the COMET 3 numerical simulator, which was used to further explore coupling between the variables that influence cleat performance in coal-seam CO₂ [storage]. The numerical results show that the influence of injection pressure on cleat performance is dependent on injection depth, whereby a given increase in injection pressure will have more detrimental effects on cleat performance at greater depths than it would at more shallow depths. The influence of injection depth on cleat performance is similarly dependent on the absolute depth range considered. Coupling was observed in the influence of temperature on cleat performance and both injection pressure and depth. Modeling shows that increasing temperature has a negative influence on cleat performance for low injection pressures (i.e. 6 MPa), but a positive influence on cleat performance for higher injection pressures (i.e. 12 MPa). Modeling shows that temperature will have an influence on the manner by which depth effects cleat performance if injection pressures are high (i.e. 12 MPa), but no such influence if injection pressures are low (i.e. 6 MPa).” **M.S.A. Perera, P.G. Ranjith, D.R. Viete, and S.K. Choi**, *International Journal of Coal Geology*, Available online April 5, 2012, doi:10.1016/j.coal.2012.03.010, <http://www.sciencedirect.com/science/article/pii/S016651621200095X>. (Subscription required.)

“Cross-hole electromagnetic and seismic modeling for CO₂ detection and monitoring in a saline [formation].”

The following is the Abstract of this article: “The injection of CO₂ in saline [formations] and depleted hydrocarbon wells is one solution to avoid the emission of that greenhouse gas to the atmosphere. Carbon taxes can be avoided if geological [storage] can efficiently be performed from technical and economic perspectives. For this purpose, [the authors] present a combined rock-physics methodology of electromagnetic (EM) and seismic wave propagation for the detection and monitoring of CO₂ in crosswell experiments. First, [the authors] obtain the electrical conductivity and seismic velocities as a function of saturation, porosity, permeability and clay content, based on the CRIM and White models, respectively. Then, [the authors] obtain a conductivity-velocity relation.

TECHNOLOGY (CONTINUED)

This type of relations is useful when some rock properties can be more easily measured than other properties. Finally, [the authors] compute crosswell EM and seismic profiles using direct modeling techniques. P- and S-wave attenuation is included in the seismic simulation by means of White's mesoscopic theory. The modeling methodology is useful to perform sensitivity analyses and it is the basis for performing traveltimes EM and seismic tomography and obtain reliable estimations of the saturation of [CO₂]. In both cases, it is essential to correctly pick the first arrivals, particularly in the EM case where diffusion wavelength is large compared to the source-receiver distance. The methodology is applied to CO₂ injection in a sandstone [formation] with shale intrusions, embedded in a shale formation. The EM traveltimes are smaller after the injection due to the higher resistivity caused by the presence of [CO₂], while the effect is opposite in the seismic case, where water replaced by gas decreases the seismic velocity." **José M. Carcione, Davide Gei, Stefano Picotti, and Alberto Michellini**, *Journal of Petroleum Science and Engineering*, Available March 30, 2012, doi:10.1016/j.petrol.2012.03.018, <http://www.sciencedirect.com/science/article/pii/S092041051200071X>. (Subscription required.)



TERRESTRIAL

"Influence of Soil and Climate Conditions on CO₂ Emissions from Agricultural Soils."

The following is the Abstract of this article: "Many of the environmental problems related to agriculture will still be serious over the next 30 years. However, the seriousness of some of those problems may increase more slowly than in the past or even diminish in other cases. Agriculture plays two different roles in climate change; on one hand, it suffers from the impact of climate change, on the other hand, it is responsible for 14 [percent] of total greenhouse gases. Nevertheless, agriculture is also part of the solution, as it is capable of mitigating a significant amount of global emissions. This paper aims to study the influence of edapho-climate conditions on soil CO₂ emissions into the atmosphere. In order to do so, [the authors] conducted three field trials in different areas in southern Spain, which have different soil textures and different climate conditions. The results show how interaction between the temperature and rainfall recorded has a greater influence on emissions than each of the factors separately. However, at the same time, the texture of the soil at each of the locations was also found to be the most dominant variable in the gas emission process." **Rosa María Carbonell-Bojollo, Miguel Angel Repullo-Ruibérriz de Torres, Antonio Rodríguez-Lizana, and Rafaela Ordóñez-Fernández**, *Water, Air, & Soil Pollution*, Available online March 13, 2012, doi:10.1007/s11270-012-1121-9, <http://www.springerlink.com/content/bl4244j9lx55773u/>. (Subscription required.)



TRADING

RGGI News Release, "RGGI Auction Sells 21.5 Million CO₂ Allowances."

The states participating in the second Regional Greenhouse Gas Initiative (RGGI) control period announced that 21,559,000 CO₂ allowances (62 percent of the 34,843,858 allowances offered) were sold in RGGI's 15th quarterly auction. Bids for the current control period (2012-2014) ranged from \$1.93 to \$5.36 per allowance, with a clearing price of \$1.93 (the minimum reserve price). The auction generated \$41.6 million in proceeds, which will continue to be invested in a variety of consumer-benefit initiatives. Since 2008, electricity generators and their corporate affiliates have won 87 percent of CO₂ allowances sold in RGGI auctions, according to the independent market monitor's report. The states participating in RGGI are currently conducting a comprehensive review of RGGI's first three years of implementation; the review will gather stakeholder comments on all aspects of the program and will consider, among other things, the reduction in emissions that has occurred since the regional emissions cap was put into place. The next RGGI auction is scheduled for June 6, 2012. March 16, 2012, http://www.rggi.org/docs/PR031612_Auction15Results.pdf.

"A robust optimization method for planning regional-scale electric power systems and managing carbon dioxide."

The following is the Abstract of this article: "The uncertainties that are inherent in the energy systems planning process and complexities interaction among various uncertain parameters are challenging managers and decision makers. In this study, a robust interval-stochastic optimization (RISO) method is developed for planning energy systems and trading CO₂, through incorporating interval-parameter programming (IPP) within a robust optimization (RO) framework. In the RISO modeling formulation, penalties are exercised with the recourse against any infeasibility, and robustness measures are introduced to examine the variability of the second stage costs that are above that the expected levels. The RISO is generally suitable for risk-averse planners under high-variability conditions. The RISO method is applied to a case of planning regional-scale electric power systems under consideration of CO₂ trading scheme. A number of solutions under different robustness levels have been generated. They are helpful for supporting (a) adjustment or justification of allocation patterns of regional energy resources and services, (b) formulation of local policies regarding energy consumption, economic development, and energy structure, (c) analysis of the effect of CO₂ trading scheme, and (d) in-depth analysis of tradeoffs between system cost and CO₂-mitigation levels under total emission permissions. The modeling results from the RISO can help generate desired decision alternatives that will be able to not only enhance energy-supply safety with a low system-failure risk level but also mitigate total CO₂-emissions under an effective trading scheme." **C. Chen, Y.P. Li, G.H. Huang, and Y.F. Li**, *International Journal of Electrical Power & Energy Systems*, Available online March 14, 2012, doi:10.1016/j.ijepes.2012.02.007, <http://www.sciencedirect.com/science/article/pii/S0142061512000348>. (Subscription may be required.)

RECENT PUBLICATIONS

“CCS Roadmap: Supporting Deployment of Carbon Capture and Storage in the UK.”

The following is from the Executive Summary of this document: “CCS has the potential to be one of the most cost effective technologies for [decarbonization] of the UK’s power and industrial sectors, as well as those of economies worldwide. CCS can remove CO₂ emissions created by the combustion of fossil fuels in power stations and in a variety of industrial processes and transport it for safe permanent storage deep underground, for example deep under the North and Irish Seas. [Modeling] for the Carbon Plan shows that CCS can play a significant role in achieving [decarbonization] of the UK economy at least cost. In the power sector CCS will contribute to diversity and security of electricity supply, and also has a unique role in providing a continuing role for flexible fossil fuel capacity that is able to respond to demand in the way that other low carbon technologies are not able to. CCS also represents a major green growth opportunity for the UK. Worldwide up to \$40 billion has been committed by Governments to support CCS projects and, if CCS opportunities develop as anticipated, benefits for UK-based firms have been estimated to be between [approximately \$4.8 to \$10.4 billion] a year by the late 2020s. The deployment of CCS is at an early stage, so to the extent that UK based business can take advantage of these local opportunities it should help to establish them as leaders in a developing worldwide market. The Government is committed to helping make CCS a viable option for reducing emissions in the UK and in doing so to accelerate the potential for CCS to be deployed in other countries. [The UK’s] vision is for widespread deployment of cost-competitive CCS. [The UK is] seeking to support the development of a sustainable CCS industry that will capture emissions from clusters of power and industrial plants linked together by a pipeline network transporting CO₂ to suitable storage sites offshore. That CO₂ might also be used to recover additional amounts of the UK’s hydrocarbon reserves, thereby improving the economics of CCS and accelerating deployment. [The UK] will support the development of a strong and robust supply chain in the UK, creating jobs and markets locally and nationally to serve the early CCS plant and later clusters of CCS activity. Playing to the UK’s business strengths and encouraging projects clustering in regions reflects the Government’s ambition to capture opportunities for ‘green jobs’ that will arise from an emerging market for CCS. To make this vision a reality [the UK] must invest now. This Roadmap sets out how [the UK] will achieve [their] goal of seeing commercial deployment of CCS in the UK in the 2020s.” The full DECC document is available at: <http://www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-capture-storage/4899-the-ccs-roadmap.pdf>.

“Independent assessment of high-capacity offshore CO₂ storage options.”

The following is from the Executive Summary of this document: “In early 2010, the Rotterdam Climate Initiative (RCI) contracted TNO Built Environment and Geosciences (TNO) to conduct an Independent CO₂ Storage Assessment (ISA) of offshore CO₂ storage sites under the Dutch North Sea, so as to support the early deployment of CCS in the Netherlands. The ISA was conducted in three phases, with this report summarizing Phase 3. Phases 1 and 2 are covered in two previous reports, one detailing the methodology employed and one presenting the results. As a whole, the ISA studies are intended to provide a comprehensive view of potential offshore CO₂ storage, with the specific goals of: ensuring that planning for CO₂ storage does not lag planning of other portions of the CCS value chain; identifying and progressing work on several potential CO₂ storage sites, to provide sufficient alternatives should individual sites prove to be unavailable on desired timelines or prove less attractive during later stage work; providing greater certainty among emitters regarding storage availability and capacity, enhancing their confidence in planning CO₂ capture projects; and providing good, harmonized data for emitters to use in their planning and in applying for funding for CCS projects. ISA Phases 1 and 2 sought to support first-mover CCS projects by providing detailed assessment of the most promising prospective CO₂ storage sites available from 2015 to 2020. In doing so, Phase 1 screened the P and Q blocks close to Rotterdam to identify the most attractive options and to ensure that no good short-term prospects had been overlooked. Phase 2 then characterized the four most attractive prospects in greater detail, including feasibility-level analysis of their technical viability, capacity, availability and cost, as well as key actions and risks to bring each site operation. ISA Phase 3 broadens Phase 1 and 2 screening to underpin longer-term CCS deployment, seeking to identify high-capacity CO₂ storage sites throughout the entire Dutch Continental Shelf, irrespective of their location and of the timing of their availability. High-capacity sites were targeted because, while ISA Phases 1 and 2 successfully identified several near-term prospects, these sites do not represent sufficient CO₂ storage capacity for the volume of CO₂ capture anticipated with the commercialization of CCS, a concern that has grown in strategic importance for emitters throughout the Netherlands with the Dutch Government’s prohibition of onshore CO₂ storage.” The full document is available at: <http://www.globalccsinstitute.com/publications/independent-assessment-high-capacity-offshore-co2-storage-options>.

“CCS RETROFIT: Analysis of the Globally Installed Coal-Fired Power Plant Fleet.”

The following is from the Scope of this Study: “A large number of coal-fired power plants are currently in operation worldwide. No complete set of technical information of individual units of this globally installed fleet exists. However, available databases cover the bulk of these plants in a relatively comprehensive manner. These databases typically include key information related to the size, age, and performance level of the vast majority of the globally installed coal-fired power plants. The following analysis is based on IEA statistical information in combination with data from the UDI World Electric Power Plants Data Base, referred to henceforth as the WEPP database. Data from the IEA are used in this study for validation of WEPP results. IEA data are typically based on direct submissions by IEA member and non-member countries, as well as the agency’s own analysis. Submitted data are often aggregated on a country-wide level. This study illustrates the size and regional distribution of the globally installed

RECENT PUBLICATIONS (CONTINUED)

coal-fired power plant fleet that is potentially relevant for CCS retrofitting. The study draws upon existing research on CCS retrofitting: several studies have estimated the effective potential for retrofitting on a regional level, often based on generic assumptions. While significant progress has been made on understanding the importance of different aspects relevant for assessing CCS retrofitting, the realistic global potential is still unclear. No detailed economic analysis is performed under this study. Instead, a range of selected criteria for coal-fired power plants is extracted from global databases and combined with fundamental economic considerations in order to provide a realistic estimate of the potential for retrofitting plants with CCS. More specifically, the following analysis illustrates the global and regional distribution – broken down to a generation unit level (or power plant “block” size) – of power generation capacities, performance levels, and plant age.” The document can be viewed from: http://www.iea.org/papers/2012/CCS_retrofit.pdf.

LEGISLATIVE ACTIVITY

Senator Bingaman Press Release, “Bingaman Bill Drives Cleaner Electricity Generation in America’s Power Sector.”

On March 1, 2012, U.S. Senator Jeff Bingaman introduced the Clean Energy Standard Act of 2012 (CES). The legislation emphasizes a market-based approach for a wide variety of electricity-generating technologies. The CES sets a national grid for clean energy and establishes a transparent framework for resources to compete. Under the plan, all generators of clean energy are

given credits based upon their carbon emissions; to be considered “clean,” a generator must be either a zero-carbon energy source or have lower carbon intensity than a modern, efficient coal plant. Allowing a wide variety of sources to be used to meet the standard enables market forces to determine the optimal mix of technologies and fuels, making it easier for new technologies to be incorporated. In addition, the CES also rewards industrial efficiency, as combined heat and power units are treated as clean generators, helping deploy this kind of efficiency and provide another source of inexpensive, clean energy. To view the CES, go to: http://www.energy.senate.gov/public/index.cfm/files/serve?File_id=b3580f37-ec8c-4698-a635-3e19f9815b9a. March 1, 2012, <http://bingaman.senate.gov/news/20120301-02.cfm>.



EVENTS

April 30-May 3, 2012, **11th Annual Carbon Capture, Utilization, and Sequestration Conference**, *David L. Lawrence Convention Center, Pittsburgh, Pennsylvania, USA*. The intent of the conference is to: provide a forum for the exchange of experience among U.S. and international scientific and engineering communities working on such technologies and systems; facilitate the necessary dialogue between technology developers/purveyors, industry, and the public on the development and deployment of viable technologies; and share experience on developing the necessary capacity within the public and private sector to move the technology base forward. More information is available at: <http://www.carbonsq.com/>.

May 9-10, 2012, **4th Carbon Capture & Storage Summit**, *Cologne, Germany*. This summit is geared toward utilities, government, oil and gas companies, and technology developers. A site visit at a state-of-the-art pre-combustion CO₂ capture pilot at an integrated gasification combined cycle (IGCC) plant (Nuon’s Willem-Alexander Power Plant) will precede the summit. For more information, visit: <http://www.wplgroup.com/aci/conferences/eu-ecc4.asp>.

May 15, 2012, **3rd Annual Brussels Carbon Capture and Storage Summit 2012**, *Le Chatelain All Suite Hotel, Brussels, Belgium*. This event will feature industry professionals, European Union (EU) policymakers, and other stakeholders debating the progress of CCS in Europe. Discussions will focus on the impact of global finances on CCS commercialization; the state of play regarding CCS funding models, including future roles for public subsidies; and future CCS applications and uses that may help drive its commercialization potential. For more information, click: http://www.eu-ems.com/summary.asp?event_id=102&page_id=744.

May 21-23, 2012, **Global Conference on Oceans, Climate, and Security**, *Seaport Hotel and World Trade Center, Boston, Massachusetts, USA*. This three-track conference will focus on mitigating the effects of potential climate change on ecosystems, as well as the security interests of the Nation. Included is a Science and Technology Needs track, which will discuss, among other topics, technologies and innovations, modeling solutions and simulations, and emerging sciences. For more information, visit: <http://www.goccs.org/>.



EVENTS (CONTINUED)

May 30-June 1, 2012, **Carbon Expo 2012**, *Koelnmesse, Cologne, Germany*. This event will include discussions on the effects of the Durban Global Climate Conference and economic forecasts for the EU and their influence on emissions trading. In addition, this expo will cover topics such as trends in the global carbon and energy markets, energy and carbon market ecosystems, and the potential market impacts CCS could have on the Clean Development Mechanism (CDM). For more information, click: http://www.carbonexpo.com/en/carbon_expo/home/index.php.

June 4-8, 2012, **7th Asia Clean Energy Forum**, *ADB Headquarters, Mandaluyong City, Philippines*. Participants of this forum will discuss successful strategies and mechanisms for accelerating access to affordable, low-carbon energy. The Pre-Forum, held the first two days of the event, includes a Regional Workshop on Greenhouse Gas Inventories and Accounting. The Main Forum, held the last three days of the event, will be made up of 32 plenary and breakout sessions. A full agenda has yet to be developed. To learn more, go to: <http://www.asiacleanenergyforum.org/>.

June 14-15, 2012, **World Climate 2012**, *Vienna University of Technology, Vienna, Austria*. This conference focuses on potential climate change, bringing together academic scientists, engineers, industry researchers, politicians, activists, and scholars to exchange research results. For more information, visit the conference website at: <http://www.vienna-conference.com/worldclimate/index.html>.

July 9-12, 2012, **2012 NETL CO₂ Capture Technology Meeting**, *Sheraton Station Square Hotel, Pittsburgh, PA, USA*. NETL's 2012 CO₂ Capture Technology Meeting will provide a public forum to present CO₂ capture technology development status and accomplishments made under NETL's IEP, Carbon Storage, and Demonstration Programs, as well as highlight DOE's Advanced Research Projects Agency-Energy (ARPA-E) CO₂ capture portfolio. In addition to covering post-, oxy-, and pre-combustion technologies, the meeting will also cover solvent, membrane, chemical looping, and compression technologies. To learn more, go to: <http://netldev.netl.doe.gov/business/event-all>.

July 12-13, 2012, **4th International Conference on Climate Change: Impact and Responses**, *The University of Washington, Washington, USA*. This conference will address a range of themes relating to potential climate change, such as natural and human causes; ecosystemic and human impacts; and technological, social, ethical, and political responses. The conference program will consist of a mix of plenary and parallel sessions. More information is available at: <http://on-climate.com/conference-2012/>.

July 23-25, 2012, **Carbon Capture and Storage: Science, Technology, and Policy**, *MIT, Cambridge, Massachusetts, USA*. This energy short course covers the science, technology, and policy aspects of CCS, focusing on the role of CCS in the climate change mitigation portfolio; the technical approaches to CO₂ capture; the science behind geologic storage, site selection, and risk evaluation; and the role of policy in establishing a market and business opportunities for CCS. For more information, visit the course website at: http://web.mit.edu/professional/short-programs/courses/carbon_capture_storage.html.

August 21-23, 2012, **2012 NETL Carbon Storage R&D Project Review Meeting**, *Sheraton Station Square Hotel, Pittsburgh, PA, USA*. The DOE Carbon Storage R&D Project Review Meeting includes more than 120 DOE-sponsored projects, covering DOE's carbon storage Infrastructure and Core R&D projects. 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/business/event-all>.

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. A formal agenda has not yet been developed; however, planning for GHGT-11 is underway. 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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