NETL

Carbon Sequestration Newsletter

A Call for Abstracts

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August 2008

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 Regional Partnerships Find New Use for Unmined Coal."**

The Midwest Geological Sequestration Consortium (MGSC) became the first of the seven Regional Carbon Sequestration Partnerships (RCSP) created by the US Department of Energy (DOE) to inject carbon dioxide (CO_2) into a coal seam in the United States in a field project in Wabash County, Illinois. The Phase II pilot project, headed by the National Energy Technology Laboratory (NETL) and the Illinois and Indiana State Geological Surveys, will test the viability of turning unmined coal deposits into a source of useable energy by extracting coalbed methane trapped in the coal. The Illinois State Geological Survey estimates that there is up to 3.6 billion tons of storage capacity in the Illinois Basin, with more than 10 trillion cubic feet of recoverable coalbed methane from the unmined bituminous coal seams. The Wabash County project eliminates the need for dewatering, a process where water is pumped out of the coal to extract gas; dewatering is not conducive to carbon sequestration because it creates a low pressure environment that reduces CO_2 storage capacity. To avoid this scenario, MGSC scientists pump trucked-in CO_2 through a heater and inject it as a gas, which increases the underground pressure, allowing CO_2 to absorb onto the surface of the coal and displace methane. However, this method results in coal swelling, which has the potential to reduce the injection rate of CO_2 and limit the overall amount that can be injected and stored in the coal seam. MGSC scientists circumvent this challenge by injecting the CO_2 in eight to 24-hour cycles to give the CO_2 adequate time to absorb onto the coal, reduce well pressure, and clear any possible congestion. Researchers anticipate up to 250 tons of CO_2 will be injected over three months while field testing the new injection approach. This project is one of six small-scale field tests being conducted by MGSC during the Validation Phase of the RCSP program; other field tests involve injecting CO_2 for enhanced oil recovery (EOR) or into saline formations a mile or more below the surface. To learn more about DOE's RCSP Program, go to: http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html, or click: http://www.sequestration.org/ for more information about MGSC. July 17, 2008, http://www.fossil.energy.gov/news/techlines/2008/08026-Regional_Partnerships_Tap_Unmined_Coal.html.

Sequestration in the News

***Kentucky Post,* "Ky. Partners To Research CO_2 Storage," and *Courier-Journal.com,* "Kentucky Carbon Storage Test Partnership Formed."**

The Western Kentucky Carbon Storage Foundation has teamed up with the Kentucky Geological Survey to improve the long-term CO_2 storage opportunities within the state. The $7.8 million research project will drill more than 8,000 feet deep into the Knox and Mount Simon geological formations in Hancock County to test their ability to store CO_2. While the Kentucky Geological Survey will lead the project research with other state agencies, the Western Kentucky Carbon Storage Foundation will provide technical assistance as well as most of the funding. Drilling

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 (Continued)

will begin in late 2008 and CO_2 injection is expected to occur in early 2009. The non-profit Western Kentucky Carbon Storage Foundation was formed by three private partners – Peabody Energy, ConocoPhillips, and E.ON U.S. – as a result of a mandate by the Kentucky legislature. To read the Governor's official press release, go to: http://governor.ky.gov/pressrelease.htm?PostingGUID=%7B5B8EE408-5CD8-46B1-96F9-83920FC3BE8A%7D. July 1, 2008, http://www.kypost.com/content/news/commonwealth/story.aspx?content_id=fc2102ee-f8c3-4618-b275-607e1c10c85e, and June 30, 2008, http://www.courier-journal.com/apps/pbcs.dll/article?AID=/20080630/BUSINESS/80630034.

***Boston.com*, "ND Utility to Unveil Plans to Capture CO_2," and *Greenwire*, "N.D. Utility Plans to Capture CO_2 at Power Plant."**

Basin Electric Power Cooperative and Powerspan Corporation plan to capture 1 million tons of CO_2 annually from one of the two units at the 900-megawatt Antelope Valley Station in central North Dakota. Powerspan's post-combustion technology consists of an ammonia-based solution that captures CO_2 from a power plant's flue gas and releases it in a form that is ready for compression, safe transportation, and geological storage. Basin Electric's goal is to use the technology to capture and remove the amount of CO_2 equivalent to that emitted by a 120-megawatt power plant. The CO_2 will then be piped to Canada where it will be used for EOR. The project is expected to begin in late 2009 and end in 2012. To read the official press release, go to: http://www.basinelectric.com/News_Center/News_Releases/Basin_Electric%2C_Powerspan_brin.html. June 17, 2008, http://www.boston.com/news/local/new_hampshire/articles/2008/06/17/nd_utility_to_unveil_plans_to_capture_c02/?page=full, and June 18, 2008, http://www.eenews.net/Greenwire/2008/06/18/13/.

***Reuters*, "Enhance Plans Alberta Carbon Dioxide Pipeline," and *globeandmail.com*, "Shell Launches Carbon-Capture Project."**

The Government of Alberta will invest $1.98 billion ($2 billion Canadian) over the next five years to launch several large-scale, industry run carbon capture and storage (CCS) projects. Royal Dutch Shell PLC, in one of the first initiatives under the new plan, will begin testing for ways to capture and store CO_2 at its Scotford Upgrader near Fort Saskatchewan, Alberta. Shell's project, Quest, would reduce emissions from their oil sands operations by 1 million tonnes a year beginning in 2015. The Scotford mine and upgrader currently produces more than 1.75 million tonnes of emissions annually. Enhance Energy Incorporated plans to build Alberta's first major CO_2 pipeline system in central Alberta that will capture GHGs from a planned oil sand upgrader and nitrogen plant and transport them 149 miles (240 kilometers) to oilfields for EOR. Enhance's $300 million CO_2 pipeline will initially have a capacity of 5,000 tonnes per day and increase to 25,000 tonnes per day over time. Regulatory applications are planned for the spring of 2009 and project start-up is expected in 2011. A video of Alberta Premier Ed Stelmach's announcement is available at: http://www.premier.alberta.ca/media/mediaPage.cfm. July 10, 2008, http://www.reuters.com/article/environmentNews/idUSN1020839120080710,

Sequestration in the News (Continued)

and July 9, 2008, http://www.theglobeandmail.com/servlet/story/LAC.20080709.RSHELL09/TPStory/Business. (Subscription required).

***Bloomberg*, "Australia Agency Captures Carbon from Power Plant Gas," and *ClimateWire*, "Australia Successfully Tests Gas-Trapping Method."**

Australia's national science agency, the Commonwealth Scientific and Industrial Research Organization (CSIRO), successfully captured CO_2 at the coal-fired Loy Yang power plant in Victoria. According to CSIRO, the trial technology could capture as much as 1,000 metric tons of CO_2 per year, which is more than 85 percent of total emissions. This marks the first time post-combustion capture technology has been successfully applied in the Southern Hemisphere. The project is a joint collaboration between the Australian Government, Loy Yang Power, and International Power PLC. Australia generates more than 80 percent of its energy from coal. To learn more about CSIRO's research, visit: http://www.csiro.au/science/ps3m.html. July 9, 2008, http://www.bloomberg.com/apps/news?pid=20601081&sid=azRqQQ4pghr0#, and July 10, 2008, http://www.eenews.net/climatewire/print/2008/07/10/8.

Announcements

NETL Releases Annual Accomplishments Report.

NETL released its annual Accomplishments Report showcasing its successes in research and technology during the past fiscal year. Also included are sections about technology transfer and awards received in the course of achieving NETL's primary goal – the successful commercialization of advanced technologies to benefit the United States. The complete accomplishment report is available at: http://www.netl.doe.gov/publications/others/accomp_rpt/accomp_fy07.pdf.

Teacher Training Opportunity.

The Keystone Center for Education is holding a teacher training, titled "CSI: Climate Status Investigations," in southeastern New Mexico on September 25-26, 2008. Hosted by the Southwest Regional Partnership (SWP), the training will use hands-on, inquiry-based activities to help teachers explore the global climate change issue with their students by examining economic, environmental, and social factors involved in the climate change debate. To view the online brochure, go to: http://www.southwestcarbonpartnership.org/_Resources/PDF/NM%20Brochure.pdf.

Call for Abstracts.

Organizers for the "Climate Change: Global Risks, Challenges, and Decisions" conference, scheduled for March 10-12, 2009, in Copenhagen, Denmark, are requesting original research into topics relevant to the conference themes. Topics include: CO_2 sinks and emissions; CCS technologies; and approaches to cap-and-trade programs. The deadline for abstract submission is September 1, 2008. To submit an abstract, go to: https://www.ics-online.com/ei/getdemo.ei?id=370&s=_2P00V60DO.

EAGE Workshop.

The European Association of Geoscientists and Engineers (EAGE) is hosting its first CO_2 Geological Storage (CGS) workshop on September 29-30, 2008, at the Hungarian Academy of Sciences in Budapest, Hungary. The goal of the workshop is for EAGE, as well as the growing community of European researchers focusing on improving the capturing and storage of CO_2, to assess the progress of CCS. More information is available at: http://www.eage.org/events/index.php?evp=1248&ActiveMenu=3&Opendivs=s2&eventid=71.

IEA Workshop.

The International Energy Agency (IEA), the International Emissions Trading Association (IETA), and the Electric Power Research Institute (EPRI) are hosting the 8th Annual Workshop of Greenhouse Gas Emission Trading in Paris, France, on September 22-23, 2008. Attendees of the workshop will be presented with discussion topics such as: carbon market news; GHG emissions trading schemes; GHG policy and offsets; and a session on CO_2 cost containment mechanisms. To learn more, go to: http://www.iea.org/Textbase/work/workshopdetail.asp?WS_ID=381.

Science

***Science Daily*, "Whales Set To Chase Shrinking Feed Zones," and *Reuters*, "Retreating Antarctic Sea Ice Threatens Southern Whales."**

Research conducted by the World Wildlife Fund (WWF) found that endangered migratory whales may be faced with shrinking Antarctic foraging zones that will contain less food and will be farther away. WWF's research, which was summarized in the report titled, "Ice breaker: Pushing the boundaries for whales," says that predicted global warming levels over the next 40 years could lead to a 30 percent decline of winter sea ice coverage in key areas of the Southern Ocean. The result may force migratory whale species to travel 144 to 360 miles (200 to 500 kilometers) farther south to find "frontal" zones that contain their sea ice-dependent, primary food source – krill. As the amount of sea ice drops, the abundance of krill is expected to as well, reducing the quantity of food for whales in feeding areas. Also, due to the distance of the migration paths, the duration of the feeding season could be reduced. Migratory whale species, including blue whales, Earth's largest living creatures, and humpback whales, which were recently near-extinction due to commercial whaling, have the potential to be affected. WWF's research is based on the assumption that average temperatures will rise by two degrees Celsius (3.6 [degrees Fahrenheit]) by 2042. To view WWF's report, go to: http://assets.panda.org/downloads/english_final_proof_final.pdf. July 1, 2008, http://www.sciencedaily.com/releases/2008/06/080629143936.htm, and June 19, 2008, http://uk.reuters.com/article/environmentNews/idUKL1943431320080619.

***Rocky Mountain News*, "North Pole Soon May Be Ice-Free," and *National Geographic*, "North Pole May Be Ice-Free for First Time This Summer."**

Scientists at the National Snow and Ice Data Center (NSIDC) at the University of Colorado in Boulder believe the ice at the North Pole could be completely melted by September 2008, before refreezing during the Arctic winter. NSIDC believes GHGs have helped elevate temperatures two to seven degrees Fahrenheit across the Arctic. Last September, the part of the Arctic Ocean that was ice-free opened up a new area of water the size of California and Texas combined. The melting has accelerated at such levels in recent years that scientists predict the entire Arctic Ocean could be ice-free for at least one day by 2020 – 50 years sooner than originally predicted. Satellite images show that the area around the North Pole is mostly made up of first-year ice – thin, new ice that forms each year and is more susceptible to melting during warmer months than multiyear ice, which is thicker and denser. According to researchers, sea ice is crucial to the global climate system, as without it the Earth loses its capacity to regulate temperature via the ocean currents. Scientists have been tracking the recession of sea ice in the Arctic Sea for 29 years using satellite data. The North Pole has never been ice-free in its recorded history. To view NSIDC's website, which offers daily Arctic sea ice data, visit: http://www.nsidc.org/arcticseaicenews/. June 28, 2008, http://www.rockymountainnews.com/news/2008/jun/27/north-pole-may-be-ice-free-september/, and June 20, 2008, http://news.nationalgeographic.com/news/2008/06/080620-north-pole.html.

Policy

***EPA News Release*, "EPA Lays Groundwork for Promising Technologies to Help Mitigate Climate Change," and *Oil and Gas Journal*, "EPA Proposes Rules for Carbon Dioxide Storage."**

The US Environmental Protection Agency (EPA) has proposed regulations for the long-term, underground storage of CO_2. The proposed regulations would establish a new class of injection wells under EPA's existing Underground Injection Control (UIC) program and would update the Safe Drinking Water Act (SDWA). Under the proposed rules, a new category of injection well, Class VI, would be established to monitor the long-term, geologic storage of CO_2. The proposed regulation will build on the existing UIC program by including requirements to ensure wells are properly located, constructed, tested, monitored, and closed with proper funding. EPA is requesting public comments on the proposed rule for 120 days following its release, and a final rule is anticipated in late 2010 or early 2011. EPA is working with DOE on carbon sequestration research and development and monitors the progress of sequestration projects throughout the United States, including those initiated by DOE's RCSPs. The proposed rule results from EPA's coordination with DOE to monitor the progress of pilot-scale geologic storage projects and seven workshops held since 2005 to discuss various technical issues associated with geologic storage. To view the proposed rule, go to: http://www.epa.gov/safewater/uic/pdfs/prefr_uic_co2rule.pdf. To listen to a sound bite from EPA Administrator Stephen L. Johnson, click: http://www.epa.gov/adminweb/multimedia/newscontent/2008-07-15-oa/audio/071508.mp3. July 15, 2008, http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/d35b72dfe481043b85257487005e47cd!OpenDocument, and July 15, 2008, http://www.ogj.com/display_article/334413/7/ONART/none/GenIn/1/EPA-proposes-rules-for-carbon-dioxide-storage/.

"Environmental bonds and the challenge of long-term carbon sequestration."

The potential to capture carbon from industrial sources and dispose of it for the long-term, known as carbon capture and storage (CCS), is widely recognized as an important option to reduce atmospheric carbon dioxide emissions. Specifically, CCS has the potential to provide emissions cuts sufficient to stabilize greenhouse gas levels, while still allowing for the continued use of fossil fuels. In addition, CCS is both technologically feasible and commercially viable compared to alternatives with the same emissions profile. Although the concept appears to be solid from a technical perspective, initial public perceptions of the technology are uncertain. Moreover, little attention has been paid to developing an understanding of the social and political institutional infrastructure necessary to implement CCS projects. In this paper [the authors] explore a particularly dicey issue—how to ensure adequate long-term monitoring and maintenance of the carbon sequestration sites. Bonding mechanisms have been suggested as a potential mechanism to reduce these problems (where bonding refers to financial instruments used to

Policy (Continued)

ensure regulatory or contractual commitments). Such mechanisms have been successfully applied in a number of settings (e.g., to ensure court appearances, completion of construction projects, and payment of taxes). The paper examines the use of bonding to address environmental problems and looks at its possible application to nascent CCS projects. [The authors] also present evidence on the use of bonding for other projects involving deep underground injection of materials for the purpose of long-term storage or disposal. **David Gerard and Elizabeth J. Wilson**, *Journal of Environmental Management*, Available online July 10, 2008, doi:10.1016/j.jenvman.2008.04.005, http://www.sciencedirect.com/science/article/B6WJ7-4SYDB0K-1/1/6a8552ff2a455bb734c35f53553dbef0. (Subscription may be required.)

Geology

"The role of optimality in characterizing CO_2 seepage from geologic carbon sequestration sites."

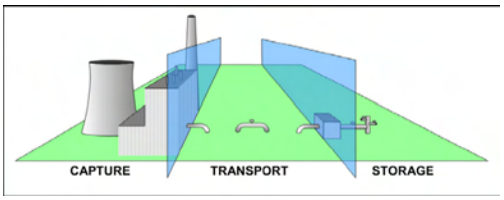
Storage of large amounts of carbon dioxide (CO_2) in deep geologic formations for greenhouse-gas mitigation is gaining momentum and moving from its conceptual and testing stages toward widespread application. In this work [the authors] explore various optimization strategies for characterizing surface leakage (seepage) using near-surface measurement approaches such as accumulation chambers and eddy covariance towers. Seepage characterization objectives and limitations need to be defined carefully from the outset especially in light of large natural background variations that can mask seepage. The cost and sensitivity of seepage detection are related to four critical length scales pertaining to the size of the: (1) region that needs to be monitored; (2) footprint of the measurement approach, (3) main seepage zone; [and] (4) region in which concentrations or fluxes are influenced by seepage. Seepage characterization objectives may include one or all of the tasks of detecting, locating, and quantifying seepage. Each of these tasks has its own optimal strategy. Detecting and locating seepage in a region in which there is no expected or preferred location for seepage nor existing evidence for seepage requires monitoring on a fixed grid, e.g., using eddy covariance towers. The fixed-grid approaches needed to detect seepage are expected to require large numbers of eddy covariance towers for large-scale geologic CO_2 storage. Once seepage has been detected and roughly located, seepage zones and features can be optimally pinpointed through a dynamic search strategy, e.g., employing accumulation chambers and/or soil-gas monitoring. Quantification of seepage rates can be done through measurements on a localized fixed grid once the seepage is pinpointed. Background measurements are essential for seepage detection in natural ecosystems. Artificial neural networks are considered as regression models useful for distinguishing natural system behavior from anomalous behavior suggestive of CO_2 seepage without need for detailed understanding of natural system processes. Because of the local extrema in CO_2 fluxes and concentrations in natural systems, simple steepest-descent algorithms are not effective and evolutionary computation algorithms are proposed as a paradigm for dynamic monitoring networks to pinpoint CO_2 seepage areas. **Andrea Cortis, Curtis M. Oldenburg and Sally M. Benson**, *International Journal of Greenhouse Gas Control*, Available online June 9, 2008, doi:10.1016/j.ijggc.2008.04.008, http://www.sciencedirect.com/science/article/B83WP-4SPSPRR-1/1/7bb902e2fa88083c81e3249fe1d63517. (Subscription may be required.)

"Assessing geochemical carbon management."

The challenge of reversing rising atmospheric CO_2 concentrations is growing with the continued expansion of CO_2-emitting energy infrastructure throughout the world and with the lack of coordinated, effective measures to manage and reduce emissions. Given this situation, it is prudent for society to explore all potential carbon management options, including those with seemingly low probability for success. Recent initiatives for advancing and enhancing carbon storage options have focused primarily on the physical trapping of CO_2 in underground geologic formations and on the biological uptake of CO_2; less attention has been given to approaches that rely primarily on geochemical reactions that enhance transformation of CO_2 gas into dissolved or solid phase carbon by liberating cations to neutralize carbonic acid. This paper provides a structured review of the technical status of these geochemical approaches, and also presents a simple framework for assessing the potential and limitations of various proposed geochemical approaches to assist prioritizing future research in this area. Despite major limitations, geochemical approaches have unique potential to contribute to CO_2 reductions in ways that neither physical nor biological carbon storage can by allowing for the direct removal of CO_2 from the atmosphere with minimal requirements for integrating with existing infrastructure. Recognizing the severity and urgency of the need for carbon management options, [the authors] argue for an increase in research activity related to geochemical approaches to carbon management. **Jennie C. Stephens and David W. Keith**, *Climatic Change*, Available online June 24, 2008, DOI:10.1007/s10584-008-9440-y, http://www.springerlink.com/content/85838m000280xl77/?p=79160e5a36774749841cb0ee51c24be1&pi=5. (Subscription required.)

Technology

"Impurity impacts on the purification process in oxy-fuel combustion based CO_2 capture and storage system."



Based on the requirements of CO_2 transportation and storage, non-condensable gases, such as [oxygen (O_2)], [nitrogen (N_2)] and [Argon (Ar)] should be removed from the CO_2-stream captured from an oxy-fuel combustion process. For a purification process, impurities have great impacts on the design, operation and optimization through their impacts on the thermodynamic properties of CO_2-streams. [Study results show that the increments of impurities will increase the energy consumption of purification; and decrease the CO_2 purity of the separation product and CO_2 recovery rate.] In addition, under the same operating conditions, energy consumptions have different sensitivities to the variation of

Technology (Continued)

the impurity mole fraction of feed fluids. The isothermal compression is more sensitive to the variation of [sulfur dioxide (SO_2)]; while the isentropic compression is more sensitive to the variation of [Argon]. In the flash system, the energy consumption of condensation is more sensitive to the variation of [Argon]; but in the distillation system, the energy consumption of condensation is more sensitive to the variation of SO_2, and CO_2 purity of separation is more sensitive to the variation of SO_2. **H. Li, J. Yan, J. Yan and M. Anheden**, *Applied Energy*, Available online July 7, 2008, doi:10.1016/j.apenergy.2008.05.006, http://www.sciencedirect.com/science/article/B6V1T-4SXRYH3-1/1/ad9be262beb4584b3310675be6eae250. (Subscription may be required.)

"Geochemical effects of CO_2 sequestration in sandstones under simulated in-situ conditions of deep saline aquifers."

The geochemical effects of brine and supercritical CO_2 ($SCCO_2$) on reservoir rocks from deep (1500 to 2000 [meters]) saline aquifers were examined via experimental simulation at in-situ conditions. Dry sandstone samples were mounted in a triaxial cell and autoclave system, evacuated, and saturated with 1 M [sodium chloride (NaCl)] solution. The brine-rock system was allowed to react at 30 [millipascals (MPa)] confining pressure, 15 MPa pore fluid pressure, and 60 [degrees Celsius] while $SCCO_2$ was injected at a pressure gradient of 1-2 MPa. The experiment was conducted for a period of 1496 [hours], during which fluids were periodically sampled and analyzed. The pH measured in partially degassed fluid sample at 25 [degrees Celsius] decreased from a starting value of 7.0 to 4.3 (9 days) and finally 5.1 after saturation with $SCCO_2$. Fluid analyses indicate that most of the major [(e.g. calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn)] and trace elements [(e. g. strontium (Sr), barium (Ba), lead (Pb)] of the sandstone increase in concentration during the reaction with brine and $SCCO_2$. These results are supported by scanning electron microscopy which indicated dissolution of dolomite cement, [potassium] feldspar, and albite. In addition to dissolution reactions the formation of montmorillonite was observed. By adjusting surface area and reaction rates of dissolution and precipitation, geochemical modeling of the experiments could reproduce long-term trends in solution chemistry and indicated limited rates of dissolution as the system remained strongly undersaturated with most minerals, including carbonates. The geochemical models could not account for decreases in concentration of some elements, changes in solution composition resulting from changes in imposed pressure gradient, and the observed Ca/Mg and [silicon/aluminum (Si/Al)] ratios in solution. **M. Wigand, J.W. Carey, H. Schütt, E. Spangenberg and J. Erzinger,** *Applied Geochemistry*, Available online June 25, 2008, doi:10.1016/j.apgeochem.2008.06.006, http://www.sciencedirect.com/science/article/B6VDG-4SV5V50-1/1/a245ece039ba1a57db9662ffbe1a1dd4. (Subscription may be required.)

Terrestrial/Ocean

"Impacts of long-term and recently imposed tillage practices on the vertical distribution of soil organic carbon."

Although many studies suggest that no-tillage (NT) increases soil organic carbon (SOC) within the soil profile relative to mouldboard ploughing, other studies indicate that no net change occurs. The latter studies suggest that NT only stratifies the SOC, where a near-surface increase in SOC is offset by a concomitant decrease in the subsurface. [The authors] examined the SOC distribution and stocks in a cool, humid Brookston clay (Typic Argiaquoll) soil under four soil management systems with a corn–soybean rotation. The objectives of this study were to compare the profile distribution and total amount of SOC under long-term (21 years) NT and mouldboard plough (MP) tillage with the changes that occur over 8 years when 13-years continuous NT is converted to MP, and when 13-years continuous MP is converted to NT. In the top 5 cm of soil, the long-term NT management accumulated greater SOC compared with the long-term MP treatment. However, this near-surface increase was offset by lower SOC concentrations in the 10–20 cm depth, resulting in similar total amounts of SOC stored in 0–20 cm for both long-term NT and MP. The SOC stratification that existed after 13 years of NT management was eliminated with one mouldboard ploughing operation, however the total SOC content in the plough layer of the new-MP treatment remained relatively constant over the subsequent 8 years. Soil organic carbon stratification was evident in the new no-tillage treatment 3 years after the cessation of tillage. The continuous build-up of SOC in the surface of new-NT soils was associated with no change in the total amount of SOC in the plough layer relative to long-term NT. This implies that the diminution of SOC in the 10–20 cm depth was at the same rate as the accumulation of SOC in the 0–5 cm depth. Although there was no net effect of tillage on total carbon stocks in this fine-textured soil, SOC stratification required several years to build-up after adoption of NT, but only a single year to destroy under MP. **X.M. Yang, C.F. Drury, W.D. Reynolds and C.S. Tan**, *Soil and Tillage Research*, Available online July 1, 2008, doi:10.1016/j.still.2008.05.003, http://www.sciencedirect.com/science/article/B6TC6-4SWG0BG-1/1/1d80d2e3bb077aaa96ec5a66b6ccf7ff. (Subscription may be required.)

Trading

Carbon Market Update, July 17, 2008	
CCX-CFI 2008 ($/tCO$_2$) $4.00 (Vintage 2008)	EU ETS-EUA DEC 2008 ($/tCO$_2$) $40.84 (Converted from € to US$)

***ClimateWire*, "Northeast Carbon Market to Begin Sept. 25." and *Regional Greenhouse Gas Initiative Press Release*, "RGGI States Announce Preliminary Release of Auction Application Materials."**

The 10-state Regional Greenhouse Gas Initiative (RGGI) will begin a cap-and-trade system in late September that will allow power plants to purchase GHG emission credits from a regional auction. Technical materials were released on July 11 by RGGI outlining the process and requirements for market participants interested in bidding in the auction. The materials provide a preview of applications and procedures for the initial auction, which is set to take place September 25, 2008; the next two auctions are scheduled for December 17, 2008, and March 19, 2009. The September auction will make 12.5 million allowances available, or 25 percent of the total GHG emissions cap for 2009. Companies in Connecticut, Maine, Maryland, Massachusetts, Rhode Island, and Vermont are expected to participate in the selling of emissions at the first auction, with companies in Delaware, New Jersey, New Hampshire, and New York eligible to buy. All RGGI-affiliated states, dependent upon completion of their rule-making proceedings, are expected to be authorized to fully participate in RGGI by the March 2009 auction. Several advance trades have already taken place in the range of $5 to $10 per ton; the reserve price is $1.85 per ton. In 2005, RGGI agreed to cap GHG emissions at 50.6 million metric tons a year from 2009 to 2014, and then reduce the cap by 2.5 percent annually through 2018. The purpose of the cap-and-trade system is to reduce overall GHG emissions by 10 percent by 2020. July 14, 2008, http://www.eenews.net/climatewire/print/2008/07/14/4, and July 11, 2008, http://www.rggi.org/docs/20080711news_release.pdf.

Recent Publications

"Returns to Scale in Carbon Capture and Storage Infrastructure and Deployment."
The degree to which carbon capture and storage (CCS) is deployed will be partly determined by the returns to scale of the technological system that captures, transports, and stores carbon dioxide (CO_2). This technological system spatially connects the organization of CO_2 point sources with the organization of geologic CO_2 storage reservoirs. These point sources and storage reservoirs are heterogeneous in the amount of CO_2 that they produce or store and in the costs of capturing or storing CO_2, and the associated cost structures interact to determine the returns to scale for the entire coupled system. The SimCCS cost-minimizing geospatial deployment model is used to deploy CCS for a variety of combinations of CO_2 sources and injection reservoirs and determine the returns to scale for CCS deployment and unravel the determinants thereof. SimCCS minimizes the total costs of the entire capture, transport, and storage system by simultaneously determining how much CO_2 is captured from each source, how much CO_2 is stored in each storage reservoir, and assigning CO_2 flows through pipeline networks that include trunk distribution lines that are routed to minimize the influence of the social and physical topography. The returns to scale for the entire CCS system involves the interaction of the cost structures for each link in the CCS chain - capture at the source, transport through the network, and storage at the reservoir - each of which is modeled with cost structures that allow for increasing returns to scale. While it is possible that these cost structures can reinforce each other, the variability of source and reservoir costs and capacities interact with the spatial organization of sources and reservoirs to limit and ultimately reverse the returns to scale for CCS as the scale of the system expands. The complete discussion paper is available at: http://belfercenter.ksg.harvard.edu/files/Bielicki_CCSReturnsToScale.pdf.

"Carbon Capture and Storage: A Solution to the Problem of Carbon Emissions."
Carbon capture and storage (CCS) is a technically feasible solution for mitigating global warming. It does so by capturing carbon dioxide from large single-point sources and storing it underground rather than allowing it to be released into the atmosphere. In September 2007, The Boston Consulting Group analyzed global sources of carbon dioxide and determined that if the CCS were implemented at the 250 largest stationary emitters worldwide, carbon dioxide emissions would be reduced by 4 Gton per year – 25 percent of the total from all stationary sources worldwide. Implementing CCS at the 1,000 largest stationary sources would reduce emissions by 8 Gton per year – a 50 percent reduction. Over time, the benefits of CCS would grow. By 2030, its use at the 1,000 largest stationary sources would reduce emissions by 15 Gton per year. That would represent a reduction of more than one-third of the 42 Gton of global emissions from all sources estimated for 2030 – a significant contribution to solving the global warming problem. The BGG analysis also looked at how to pay for CCS. [The authors] concluded that by 2030, assuming a stable global market price of [$47.09 (€30)] per ton, carbon trading would offset the likely cost of capturing, transporting, and storing the carbon dioxide emitted by stationary fossil-fuel-burning sources in Europe and North America. Today, however, it would cost a minimum of about [$70.64 (€45)] per ton to implement CCS at these facilities. [The authors'] estimates indicate that financing the technological advancements that will lower the cost of CCS to the threshold of [$47.09 (€30)] per ton will require approximately [$793 billion (€500 billion)] in government subsidies and company investments through 2030, most of which could be recovered through the trading of carbon certificates. Although the required government share of subsidies is difficult to predict, [the authors] expect it to be no more than about [$158.6 billion (€100 billion)], or one-fifth of the total estimated cost. To read the complete publication, go to: http://www.bcg.com/impact_expertise/publications/files/Carbon_Capture_and_Storage_Jun_2008.pdf.

Recent Publications (Continued)

"Six Thousand Feet Under: Burying the Carbon Problem."
The challenge of reducing emissions to tackle climate change is one of the toughest faced by modern economies. The political consensus is that carbon emissions [need to be reduced by 60 to 80 percent] by 2050 and yet, instead of falling, they continue to rise. Worldwide emissions from fossil fuels are expected to rise 62 [percent] by 2030, with two thirds of that in India and China. Carbon Capture and Storage (CCS) is a term for a set of technologies which could tackle part of this problem by capturing up to 95 [percent] of the carbon dioxide (CO_2) released by coal and gas fired power stations. The CO_2 is captured from the station emissions, liquefied for transport by ship or pipeline before being finally stored underground in depleted oil and gas fields, coal seams or deep saline aquifers. [The authors'] report finds that: (1) fitting CCS equipment to coal and gas power stations could slash global emissions by between 28-50 [percent] by 2050; (2) fitting CCS to UK plants could cut emissions by 20 [percent] by 2020; and (3) these emission reductions could be extremely affordable. If all large gas and coal fuelled electricity plants in the UK were fitted with commercially viable CCS, the additional cost of electricity would be around $118.77 (£60) per household per year. To view the complete report, visit: http://www.policyexchange.org.uk/images/libimages/390.pdf.

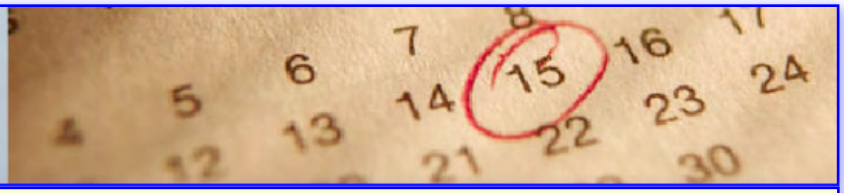
Legislative Activity

***ClimateWire*, "Wash. Sets CO_2 Emissions for New Power Plants…," and *Washington Department of Ecology News Release*, "Adopting New Rules, Washington Continues Leadership in Limiting Climate Change."**

The state of Washington set standards for emissions performance on all new electrical generation, as well as adopted guidelines for CCS. The emission standards, which immediately went into effect for power plants generating less than 350 megawatts, restrict facilities to the average emissions of combined-cycle natural gas turbine plants, or 1,100 pounds of CO_2 per megawatt-hour; the standard for larger power plants went into effect July 25, 2008. Both emission standards only apply to long-term power contracts of five or more years and impose a $1.60 charge per metric ton of CO_2, with discounts for co-generation and CO_2 sequestration. Emissions that are permanently sequestered are not counted when determining if a generating facility meets the emissions performance standard. The CCS guidelines address safety, public hearings, and post-closure monitoring issues. However, the guidelines do not cover long-term liability or how to settle property rights issues, nor do they estimate the state's storage capacity for CO_2. The legislation is available at: http://www.ecy.wa.gov/laws-rules/wac173407_218/x0711a.pdf. July 8, 2008, http://www.eenews.net/climatewire/rss/2008/07/08/4, and June 30, 2008, http://www.ecy.wa.gov/news/2008news/2008-180.html.

***Sun Advocate*, "Utah, North Dakota Senators Introduce Federal Clean Coal Technology Legislation."**

On June 26, Senators Orrin Hatch of Utah and Kent Conrad of North Dakota unveiled Federal legislation to expand the use of clean coal technology in the United States. The Carbon Reduction Technology Bridge Act of 2008, if passed by Congress, would promote private research into clean coal technology by creating tax incentives. Included in the bill are the following incentives: a tax credit for installing CCS equipment equivalent to 30 percent of the qualified investment for a taxable year; tax credits of $30 per metric ton of CO_2 injected and stored by the taxpayer; tax credits of $20 per metric ton of CO_2 compressed and transferred for storage; and tax credits of $15 per metric ton of CO_2 injected for EOR by the taxpayer. The senators believe these incentives are necessary to achieve energy independence because coal is used to generate roughly half of all electricity produced in the United States. The legislation is available at: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:s3208is.txt.pdf. To read the official press release, go to: http://hatch.senate.gov/public/index.cfm?FuseAction=PressReleases.View&PressRelease_id=c6f88aae-1b78-be3e-e089-3a5fa28d5a33. July 3, 2008, http://www.sunadvocate.com/index.php?tier=1&article_id=13492.



Events

August 6-8, 2008, **Energy Security and Climate Change: Issues, Strategies, and Options**, *Sofitel Centara Grand Bangkok, Bangkok, Thailand*. This conference provides a venue for discussions on energy security and climate change. Topics to be examined include: advanced energy resources technologies, such as carbon sequestration; climate trends and mitigation measures; and post-Kyoto Protocol strategies. To view the conference website, go to: http://www.serd.ait.ac.th/escc/.

August 13-15, 2008, **COAL-GEN**, *Kentucky International Convention Center, Louisville, Kentucky, USA*. Entering its eighth year, this conference covers the latest topics affecting the design, upgrading, operation, and maintenance of coal-fueled power plants. Attendees also will have the opportunity to take a tour of a local power plant. To view the conference website, which contains a downloadable brochure, click: http://cg08.events.pennnet.com/fl/index.cfm.

Events (Continued)

August 18-20, 2008, **4th Australia-New Zealand Climate Change Business Conference**, *SKYCITY Convention Centre, Auckland, New Zealand*. This conference will focus on the risks and opportunities posed to businesses by climate change. Sessions discussing voluntary carbon markets, regulating carbon markets, carbon market compliance, a post-Kyoto roadmap, and carbon sequestration developments will be included. To browse the conference website, which includes a draft agenda, visit: http://www.climateandbusiness.com/program.html.

September 16-17, 2008, **Carbon Markets USA**, *Kellogg Conference Hotel, Washington DC, USA*. The second edition of Carbon Markets USA brings together key players in the US carbon industry to examine and explore the latest market developments and methods to accelerate market growth. Attendees have the opportunity to question experts on carbon trading, carbon offsetting, CCS, and voluntary carbon markets. To view the conference website, go to: http://greenpowerconferences.com/carbonmarkets/carbonmarkets_USA_2008.html.

September 24-25, 2008, **US Carbon Finance Forum**, *The Metropolitan Club, New York City, New York, USA*. This forum unites investors with representatives from finance, industry, government bodies, and international organizations to examine how carbon legislation will affect stakeholders in the United States. More than 40 high-level speakers will lead the discussion about existing opportunities in carbon markets worldwide. To learn more, visit the conference website: http://www.uscarbonfinance.com/index.htm.

September 29-October 2, 2008, **The 25th Annual International Pittsburgh Coal Conference**, *The Westin Convention Center, Pittsburgh, Pennsylvania, USA*. This conference focuses on the development of future coal-based energy plants as they strive to achieve near-zero emissions of pollutants while reducing costs. Some of the topics to be discussed: combustion, gasification, and environmental control technologies; synthesis of liquid fuels; and coal chemistry. A complete program outline is available at: http://www.engr.pitt.edu/pcc/2008%20Conference.htm#SESSIONS%20and%20TOPICS.

October 6-17, 2008, **Carbon Trading**, *The Hospital de los Venerables, Seville, Spain*. This event will help train attendees interested in participating in the carbon market. Some of the topics to be discussed include: understanding the principles of cap-and-trade programs; assessing the legal and political implications of the carbon markets; and understanding carbon in the supply chain. To learn more about this training event, click: http://www.carbon-training.com/.

October 7-10, 2008, **Carbon Finance Asia 2008**, *Grand Hyatt Singapore, Singapore*. The second edition of this event aims to facilitate the meeting of buyers and sellers of certified emissions reductions (CER) across Asia. Some of the key topics to be covered include: clean energy development: challenges and prospects; clean energy development through regulatory support; and pricing, trading, and exchange of carbon credits. To view a detailed schedule of the event, visit: http://www.terrapinn.com/2008/carbon/index.stm.

November 16-20, 2008, **9th International Conference on Greenhouse Gas Technologies**, *The Omni Shoreham Hotel, Washington, DC, USA*. The Michigan Institute of Technology and IEA Greenhouse Gas R&D Programme have teamed with DOE to present this conference series on GHG mitigation technologies. Held every two years, this conference has become a focal point of CCS efforts. Attendees will be presented with 50 technical sessions that examine absorption processes for CO_2 capture, treating flue gas from oxyfuel combustion systems, and strategies for CO_2 transport infrastructure development. To learn more, click: http://mit.edu/ghgt9/index.html.

For subscription details...

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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.