



# Carbon Sequestration Newsletter

SEPTEMBER 2011

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designed to store approximately 2,500 metric tons of carbon dioxide (CO<sub>2</sub>) per day in the saline Mount Simon Sandstone formation at depths around 7,000 feet. Researchers estimate that the formation has the potential to store all of the more than 250 million tons of CO<sub>2</sub> generated by industry each year in the Illinois Basin region. The injected CO<sub>2</sub> is a byproduct from processing corn into fuel-grade ethanol at Archer Daniels Midland Company's (ADM) biofuels plant near the storage site in Decatur, Illinois. The Illinois-ICCS project is managed by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL) and received \$141.4 million in ARRA funding and \$66.5 million in private sector cost-sharing. The operations phase of the project is expected to begin in late summer 2013 and create roughly 260 jobs. The U.S. Department of Energy (DOE)/sponsored project is led by ADM, a member of DOE's Midwest Geological Sequestration Consortium (MGSC). To learn more about DOE's Carbon Sequestration Program, go to: <http://www.fossil.energy.gov/programs/sequestration/index.html>. August 24, 2011, [http://www.fossil.energy.gov/news/techlines/2011/11047-Industrial\\_CCS\\_Plant\\_Begins\\_Constr.html](http://www.fossil.energy.gov/news/techlines/2011/11047-Industrial_CCS_Plant_Begins_Constr.html).

***Fossil Energy Techline, "CO<sub>2</sub> Injection in Kansas Oilfield Could Greatly Increase Production, Permanently Store Carbon Dioxide, DOE Study Says."***

## 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, "Large-Scale Industrial Carbon Capture, Storage Plant Begins Construction."***

Construction activities have begun at an ethanol plant in Decatur, Illinois, that will demonstrate carbon capture and storage (CCS), making it the first large-scale integrated carbon capture and storage (ICCS) demonstration project funded by the American Recovery and Reinvestment Act (ARRA) to move into the construction phase. The Illinois-ICCS project is

The University of Kansas Center for Research studied the feasibility of using CO<sub>2</sub> injection for recovering 250 million to 500 million additional barrels of oil from Kansas oilfields. The DOE-funded study examined the possibility of CO<sub>2</sub> flooding in the Arbuckle Formation while simultaneously providing permanent geologic storage of CO<sub>2</sub>. Researchers used core samples from the Arbuckle Formation to simulate CO<sub>2</sub> flooding; according to the results, more than 50 percent of the residual oil remaining after water-flooding could be recovered from Berea Sandstone, Baker dolomite, and Arbuckle dolomite cores at pressures below the minimum miscibility pressure (MMP). Simulation studies were also conducted indicating that oil recovery is dependent on the degree of reservoir heterogeneity, and maximum efficiency can be achieved through proper design and optimization of CO<sub>2</sub> injection pressure, CO<sub>2</sub> injection rates, and the well pattern. The project is now moving into the second phase of research, in which a variety of tests will be conducted by researchers to improve characterization of Arbuckle reservoirs. The results of the tests will be used to determine the nature of the flow paths and average properties in the reservoir, assess the effect of geology on process performance, calibrate a reservoir simulation model, and identify operational issues and concerns for future applications of near-miscible CO<sub>2</sub> flooding.



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August 31, 2011, [http://www.fossil.energy.gov/news/techlines/2011/11050-\\_Study\\_Confirms\\_CO2\\_Injection\\_Feas.html](http://www.fossil.energy.gov/news/techlines/2011/11050-_Study_Confirms_CO2_Injection_Feas.html).

## SEQUESTRATION IN THE NEWS

### *Carbon Capture and Storage Association Press Release, "CCSA Launches New UK CCS Strategy."*

On September 7, 2011, the Carbon Capture and Storage Association (CCSA) launched a plan to reduce 100 megatonnes (Mt) of CO<sub>2</sub> per year and store 500 Mt per year by 2030 in the United Kingdom (UK). The strategy outlines the potential of CCS and describes the policy and regulatory framework required by industry for the integration of CCS technologies, which could create more than 50,000 jobs by 2030. The report includes the following highlights and recommendations: (1) a framework for a maintaining the UK's CCS Demonstration Program and enabling a "Progressive Roll-Out," increasing from 1 Gigawatt (GW) in 2018 to 3 GW per year in 2030 and beyond; (2) 20 to 30 GW of power station capacity equipped with CCS by 2030 could save 100 Mt of CO<sub>2</sub> per year with a total of 500 Mt of CO<sub>2</sub> stored by 2030; (3) emphasis on the need to launch CCS demonstration projects in the industrial sector; (4) proposal development and deployment of CCS infrastructure could create cost and operational efficiencies; and (5) analysis of regulatory barriers, R&D, and political and public perception. (See **Recent Publications** section in this newsletter to view a portion of the Executive Summary and a link to CCSA's "A Strategy for CCS in the UK and Beyond.") September 7, 2011, [http://www.ccsassociation.org.uk/index.php/download\\_file/view/252/97/](http://www.ccsassociation.org.uk/index.php/download_file/view/252/97/).

### *Wyoming Business Report, "Casper CO<sub>2</sub> Pipeline Underway."*

According to Denbury Resources, construction has initiated on the 232-mile Greencore Pipeline, which will transport CO<sub>2</sub> from the Lost Cabin gas plant located in Fremont County, Wyoming, northeast to the Bell Creek Field in Powder River County, Montana. Initial plans call for another future CO<sub>2</sub> pipeline to connect with the Greencore Pipeline. Officials said that crews began moving equipment onsite and plans call for the construction of 115 miles of the pipeline this year, ending in mid-November. Some of the crew will stake the right of way, while others will dig the trench for the 20-inch pipe. At the end of the project, fencing will be built along the right of way. A number of inspectors will work on the project to check welds, compliance with Federal permit stipulations, and reclamation of the construction site. Once complete, the pipeline will have a capacity of 725 million cubic feet of CO<sub>2</sub> per day, which can be used to pump 10 to 17 percent more oil from aging oil fields. More information on the Greencore Pipeline is available at: <http://www.greencorepipeline.com/>. September 2, 2011, <http://www.wyomingbusinessreport.com/article.asp?id=59546>.

### *Carbon Management Canada, "Research Team Developing Tools for Secure Carbon Storage."*

University of Saskatchewan researchers will test and develop new computer simulations for studying safe, permanent CO<sub>2</sub> storage underground. The project, supported by Carbon Management Canada (CMC), is aimed at determining the viability of CCS to help offset

## SEQUESTRATION IN THE NEWS (CONTINUED)

CO<sub>2</sub> emissions from coal-fired power plants. The University of Saskatchewan geomechanics group, in collaboration with researchers at the University of Waterloo and the University of Calgary, will squeeze rock cores to simulate conditions deep

underground, and inject them with pressurized water or CO<sub>2</sub> to monitor how they react under stress and how fluids flow. In addition, the cores can also be heated to test how they react to temperature change. The data acquired will form the basis for computer simulations that predict how the injected CO<sub>2</sub> might behave underground. The tools will allow for the assessment of potential CCS sites and demonstrate the most effective injection methods. August 22, 2011, <http://www.carbonmanagement.ca/news/2011/08/22/research-team-developing-tools-for-secure-carbon-storage/>.

## ANNOUNCEMENTS

### **CCS Forum.**

The American Clean Skies Foundation (ACSF) is hosting a one-day public forum, titled, "From a Bridge to a Destination: Gas Fired Power After 2020," on November 4, 2011, at the Hotel Monaco in Washington, D.C. This CCS leadership forum for natural gas-fired power plants will provide opportunities to advance CCS technology; research, design, and demonstration (RD&D); and policy. Attendees will include experts from the electric utility industry, manufacturers, government agencies, and the environmental community. To learn more, visit: <http://www.cleanskies.org/ccsforum/>.

### **CCS Workshop.**

The International Petroleum Industry Environmental Conservation Association (IPIECA) is hosting a workshop, titled, "Challenges and Opportunities of CO<sub>2</sub> Capture and Storage in the Iron and Steel Industry," on November 8-9, 2011, at the Steel Industry VDEh Auditorium in Düsseldorf, Germany. Topics to be discussed include the difficulties of CCS implementation in the iron and steel industry and the various issues and factors in the evaluation of the cost of CO<sub>2</sub> capture in an integrated steel mill. For more information, visit: <http://www.ieaghg.org/index.php?/20110609257/ccs-in-the-iron-and-steel-industry.html>.

### **DOE's Carbon Storage Program Infrastructure Annual Review Meeting.**

DOE's 2011 Annual Review Meeting, featuring the Regional Carbon Sequestration Partnerships (RCSPs), will be held at the Sheraton Station Square Hotel in Pittsburgh, Pennsylvania, on November 15-17, 2011. This meeting highlights DOE's carbon storage infrastructure projects, which include the efforts of DOE's RCSPs; however, it is now expanding to include other U.S. and international projects that are working to characterize CO<sub>2</sub> storage capacity through exploration and injection operations. An interactive reception and poster sessions will be held to highlight geologic CO<sub>2</sub> storage and characterization work being performed by ARRA-supported Regional Carbon Sequestration Training Centers, DOE's National Laboratories, RCSP subcontractors, and other organizations. For more information, go to: <http://www.netl.doe.gov/events/11conferences/Carbon%20storage%20program/index.html>.

### **The Carbon Sequestration Newsletter Annual Index.**

The Carbon Sequestration Newsletter Annual Index, covering the September 2010 to August 2011 issues of NETL's Carbon Sequestration Newsletter, is now available at: [http://www.netl.doe.gov/technologies/carbon\\_seq/refshelf/subscribe.html](http://www.netl.doe.gov/technologies/carbon_seq/refshelf/subscribe.html).

### **NATCARB Viewer Available.**

An updated and redesigned version of the National Carbon Sequestration Database and Geographic Information System (NATCARB) was launched on the NETL website. The interactive online tool integrates a wealth of information about worldwide efforts to deploy CCS technologies. The tabs within NATCARB open different maps for query and analysis capabilities, including an (1) RCSP tab; (2) ATLAS tab; (3) FIELD PROJECTS tab; and (4) WCCS tab. The NATCARB Viewer is accessible from: [http://www.netl.doe.gov/technologies/carbon\\_seq/natcarb/index.html](http://www.netl.doe.gov/technologies/carbon_seq/natcarb/index.html).



## SCIENCE

### **Canada.com, "Global Warming Brings Crab Threat to Antarctica."**

According to research conducted by the University of Hawaii at Manoa, potential climate change may cause the sea floor around the West Antarctic peninsula to attract a species of king crab that had previously only inhabited the Ross Sea on the opposite side of West Antarctica.

Biologists conducted a remotely operated vehicle survey in Palmer Deep, a mud-floored basin in the Weddin Sea located approximately 75 miles from the edge of the continental shelf, and discovered a large, reproductive population of lithodid crabs, which were believed to be excluded from cold Antarctic continental shelf waters for more than 14 million years. The survey identified 42 crabs, all at depths lower than 2,760 feet where the water was 1.4°C; none were found at shallower depths, where the seas are colder. The waters of the West Antarctic peninsula's continental shelf warm at a rate of 0.1°C per decade,

## SCIENCE (CONTINUED)

which researchers believe could allow for future advancement. This species of king crab feeds on tiny animals in the sea floor, which could have repercussions on the marine food chain. Researchers believe the total crab population in Palmer Deep could be more than 1.5 million. To view the study, which was published in the British scientific journal *Proceedings of the Royal Society B*, click: <http://rspb.royalsocietypublishing.org/content/early/2011/09/05/rspb.2011.1496.short?rss=1>. September 6, 2011, <http://www.canada.com/technology/Global+warming+brings+crab+threat+Antarctica/5360901/story.html?id=5360901>.

### **Science Daily, “Arctic Sea Ice Reached Minimum 2011 Extent, Making It Second Lowest in Satellite Record.”**

The University of Colorado Boulder’s National Snow and Ice Data Center (NSIDC) reported that the Arctic sea ice extent fell to 1.67 million square miles (4.33 million square kilometers) on September 9, 2011. The 1.67 million square miles is more than 1 million square miles below the 1979 to 2000 monthly average extent for September and the second lowest recorded since satellites began measuring it in 1979. During the all-time low in 2007, NSIDC attributed the low sea ice extent to winds pushing more warm air over the Arctic than usual, which melted the sea ice. NSIDC scientists believe that the primary driver of low sea ice conditions is rising temperatures in the Arctic, which could lead to ice-free summers by approximately 2030 to 2040. NSIDC will issue an analysis of the 2011 results and a comparison to previous years in the coming months. NSIDC’s sea ice data is provided from the Special Sensor Microwave Imager/Sounder sensor on the Defense Meteorological Satellite Program F17 satellite using methods developed at NASA’s Goddard Space Flight Center. September 15, 2011, <http://www.sciencedaily.com/releases/2011/09/110915163527.htm>.

## POLICY

### **Platts, “Canada Calls for Gradual Phase Out of Coal-Fired Plants Starting in 2015,” and Calgary Herald, “Ottawa Unveils New Coal Power Regulations.”**

Canada’s Environment Minister unveiled draft regulations on Friday, August 19, 2011, that call for the country to begin phasing out coal-fired power plants beginning in 2015 in an effort to reduce greenhouse gas (GHG) emissions from the power sector. Under the new rules, new plants will be required to be as clean as natural gas-fired generators and emit no more than 375 tonnes of CO<sub>2</sub> per GW-hour of power produced. In addition, coal plants would have to cut nearly 70 percent of emissions; existing coal facilities will have to meet new performance standards. August 19, 2011, <http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Coal/6392742>, and August 20, 2011, <http://www.calgaryherald.com/technology/Ottawa+unveils+coal+power+regulations/5282911/story.html>.

### **“The environmental impact and risk assessment of CO<sub>2</sub> capture, transport and storage – An evaluation of the knowledge base.”**

The following is the Abstract of this article: “In this study, [the authors] identify and characterize known and new environmental consequences associated with CO<sub>2</sub> capture from power plants, transport by pipeline and storage in geological formations. [The authors] have reviewed (analogous) environmental impact assessment procedures and scientific literature on CCS options. Analogues include the construction of new power plants, transport of natural gas by pipelines, underground natural gas storage (UGS), natural gas production, and enhanced oil recovery (EOR) projects. It is investigated whether crucial knowledge on environmental impacts is lacking that may postpone the implementation of CCS projects. This review shows that the capture of CO<sub>2</sub> from power plants results in a change in the environmental profile of the power plant. This change encompasses both increase and reduction of key atmospheric emissions, being: [nitrogen oxide (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), ammonia (NH<sub>3</sub>), particulate matter, mercury (Hg), hydrogen fluoride (HF) and hydrogen chloride (HCl)]. The largest trade-offs are found for the emission of NO<sub>x</sub> and NH<sub>3</sub> when equipping power plants with post-combustion capture. Synergy is expected for SO<sub>2</sub> emissions, which are low for all power plants with CO<sub>2</sub> capture. An increase in water consumption ranging between 32 [percent] and 93 [percent] and an increase in waste and by-product creation with tens of kilotonnes annually is expected for a large-scale power plant (1 GW<sub>e</sub>), but exact flows and composition are uncertain. The cross-media effects of CO<sub>2</sub> capture are found to be uncertain and to a large extent not quantified. For the assessment of the safety of CO<sub>2</sub> transport by pipeline at high pressure an important knowledge gap is the absence of validated release and dispersion models for CO<sub>2</sub> releases. [The authors] also highlight factors that result in some (not major) uncertainties when estimating the failure rates for CO<sub>2</sub> pipelines. Furthermore, uniform CO<sub>2</sub> exposure thresholds, detailed dose–response models and specific CO<sub>2</sub> pipeline regulation are absent. Most gaps in environmental information regarding the CCS chain are identified and characterized for the risk assessment of the underground, non-engineered, part of the storage activity. This uncertainty is considered to be larger for aquifers than for hydrocarbon reservoirs. Failure rates are found to be heavily based on expert opinions and the dose–response models for ecosystems or target species are not yet developed. Integration and validation of various sub-models describing fate and transport of CO<sub>2</sub> in various compartments of the geosphere is at an infant stage. In conclusion, it is not possible to execute a quantitative risk assessment for the non-engineered part of the storage activity with high confidence.” **Joris Koornneef, Andrea Ramírez, Wim Turkenburg, and André Faaij**, *Progress in Energy and Combustion Science*, Available online August 25, 2011, doi:10.1016/j.pecs.2011.05.002, <http://www.sciencedirect.com/science/article/pii/S0360128511000402>. (Subscription may be required.)

### **“The potential impacts of climate-change policy on freshwater use in thermoelectric power generation.”**

The following is the Abstract of this article: “Climate change policy involving a price on carbon would change the mix of power plants and the amount of water they withdraw and consume to generate electricity. [The authors] analyze what these changes could entail for electricity generation in the United States under four climate policy scenarios that involve different costs for emitting CO<sub>2</sub> and

## POLICY (CONTINUED)

different technology options for reducing emissions out to the year 2030. The potential impacts of the scenarios on the U.S. electric system are modeled using a modified version of the U.S. National Energy Modeling System and water-use factors for thermoelectric power plants derived from electric utility data compiled by the U.S. Energy Information Administration. Under all the climate-policy scenarios, freshwater withdrawals decline 2–14 [percent] relative to a business-as-usual (BAU) scenario of no U.S. climate policy. Furthermore, water use decreases as the price on CO<sub>2</sub> under the climate policies increases. At relatively high carbon prices (>\$50/tonne CO<sub>2</sub>), however, retrofitting coal plants to capture CO<sub>2</sub> increases freshwater consumption compared to BAU in 2030. [The authors'] analysis suggests that climate policies and a carbon price will reduce both electricity generation and freshwater withdrawals compared to BAU unless a substantial number of coal plants are retrofitted to capture CO<sub>2</sub>." **Munish K. Chandel, Lincoln F. Pratson, and Robert B. Jackson**, *Energy Policy*, Available online August 6, 2011, doi:10.1016/j.enpol.2011.07.022, <http://www.sciencedirect.com/science/article/pii/S0301421511005465>. (Subscription may be required.)

## GEOLOGY

**“Contact angle measurements of CO<sub>2</sub>-water-quartz/calcite systems in the perspective of carbon sequestration.”**

The following is the Abstract of this article: “This work presents contact angle measurements for CO<sub>2</sub>-water-quartz/calcite systems at general sequestration pressure and temperature conditions (200-3000 [pounds per square inch gauge (psig)] and 77°F-122°F). The effect of drop volume, repeated exposure of the substrates to dense water saturated CO<sub>2</sub>, pressure and temperature on the contact angles is examined. In the first measurement cycle, the contact angles for the quartz substrate varied from 46° to 48° and 47° to 46° for gaseous (water saturated) CO<sub>2</sub> and liquid (water saturated) CO<sub>2</sub> respectively, at 77°F. For calcite substrate, these values varied from 45° to 48° and 42° to 40°, respectively. Remarkably, this work highlights a characteristic permanent shift in the contact angle data with repeated exposure to dense, water saturated, CO<sub>2</sub>. The contact angle data trends after repeated exposure to the dense, water saturated CO<sub>2</sub> varied from 89° to 91° and 85° to 80° for the quartz substrate for gaseous (water saturated) CO<sub>2</sub> and liquid (water saturated) CO<sub>2</sub> respectively, at 77°F. For calcite substrates, these values varied from 60° to 59° and 54° to 48°, respectively. This important observation has serious implications towards the design and safety issues, as a permanent positive contact angle shift indicates lower CO<sub>2</sub> retention capabilities of sequestration sites due to a reduction in the capillary pressure. It is further confirmed that the permanent shift in the contact angle is due to surface phenomena. With an increase in temperature (from 77°F to 122°F), the contact angle shift is reduced from about 45° to about 20° for quartz substrates. Other observations in the contact angle data with respect to pressure are in good agreement with the trends reported in the literature.” **Prem Kumar Bikkina**, *International Journal of Greenhouse Gas Control*, Available online July 27, 2011, doi:10.1016/j.ijggc.2011.07.001, <http://www.sciencedirect.com/science/article/pii/S1750583611001241>. (Subscription may be required.)

**“Effect of the Pore Length on CO<sub>2</sub> Adsorption over Amine-Modified Mesoporous Silicas.”**

The following is the Abstract of this article: “Carbon dioxide adsorption was investigated in the presence of polyethylenimine (PEI)-impregnated mesoporous silicas with different pore lengths, namely, pore-expanded MCM-41, conventional SBA-15 with different pore diameters (7.2 and 10.5 nm), and SBA-15 with platelet morphology. The pore lengths of the silica supports were ca. 25, 1.5, and 0.2 μm, respectively. Under comparable conditions, the adsorption performance was found to be strongly dependent upon the pore length. The materials with the shortest channels showed the highest capacity and fastest adsorption. These findings were associated with diminished diffusion resistance and enhanced amine accessibility inside the pores.” **Aliakbar Heydari-Gorji, Yong Yang, and Abdelhamid Sayari**, *Energy Fuels*, Available online August 4, 2011, doi:10.1021/ef200765f, <http://pubs.acs.org/doi/abs/10.1021/ef200765f>. (Subscription may be required.)

**“Subarctic Weathering of Mineral Wastes Provides a Sink for Atmospheric CO<sub>2</sub>.”**

The following is the Abstract of this article: “The mineral waste from some mines has the capacity to trap and store CO<sub>2</sub> within secondary carbonate minerals via the process of silicate weathering. Nesquehonite [MgCO<sub>3</sub>•3H<sub>2</sub>O] forms by weathering of Mg-silicate minerals in kimberlitic mine tailings at the Diavik Diamond Mine, Northwest Territories, Canada. Less abundant [sodium (Na)]- and [calcium (Ca)]-carbonate minerals precipitate from sewage treatment effluent deposited in the tailings storage facility. Radiocarbon and stable carbon and oxygen isotopes are used to assess the ability of mine tailings to trap and store modern CO<sub>2</sub> within these minerals in the arid, subarctic climate at Diavik. Stable isotopic data cannot always uniquely identify the source of carbon stored within minerals in this setting; however, radiocarbon isotopic data provide a reliable quantitative estimate for sequestration of modern carbon. At least 89 [percent] of the carbon trapped within secondary carbonate minerals at Diavik is derived from a modern source, either by direct uptake of atmospheric CO<sub>2</sub> or indirect uptake through the biosphere. Silicate weathering at Diavik is trapping 102-114 g C/m<sup>2</sup>/y within nesquehonite, which corresponds to a [two] orders of magnitude increase over the background rate of CO<sub>2</sub> uptake predicted from arctic and subarctic river catchment data.” **Siobhan A. Wilson, Gregory M. Dipple, Ian M. Power, Shaun L. L. Barker, Stewart J. Fallon, and Gordon Southam**, *Environ. Sci. Technol.*, Available online August 20, 2011, doi:10.1021/es202112y, <http://pubs.acs.org/doi/abs/10.1021/es202112y>. (Subscription may be required.)

## TECHNOLOGY

**“Economics of CCS for coal plants: Impact of investment costs and efficiency on market diffusion in Europe.”**

The following is the Abstract of the article: “In this paper, [the authors] analyze how the development of the CCS technology used in coal-fired power plants affects its market diffusion.

## TECHNOLOGY (CONTINUED)

Specifically, [the authors] (1) show the significant variance in expectations about the economics of commercial-grade CCS hard coal power plants observed in the literature; (2) analyze the impact of CCS economics on electricity generation costs; and (3) investigate the expected deployment of CCS in the European power sector, depending on the variance of two main factors, efficiency and investment cost, using the bottom-up electricity sector model HECTOR. Simulation results show that investment costs strongly influence the market deployment of coal-fired CCS power plants, leading to a share of 16 [percent] in European generation capacity by 2025 with the lowest observed investment costs of [~1,884 \$/kW], but only 2 [percent] with the highest of [~4,037 \$/kW]. A variation of conversion efficiency between 37 [percent] and 44 [percent], the minimum and maximum observed values, only leads to a 13-15 [percent] share of CCS-equipped power plants. These findings are robust for the Base Case with a CO<sub>2</sub> price of [~58 \$/t] and also for sensitivities with [~40 and ~27 \$/t CO<sub>2</sub>], but with a lower effect, as the overall share of CCS is significantly reduced at these prices.” **Richard Lohwasser and Reinhard Madlener**, *Energy Economics*, Available online August 6, 2011, doi:10.1016/j.eneco.2011.07.030, <http://www.sciencedirect.com/science/article/pii/S0140988311001605>. (Subscription may be required.)

### “Precipitation of Calcium Carbonate by Carbon Dioxide Microbubbles.”

The following is the Abstract of this article: “The microbubble generator (MBG)—an apparatus in which tiny micron-sized gas bubbles are produced in the aqueous phase—has been widely used in water purification systems. In this study, the feasibility of utilizing the MBG to precipitate calcium carbonate along the carbonation route was examined. The effects of the calcium hydroxide concentration and the injection flow rate of [CO<sub>2</sub>] on the precipitation process were evaluated. Changes in pH, temperature of the suspension, and residual calcium ion concentration in the suspension were monitored to evaluate the proposed process. In addition, the process was compared with that based on a conventional bubble generator. This revealed a two-fold improvement in the acquisition time required for calcium carbonate precipitation as well as an increase in the conversion efficiency of [CO<sub>2</sub>] to carbonate minerals. The proposed process should be helpful for practical applications of a carbon sequestration method.” **Jun-Hwan Bang, Young Nam Jang, Wonbaek Kim, Kyung Sun Song, Chi Wan Jeon, Soo Chun Chae, Seung-Woo Lee, So-Jin Park, and Myung Gyu Lee**, *Chemical Engineering Journal*, Available online September 10, 2011, doi:10.1016/j.cej.2011.09.021, <http://www.sciencedirect.com/science/article/pii/S1385894711010795>. (Subscription may be required.)

### “Greening Coal: Breakthroughs and Challenges in Carbon Capture and Storage.”

The following is the Abstract of this article: “This paper reviews the state-of-the-art of science and technology related to CO<sub>2</sub> capture, storage, and system-wide integration. Each of these areas is covered in a separate section, with emphasis on strategies and technologies suitable for making CCS happen in the near future.

Substantial short-term effort in CCS is currently being directed toward reducing capture costs from industrial sources, mainly power plants, and ensuring that geologic sequestration can be done safely; however [the authors] include brief discussions of future directions in other areas within each section. The capture section outlines the three primary approaches currently being pursued for capture from power plants (post-combustion, oxy-combustion, and pre-combustion capture), then focuses on challenges faced by incorporating capture into existing coal-fired power plants, specifically, work on solvents, solid sorbents, and membranes that can reduce capture costs. The storage section begins with a brief review of potential storage options, including mineralization, ocean storage and others. [The authors] next focus on geologic sequestration in deep saline aquifers, with discussion of subsurface trapping mechanisms, coupled flow and transport processes, and an example of thermo-hydro-chemical-mechanical simulation that illustrates the interrelationships of these processes in CO<sub>2</sub> repositories. [The authors] finish this section with discussion of new research directions in reservoir pressure management and the role of risk analysis in sequestration projects. The system-wide integration section discusses relationships between sources, storage sites, and the connecting transportation infrastructure. Efficient design of CCS infrastructure that considers the intersection of science, policy, and industry is critical for effective and economically viable CCS development. An example is presented that demonstrates the usefulness of comprehensive system design for routing CO<sub>2</sub> to multiple storage sites. The section continues with discussion of recent developments in and implications of total system design.” **Philip Stauffer, Gordon N. Keating, Richard S Middleton, Hari Selvi Viswanathan, Rajinder P Singh, Kathryn A. Berchtold, Rajesh J. Pawar, and Anthony Mancino**, *Environ. Sci. Technol.*, Available online September 9, 2011, doi:10.1021/es200510f, <http://pubs.acs.org/doi/abs/10.1021/es200510f>. (Subscription may be required.)



## TERRESTRIAL

### “Carbon accounting and the climate politics of forestry.”

The following is the Abstract of this article: “Many proposals have been made for the more successful inclusion of Land Use, Land-Use Change and Forestry (LULUCF) in the Kyoto framework. Though the positions of individual states or the goal of avoided deforestation guide many approaches, [the authors’] model sets cost-effective strategies for climate change mitigation and the efficient and balanced use of forest resources at its center. Current approaches to forest resource-based carbon accounting consider only a fraction of its potential and fail to adequately mobilize the LULUCF sector for the successful stabilization of atmospheric GHG concentrations. The presence of a significantly large ‘incentive gap’ justifies the urgency of reforming the current LULUCF carbon accounting framework. In addition to significantly broadening the scope of carbon pools accounted under LULUCF, [the authors] recommend paying far greater attention to the trioka of competing but potentially compatible interests surrounding the promotion of standing forests (in particular for the purposes of carbon sequestration, biodiversity protection and ecosystem 15, promotion/preservation), harvested wood products (HWP) and

## TERRESTRIAL (CONTINUED)

bioenergy use. The successful balancing of competing interests, the enhancement of efficiency and effectiveness and the balanced use of forest resources require an accounting mechanism that weighs and rewards each component according to its real climate mitigation potential. Further, [the authors'] data suggest the benefits of such a broadly based carbon accounting strategy and the inclusion of LULUCF in national and international accounting and emission trading mechanisms far outweigh potential disadvantages. Political arguments suggesting countries could take advantage of LULUCF accounting to reduce their commitments are not supported by the evidence [the authors] present.” **David Ellison, Mattias Lundblad, and Hans Petersson**, *Environmental Science & Policy*, Available online August 10, 2011, doi:10.1016/j.envsci.2011.07.001, <http://www.sciencedirect.com/science/article/pii/S1462901111001079>. (Subscription may be required.)

## TRADING

### **RGGI News Release, “10 States Complete Thirteenth Regional Auction for Carbon Dioxide Allowances.”**

The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI), the Nation’s first market-based regulatory program to reduce GHG emissions, announced the results of their 13th quarterly auction of CO<sub>2</sub> allowances, held September 7, 2011. Of the 42,189,685 current control period (2009-2011) CO<sub>2</sub> allowances offered for sale, 7,487,000 (17.75 percent) were sold at the auction clearing price of \$1.89 per allowance (the minimum reserve price for the auction); 94 percent of the allowances sold were purchased by electric generators and their corporate affiliates. Bids

ranging from \$1.89 to \$5.18 were submitted by 31 entities. According to Potomac Economics, an independent market monitor, power plants and their corporate affiliates have purchased 85 percent of allowances sold in Auctions 1 through 13 and hold 97 percent of the allowances in circulation. Proceeds from the auctions now total more than \$900 million, approximately 80 percent of which is being invested in consumer benefits such as energy efficiency, renewable energy, direct assistance to consumers, and other programs. September 9, 2011, [http://www.rggi.org/docs/Auction\\_13\\_Release\\_Report.pdf](http://www.rggi.org/docs/Auction_13_Release_Report.pdf).

### **“Carbon trading: Current schemes and future developments.”**

The following is the Abstract of this article: “This paper looks at the GHG emissions trading schemes and examines the prospects of carbon trading. The first part of the paper gives an overview of several mandatory GHG trading schemes around the world. The second part focuses on the future trends in carbon trading. It argues that the emergence of new schemes, a gradual enlargement of the current ones, and willingness to link existing and planned schemes seem to point towards geographical, temporal and sectoral expansion of emissions trading. However, such expansion would need to overcome some considerable technical and non-technical obstacles. Linking of the current and emerging trading schemes requires not only considerable technical fixes and harmonization of different trading systems, but also necessitates clear regulatory and policy signals, continuing political support and a more stable economic environment. Currently, the latter factors are missing. The global economic turmoil and its repercussions for the carbon market, a lack of the international deal on climate change defining the Post-Kyoto commitments, and unfavorable policy shifts in some countries, cast serious doubts on the expansion of emissions trading and indicate that carbon trading enters an uncertain period.” **Slobodan Perdan and Adisa Azapagic**, *Energy Policy*, Available August 4, 2011, doi:10.1016/j.enpol.2011.07.003, <http://www.sciencedirect.com/science/article/pii/S030142151100526X>. (Subscription may be required.)

## RECENT PUBLICATIONS

### **“A Strategy for CCS in the UK and Beyond.”**

The following is from the Executive Summary of this document: “[CCS] is a technology that can capture 90 [percent] or more of the CO<sub>2</sub> emissions produced from the use of fossil fuels in electricity generation. The captured CO<sub>2</sub> is then transported for permanent storage in depleted oil and gas fields or deep saline formations. CCS can also be applied to industrial processes such as chemical processing and steel and cement manufacture, preventing CO<sub>2</sub> from entering the atmosphere and contributing to climate change. The value of CCS as an important CO<sub>2</sub> abatement tool is already recognized by multiple authoritative organizations, including the UK Committee on Climate Change (CCC), the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA). The IEA asserts that CCS could deliver 19 [percent] of global emissions reductions, and account for over 30 [percent] of reductions from the power sector by 2050 and that reducing emissions without CCS is likely to be 70 [percent] more expensive. For many industrial applications, CCS remains the only credible abatement option.” The complete CCSA publication is available at: [http://www.ccsassociation.org.uk/index.php/download\\_file/view/251/76/](http://www.ccsassociation.org.uk/index.php/download_file/view/251/76/).

### **“Overview of Carbon Capture and Storage in Europe.”**

The following is a description of this brief: “This brief analyzes the [CCS] industry in the UK and Europe from various angles, examining the key drivers, issues, trends, players, and costs. Using a range of sources supplemented with unique insight from industry experts, it joins the dots to provide an informative and compelling overview of the CCS industry, and is imperative reading for strategic decision makers. [Feature and

## RECENT PUBLICATIONS (CONTINUED)

benefits include:] segments the large-scale integrated projects by various angles, such as by application type, capture type, and country; highlights the key players and projects; provides an overview of the different funding sources and the legal/risk landscape, highlighting their respective problems; provides detailed insight into the economics of CCS, with cost breakdowns sourced from highly reputable organizations; and gives an estimate of the market size and future outlook.” This document is available for purchase at: [http://www.researchandmarkets.com/reportinfo.asp?report\\_id=1878356&t=d&cat\\_id](http://www.researchandmarkets.com/reportinfo.asp?report_id=1878356&t=d&cat_id).

### “CO<sub>2</sub> Emissions from Electricity Generation and Imports in the 10-State Regional Greenhouse Gas Initiative: 2009 Monitoring Report.”

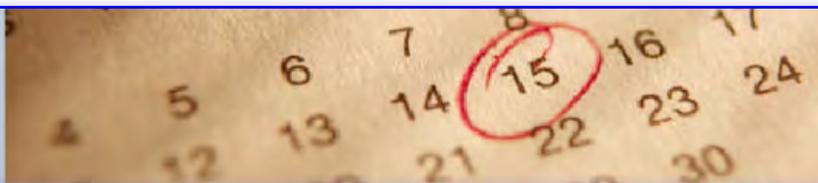
The following is from the Executive Summary of this document: “This report, the first report in a series of annual monitoring reports, summarizes data for electricity generation, electricity imports, and related CO<sub>2</sub> emissions in the [10]-state RGGI region for the period from 2005 through 2009. These monitoring reports were called for in the 2005 RGGI Memorandum of Understanding (MOU) in response to expressed concerns about the potential for the RGGI CO<sub>2</sub> Budget Trading Program to result in ‘emissions leakage.’ In the Northeast and Mid-Atlantic, CO<sub>2</sub> emissions from the regional electric power sector are a function of a highly dynamic wholesale electricity markets. The cost of compliance with the RGGI CO<sub>2</sub> Budget Trading Program is only one of several factors that influence the dispatch of electric generation, and resulting CO<sub>2</sub> emissions, through the operation of these markets. As a result, this report presents data without assigning causality to any one of the factors influencing observed trends. The observed trends in electricity demand, net electricity imports, electricity generation from multiple categories of generation sources (including electricity imports), show there has been no increase in CO<sub>2</sub> emissions or the CO<sub>2</sub> emission rate (pounds of CO<sub>2</sub> per megawatt hour or lb CO<sub>2</sub>/MWh) from non-RGGI electric generation serving load in the [10]-state RGGI region in the first year of the RGGI program operation, 2009.” This RGGI report is available at: [http://www.rggi.org/docs/Elec\\_monitoring\\_report\\_11\\_09\\_14.pdf](http://www.rggi.org/docs/Elec_monitoring_report_11_09_14.pdf).

## LEGISLATIVE ACTIVITY

### Platts, “Illinois Governor Signs CO<sub>2</sub> Legislation to Aid Pipeline Projects.”

Illinois has approved legislation that aids plans by Denbury Resources to construct a pipeline to transport CO<sub>2</sub> from several proposed clean coal plants across the state. Similar legislation enabling CO<sub>2</sub> pipeline developers to obtain property rights for their projects have already been approved

by neighboring states Indiana and Kentucky. The provisions in the bills allow Denbury Resources to move forward with plans to build a 700-mile-long pipeline that would carry CO<sub>2</sub> from several plants in Illinois, Indiana, and possibly Kentucky to the Gulf Coast for enhanced oil recovery (EOR). To view S.B. 1821, “The Carbon Dioxide Transportation and Sequestration Act,” go to: <http://www.ilga.gov/legislation/fulltext.asp?DocName=&SessionId=84&GA=97&DocTypeId=SB&DocNum=1821&GAID=11&LegID=57876&SpecSess=&Session=> August 24, 2011, <http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Coal/6408491>.



## EVENTS

October 9-11, 2011, **Reservoir Characterization and Simulation Conference and Exhibition**, *Beach Rotana Hotel, Abu Dhabi, UAE*. SPE is hosting the third edition of the Reservoir Characterization and Simulation Conference and Exhibition (RCSC), focusing on reservoir applications and different technologies for characterizing, modeling, and simulating reservoir characteristics. To learn more, visit: <http://www.spe.org/events/rcsc/2011/>.

October 9-12, 2011, **Gasification Technologies Conference 2011**, *San Francisco Marriott Marquis, San Francisco, California, USA*. The world’s largest gasification event, this conference includes sessions focused on the global gasification market and project and technology updates; CO<sub>2</sub> management and CCS demonstration projects; and underground coal gasification. For more information, including a complete conference program, visit the conference website at: <http://www.gasification.org/eventDetail.asp?a=4&eventID=9>.

October 9-14, 2011, **CO<sub>2</sub> Storage: Will we be ready in time?**, *The Algarve, Portugal*. This forum, designed for professionals in the oil and gas, power, and alternative energy industries who focus on CCS schemes, will address the opportunities and challenges related to the development of CO<sub>2</sub> geologic storage activities that would be several orders of magnitude larger than current demonstration projects. For more information, visit: <http://www.spe.org/events/11fse3/pages/about/index.php>.



## EVENTS (CONTINUED)

October 19-20, 2011, **Carbon Capture and Storage – The Leading Edge**, *London, United Kingdom*. This Institution of Mechanical Engineers seminar will discuss carbon capture technology and the implications across the regulatory, financial, and process technology fields. The following areas will also be covered: properties of CO<sub>2</sub>, European Union competition, and front-end engineering design (FEED) case studies. Seminar details are located at: <http://events.imeche.org/EventLocation.aspx?EventID=1204>.

October 20-21, 2011, **The Carbon Show 2011**, *Business Design Center, London, England*. This conference offers a program dedicated to the following topics: climate finance, CRC energy efficiency scheme, carbon management, and green technology and renewables. Industry experts will share best practices and offer attendees the opportunity to debate and discuss carbon and carbon market developments. Conference details are available at: <http://www.thecarbonshow.com>.

November 15-16, 2011, **Low-Carbon Energy Technologies: Innovations in Efficiency and Greenhouse Gas Reduction Science and Technology Seminar**, *Southwest Research Institute, San Antonio, Texas, USA*. This seminar will focus on alternative energy technologies, carbon reduction through improvements in efficiency, and carbon conversion and storage. Topics include: efficiency improvements to reduce carbon footprint, alternative power (wind, solar, and energy storage), low-carbon emission power plant cycles, CO<sub>2</sub> compression and storage, and CO<sub>2</sub> conversion and utilization. For more information, go to: <http://www.swri.org/mailler/Div18/2011/IndLectureFlyr-4.pdf>.

November 15-17, 2011, **DOE's Carbon Storage Program Infrastructure Annual Review Meeting**, *Sheraton Station Square, Pittsburgh, Pennsylvania, USA*. This meeting highlights DOE's carbon storage infrastructure projects, which include the efforts of DOE's RCSPs; however, it is now expanding to include other U.S. and international projects that are working to characterize storage capacity through exploration and injection operations. For more information, go to: <http://www.netl.doe.gov/events/>.

December 13-15, 2011, **POWER-GEN International 2011**, *Las Vegas Convention Center, Las Vegas, Nevada, USA*. POWER-GEN International is the industry leader in providing comprehensive coverage of trends, technologies, and issues facing the generation sector. This year's program consists of a variety of tracks, including: industry trends, power generation, environmental issues, fossil technologies, gas turbine technologies, renewable energy, onsite power, and plant performance. Conference details are available at: <http://www.power-gen.com>.

February 7-9, 2012, **Carbon Management Technology Conference**, *Caribe Royale Hotel & Convention Center, Orlando, Florida, USA*. This inaugural conference draws professionals from all engineering disciplines to share their expertise on the reduction of GHG emissions and adaptation to changing climate. The conference will focus on engineering perspectives regarding key issues, including technologies, strategies, policies, and management systems. More information is located at: <http://www.spe.org/events/cmtc/2012/index.php>.

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, with a call for papers expected to open toward the end of September 2011. Visit: <http://www.ghgt.info/index.php/Content-GHGT11/ghgt-11-overview.html> for more details.

## FOR SUBSCRIPTION DETAILS...

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To view an archive with past issues of the newsletter, see: [http://www.netl.doe.gov/technologies/carbon\\_seq/refshelf/subscribe.html](http://www.netl.doe.gov/technologies/carbon_seq/refshelf/subscribe.html).

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