



# Carbon Sequestration Newsletter

MARCH 2010

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## 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, "President Requests \$760.4 Million for Fossil Energy Programs."***

President Obama has requested \$760.4 million for the Office of Fossil Energy (FE) in the Fiscal Year (FY) 2011 budget to support improved energy security and rapid development of climate-oriented technology. Of this total, \$586.5 million would go toward Fossil Energy Research and Development (FE R&D), which is comprised of

the Fuels and Power Systems Program. The Fuels and Powers Systems Program would receive \$403.9 million to research, develop, and deploy technologies that use the Nation's fossil fuels more cleanly and efficiently. The core research and development (R&D) efforts of the Fuels and Power Systems Program focus on the creation of a portfolio of technologies that can capture and permanently store carbon dioxide (CO<sub>2</sub>) from power plants and industrial processes, capture carbon from existing coal-fired power plants, improve efficiency for existing and new power generation, and improve turbines for future coal-based combined cycle plants. The U.S. Department of Energy (DOE) is requesting \$143.0 million for FE's Carbon Sequestration Program to continue efforts to develop technologies that decrease the release of CO<sub>2</sub> into the atmosphere, complete and evaluate small- and large-scale CO<sub>2</sub> injection tests under the Regional Carbon Sequestration Partnership (RCSP) Program, and continue U.S. engagement and collaboration with the global community. To view a complete breakdown of the FY2011 Fossil Energy Budget, click: [http://www.fossil.energy.gov/aboutus/budget/11/FY\\_2011\\_Budget.html](http://www.fossil.energy.gov/aboutus/budget/11/FY_2011_Budget.html). February 1, 2010, [http://www.fossil.energy.gov/news/techlines/2010/10002-President\\_Requests\\_%24760.4\\_Million\\_.html](http://www.fossil.energy.gov/news/techlines/2010/10002-President_Requests_%24760.4_Million_.html).

## SEQUESTRATION IN THE NEWS

***Carbon Capture Journal, "Obama Announces CCS Task Force."***

President Obama released a Presidential Memorandum creating an Interagency Task Force on carbon capture and sequestration (CCS) that will seek to "develop a comprehensive and coordinated Federal strategy to speed the commercial development and deployment of clean coal technologies." The memorandum, which sets a goal for five to 10 commercial demonstration projects to be running by 2016, states that the task force will be co-chaired by representatives from DOE and the U.S. Environmental Protection Agency (EPA). By August 2010, the task force will develop a proposed plan to explore incentives for the adoption of CCS, as well as address any financial, economic, technological, legal, institutional, or other barriers to deployment within the next 10 years. The task force will consider how best to coordinate existing Federal authorities and programs and identify areas in which additional Federal authority may be necessary. Periodically, progress will be reported to President Obama through the Chair of the Council on Environmental Quality. The Presidential Memorandum, titled, "A Comprehensive Federal Strategy on Carbon Capture and Storage," was released by the White House Office of the Press Secretary on February 3, 2010, and can be viewed at:



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## SEQUESTRATION IN THE NEWS (CONTINUED)

<http://www.whitehouse.gov/the-press-office/presidential-memorandum-a-comprehensive-federal-strategy-carbon-capture-and-storage>. February 8, 2010, <http://www.carboncapturejournal.com/displaynews.php?NewsID=506&PHPSESSID=2kedq1bb5lmvjjfvnv075491c6>.

*The Wall Street Journal*, "Alberta Signs CO<sub>2</sub> Capture, Economic Pact With Abu Dhabi," and *The Government of Alberta News Release*, "Stelmach Signs Two Groundbreaking Agreements in the UAE."

The province of Alberta reached an economic and energy technology cooperation agreement with Abu Dhabi, the capital of the United Arab Emirates (UAE). The Premier of Alberta signed a Memorandum of Understanding (MOU)



with the Chairman of the Abu Dhabi Department of Economic Development, setting the stage for stronger relations in areas such as energy, environmental protection, technology, and innovation. The Premier of Alberta also signed an MOU on CCS with Masdar, a company of the Government of Abu Dhabi, which commits both nations to share information on CCS technologies and policies, support projects of mutual interest, and explore opportunities for collaboration between public and private partners in both nations. January 20, 2010, [http://online.wsj.com/article/BT-CO-20100120-711420.html?mod=WSJ\\_World\\_MIDDLEHeadlinesMideast](http://online.wsj.com/article/BT-CO-20100120-711420.html?mod=WSJ_World_MIDDLEHeadlinesMideast) (subscription may be required), and January 20, 2010, <http://www.alberta.ca/acn/201001/276694C8615A0-9EDC-B9B2-DAA52CC7423B59CC.html>.

*The Billings Gazette*, "Anadarko Sequesters CO<sub>2</sub> in Getting More Oil."

Anadarko Petroleum has sequestered 181 billion cubic feet of CO<sub>2</sub> during an enhanced oil recovery (EOR) project that began in 2003. According to the company, an additional 10 million barrels of oil were extracted from the Salt Creek field north of Casper,



Wyoming, by the CO<sub>2</sub> injected into the aging oilfield. The CO<sub>2</sub> injection is responsible for approximately 13 million barrels of oil production per year in Wyoming; the 100-year-old Salt Creek field approaches 10,000 barrels per day. January 11, 2010, [http://billingsgazette.com/news/state-and-regional/wyoming/article\\_be20701c-ff32-11de-9c75-001cc4c03286.html](http://billingsgazette.com/news/state-and-regional/wyoming/article_be20701c-ff32-11de-9c75-001cc4c03286.html).

## ANNOUNCEMENTS

### **UNIDO Developing CCS Roadmap.**

The United Nations Industrial Development Organization (UNIDO) announced that it will develop a global technology roadmap for CCS in industrial processes. The project will draw from the methodologies and experience of its partners, the Norwegian Ministry of Petroleum and Energy and the Global CCS Institute, to provide a vision of industrial CCS storage up to 2050, with a focus on developing countries with energy-intensive industries. The roadmap will inform policymakers and investors about the potential of CCS, as well as the milestones that need to be achieved. For more information, visit: [http://www.unido.org/index.php?id=7881&tx\\_ttnews\[tt\\_news\]=444&cHash=2e3e3e65dc](http://www.unido.org/index.php?id=7881&tx_ttnews[tt_news]=444&cHash=2e3e3e65dc).

### **International Interdisciplinary CCS Summer School 2010.**

Held from August 22-27, 2010, at Loneyarbyen, Svalbard, Norway, this course will cover the entire CCS field, aiming to present the most up-to-date results from several active R&D fields, including: sources, capture, and transport of CO<sub>2</sub>; underground geological storage; economic potential of CCS; and implications of CCS for greenhouse gas (GHG) inventories and accounting. For more information, visit the summer school's website at: <http://www.ieaghg.org/index.php?/20100113166/international-interdisciplinary-ccs-summer-school-2010.html>.

### **DOE Awards Supercomputing Hours.**

DOE awarded 1.6 billion supercomputing processor hours to 69 research projects through the Innovative and Novel Computational Impact on Theory and Experiment (INCITE) Program. Projects receiving INCITE awards utilize complex simulations to accelerate groundbreaking technologies. Projects selected feature research in carbon sequestration, potential climate change, improving climate models, and other areas. To view the DOE press release, click: <http://www.energy.gov/news2009/8557.htm>.

### **Geophysical Aspects of CO<sub>2</sub> Storage Workshop.**

On March 19, 2010, the German Geophysical Society (DGG) and the Society of Exploration Geophysicist (SEG) will hold a workshop, titled, "Geophysical Aspects of CO<sub>2</sub> Storage – Challenges and Strategies." This one-day workshop will provide an overview of state-of-the-art research related to worldwide CO<sub>2</sub> storage efforts, with a focus on geophysical methods. Sessions will cover site characterization, rock physics, monitoring, opportunities and fundamental strategies, and public outreach. For detailed information, go to: <http://www.ccs-workshop.dmt.de/index.php>.

### **CCS Workshop.**

This informal workshop, titled, "CCS: Can Anything Be Learned from 35 Years Experience in Geological Disposal of Radioactive Wastes," will be held on April 27-30, 2010, in Meiringen, Switzerland. It will explore lessons that can be learned from the geological disposal of radioactive waste (GDRW). Experienced practitioners in the CCS and GDRW sectors will discuss their experiences and help identify any crossover applications. For more information, visit the workshop website at: <http://www.itc-school.org/index.php/Present-Courses/Carbon-Capture-and-Storage.html>.

### **10<sup>th</sup> International Conference on Greenhouse Gas Control Technologies.**

The 10<sup>th</sup> International Conference on Greenhouse Gas Control Technologies (GHGT-10) will be held in Amsterdam, Netherlands, on September 19-23, 2010. This conference will provide a platform for discussions on overcoming barriers involved in the implementation of greenhouse gas (GHG) mitigation technologies. For more information, visit the conference website at: <http://www.ghgt.info/ghgt10.html>.

## SCIENCE

### ***Science Daily*, "Disappearing Ducks?"**

According to research published in the journal *DiqUekpeg*, millions of waterfowl that depend on the prairie pothole region of central North America for food, shelter, and a place to raise their young will be impacted by a warmer and drier climate. By developing a new wetland model to understand the impacts potential climate change could have



on wetlands in the prairie pothole region, researchers discovered that the region is much more sensitive to climate change than previously thought. The new model projected major reductions in water volume, shortening of the time water remains in wetlands, and changes to wetland vegetation dynamics in the 800,000-square kilometer region of central North America. Most dabbling ducks, such as mallards and teal, require approximately 95 days of surface water for their young to grow and develop; they also need an abundance of wetlands, as breeding waterfowl often isolate themselves from the rest of their species. The model suggests that under potential climate change, the region's conditions will not be conducive to the species' needs. February 2, 2010, <http://www.sciencedaily.com/releases/2010/02/100201145432.htm>.

## SCIENCE (CONTINUED)

**USA Today, “Study: Trees Are Growing Faster Because of Climate Change.”**

According to a new study, forests in the eastern United States are growing at a faster rate than in the past as a result of climate change. The 22-year-long study, which was published in a February issue of *Proceedings of the National Academy of Sciences*, analyzed 55 groups of mixed hardwood forest plots in Maryland that are considered representative of trees on the East Coast. Researchers found that more than 90 percent of all the trees that were analyzed grew at a rate of two to four times faster than predicted. Researchers reported in their findings that they believe the main cause for the tree’s accelerated growth is climate change. Researchers also believe that the growth rate will eventually level off due to limited water availability and soil nutrients. To view the entire study, titled, “Evidence for a recent increase in forest growth,” click: <http://www.pnas.org/content/early/2010/02/02/0912376107>. February 2, 2010, <http://content.usatoday.com/communities/greenhouse/post/2010/02/study-trees-are-growing-faster-because-of-climate-change/1>.



## POLICY

**The White House Press Release, “President Obama Sets Greenhouse Gas Emissions Reduction Target for Federal Operations.”**

President Obama announced that the Federal Government will reduce its GHG emissions by 28 percent by 2020. This Executive Order is expected to spur clean energy investments that can create new private-sector jobs, drive long-term savings, build local market capacity, and foster innovation and entrepreneurship in clean energy industries. The Federal Government is the largest energy consumer in the U.S. economy, having spent more than \$24.5 billion on electricity and fuel in 2008. By reaching the Federal GHG emission target, Federal energy use will be reduced by the equivalent of 646 trillion British thermal units (Btu), which is also equivalent to a cumulative total of \$8 billion to \$11 billion in avoided energy costs through 2020. Federal Departments and Agencies will achieve their GHG reduction targets by measuring their current energy and fuel use; becoming more energy efficient; and shifting to clean energy sources, such as solar, wind, and geothermal. Each agency’s sustainability plan will be validated and scored by the Office of Management and Budget (OMB); annual progress will also be measured and made public. Examples of agency actions that are currently underway can be found on the White House Council on Environmental Quality website at: <http://www.whitehouse.gov/administration/eop/ceq>. January 29, 2010, <http://www.whitehouse.gov/the-press-office/president-obama-sets-greenhouse-gas-emissions-reduction-target-federal-operations>.

**New York Times, “California Sets Up Statewide Network to Monitor Global-Warming Gases.”**

California plans to install a system of monitoring devices on towers throughout the state that will detect GHG emissions. Unlike preexisting monitoring networks used across the globe, which are deliberately placed in remote locations and measure the average global concentrations of GHGs, this network is intended to help California find specific sources of emissions, while verifying the state’s overall compliance with its adopted plan to limit GHGs. Seven portable analyzers have been purchased by the California Air Resources Board (CARB) and will be deployed on towers in the San Joaquin and Sacramento Valleys. One analyzer is capable of covering as much as several hundred miles, according to scientists. CARB currently uses computer modeling to estimate state GHG emissions; the first task of the new network will be to see if actual concentrations of GHGs match those estimates. California’s climate change law requires that GHG emissions be cut to 1990 levels by 2020. February 2, 2010, <http://www.nytimes.com/2010/02/03/business/energy-environment/03emit.html?ref=earth>.

**“Geological storage of CO<sub>2</sub> in saline aquifers – A review of the experience from existing storage operations.”**

The following is the Abstract of this article: “The experience from CO<sub>2</sub> injection at pilot projects (Frio, Ketzin, Nagaoka, [RCSPs]) and existing commercial operations (Sleipner, Snøhvit, In Salah, acid-gas injection) demonstrates that CO<sub>2</sub> geological storage in saline aquifers is technologically feasible. Monitoring and verification technologies have been tested and demonstrated to detect and track the CO<sub>2</sub> plume in different subsurface geological environments. By the end of 2008, approximately 20 Mt of CO<sub>2</sub> had been successfully injected into saline aquifers by existing operations. Currently, the highest injection rate and total storage volume for a single storage operation are approximately 1 Mt CO<sub>2</sub>/year and 25 Mt, respectively. If CCS is to be an effective option for decreasing [GHG] emissions, commercial-scale storage operations will require orders of magnitude larger storage capacity than accessed by the existing sites. As a result, new demonstration projects will need to develop and test injection strategies that consider multiple injection wells and the optimization of the usage of storage space. To accelerate large-scale CCS deployment, demonstration projects should be selected that can be readily employed for commercial use; i.e. projects that fully integrate the capture, transport and storage processes at an industrial emissions source.” **K. Michael, A. Golab, V. Shulakova, J. Ennis-King, G. Allinson, S. Sharma, and T. Aiken**, *International Journal of Greenhouse Gas Control*, Available online January 25, 2010, doi:10.1016/j.ijggc.2009.12.011, <http://www.sciencedirect.com/science/article/B83WP-4Y7MN79-1/2/2f5b9abab49358cd40a7e841b6c92077>.

## GEOLOGY

**“Potential for [enhanced coalbed methane (ECBM)] and CO<sub>2</sub> storage in mixed gas Australian coals.”**

The following is the Abstract of this article: “Coal seams in Australia often contain large volumes of gas and in many cases mixed gas conditions prevail where coal seam gas (CSG) consists of a mixture of CO<sub>2</sub> and methane (CH<sub>4</sub>). While in most coalfields of the world CH<sub>4</sub> is the dominant gas, in

## GEOLOGY (CONTINUED)

Australian coalfields either of the two gases can be the dominant gas. The occurrence of large volumes of CO<sub>2</sub> in Australian coal seams provides valuable insights into the mechanism of long term storage of CO<sub>2</sub> in coal seams. Australia is also a major producer of CSG,



otherwise known as coalbed methane (CBM). Some of the CSG fields in Australia are among the most productive fields in the world and some coal seams have been drained for more than a decade. For coal seams where the gas content is approaching the residual content, the remaining gas may be released if the production is stimulated by injecting CO<sub>2</sub>. In this paper the results from observations of mixed gas conditions in coal seams and laboratory measurements of gas storage and diffusion properties of coals from Sydney Basin coalfields in Australia are reported. While the gas content data show that CH<sub>4</sub> and CO<sub>2</sub> have similar upper limits, the adsorption data show higher storage capacities for CO<sub>2</sub> than for CH<sub>4</sub>. Therefore, the CO<sub>2</sub> undersaturation in coal is more pronounced compared to CH<sub>4</sub> and this seems to be a common aspect of CSG in coal, at least for the coalfields studied. The reasons for CO<sub>2</sub> undersaturation in Australian coals and its effect on potential for CO<sub>2</sub> storage are assessed and discussed in this paper.” **A. Saghafi**, *International Journal of Coal Geology*, Available online January 11, 2010, doi:10.1016/j.coal.2010.01.002, <http://www.sciencedirect.com/science/article/B6V8C-4Y4R2XP-1/2/78edb31a2f7a7f685a934d5f78675348>. (Subscription may be required.)

“A response surface methodology to address uncertainties in cap rock failure assessment for CO<sub>2</sub> geological storage in deep aquifers.”

The following is the Abstract of this article: “Cap rock failure assessment, either tensile fracturing or shear slip reactivation of pre-existing fault, is a key issue for preventing CO<sub>2</sub> leakage from deep aquifer reservoirs up to the surface. For an appropriate use in risk management, the uncertainties associated with such studies should be investigated. Nevertheless, uncertainty analysis requires multiple simulations and a direct use of conventional numerical approaches might be too computer time consuming. An alternative is to use conventional analytical models, but their assumptions appear to be too conservative. An intermediate approach is then proposed based on the response surface methodology, consisting in estimating the effective stress state after CO<sub>2</sub> injection as a linear combination of the most influential site properties based on a limited number of numerical simulations. The decision maker is provided with three levels of information: (1) the identification of the most important site properties; (2) an analytical model for a quick assessment of the maximal sustainable overpressure; and (3) a simplified model to be used in a computationally intensive uncertainty analysis framework. This generic methodology is illustrated with the Paris Basin case using a large-scale hydromechanical model to assess cap rock failure in the injector zone.” **Jeremy Rohmer and Olivier Bouc**, *International Journal of Greenhouse Gas Control*, Available online January 4, 2010, doi:10.1016/j.ijggc.2009.12.001, <http://www.sciencedirect.com/science/article/B83WP-4Y34G8F-1/2/8e4e32307a99810435703d75d1e86f71>. (Subscription may be required.)

“Monitoring Phase Behavior of Sub- and Supercritical CO<sub>2</sub> Confined in Porous Fractal Silica with 85 [Percent] Porosity.”

The following is the Abstract of this article: “Phase behavior of CO<sub>2</sub> confined in porous fractal silica with volume fraction of SiO<sub>2</sub>  $\phi_s = 0.15$  was investigated using small-angle neutron scattering (SANS) and ultrasmall-angle neutron scattering (USANS) techniques. The range of fluid densities ( $0 < (\rho_{\text{CO}_2})_{\text{bulk}} < 0.977 \text{ g/cm}^3$ ) and temperatures ( $T = 22^\circ\text{C}, 35 \text{ and } 60^\circ\text{C}$ ) corresponded to gaseous, liquid, near critical and supercritical conditions of the bulk fluid. The results revealed formation of a dense adsorbed phase in small pores with sizes  $D < 40 \text{ \AA}$  at all temperatures. At low pressure ( $P < 55 \text{ bar}$ ,  $(\rho_{\text{CO}_2})_{\text{bulk}} < 0.2 \text{ g/cm}^3$ ) the average fluid density in pores may exceed the density of bulk fluid by a factor up to 6.5 at  $T = 22^\circ\text{C}$ . This ‘enrichment factor’ gradually decreases with temperature, however significant fluid densification in small pores still exists at temperature  $T = 60^\circ\text{C}$ , i.e., far above the liquid–gas critical temperature of bulk CO<sub>2</sub> ( $T_c = 31.1^\circ\text{C}$ ). Larger pores are only partially filled with liquid-like adsorbed layer which coexists with unadsorbed fluid in the pore core. With increasing pressure, all pores become uniformly filled with the fluid, showing no measurable enrichment or depletion of the porous matrix with CO<sub>2</sub>.” **Yuri B. Melnichenko, H. Mayama, G. Cheng, and T. Blach**, *Langmuir*, Available online December 31, 2009, doi:10.1021/la904032p, <http://pubs.acs.org/doi/abs/10.1021/la904032p>. (Subscription may be required.)

## TECHNOLOGY

“CO<sub>2</sub>-ECBM field tests in the Ishikari Coal Basin of Japan.”

The following is the Abstract of this article: “The feasibility of extracting gas from coal seam while storing CO<sub>2</sub> underground was evaluated in Japan. A CO<sub>2</sub>-ECBM project had begun near the town of Yubari on the island of Hokkaido in northern Japan. The primary coal



seam of interest was 5-6 m thick Yubari coal seam located at the depth of 900 m. A micro-pilot test with a single well and multi-well CO<sub>2</sub> injection tests, involving an injection and production wells, were carried out in the period from May 2004 to October 2007. There were a variety of tests conducted in the injection well, including an initial water-injection falloff test and a series of CO<sub>2</sub> injection and falloff tests. Although gas production rate was obviously enhanced by CO<sub>2</sub> injection, water production rate was not clearly affected by CO<sub>2</sub> injection. Several injection tests suggested that injectivity of CO<sub>2</sub> into the virgin coal seam saturated with water was eventually increased as the water saturation near the injector was decreased by the injected CO<sub>2</sub>. It was estimated that low injectivity of CO<sub>2</sub> was caused by the reduction in permeability induced by coal swelling. [Nitrogen (N<sub>2</sub>)] flooding test was performed in 2006 to evaluate the effectiveness of N<sub>2</sub> injection on improving well injectivity. The N<sub>2</sub> flooding test showed that daily CO<sub>2</sub> injection rate was boosted, but only temporarily. Moreover, the permeability did not return to the initial value after CO<sub>2</sub> and N<sub>2</sub> were repeatedly injected. It was also indicated that the coal matrix swelling might create a high stress zone near to the injection well.” **Masaji Fujioka, Shinji Yamaguchi**,

## TECHNOLOGY (CONTINUED)

and Masao Nako, *International Journal of Coal Geology*, Available online January 25, 2010, doi:10.1016/j.coal.2010.01.004, <http://www.sciencedirect.com/science/article/B6V8C-4Y7P6PT-1/2/5efc9b84a43102b801fde98fa805f0ab>. (Subscription may be required.)

### “Retrieving surface deformation by PSInSAR™ technology: A powerful tool in reservoir monitoring.”

The following is the Abstract of this article: “Reservoir monitoring improves understanding of reservoir behavior and helps achieve more effective reservoir management and prediction of future performance with obvious economic benefits. It relies on an integrated approach involving both surveillance (well or surface based; seismic, electrical, leakage, flow and deformation measurements, etc.) and modeling. Surface deformation monitoring can provide valuable constraints on the dynamic behavior of a reservoir enabling the evaluation of volumetric changes in the reservoir through time. Leveling campaigns, tiltmeters, GPS permanent stations and Permanent Scatterer SAR Interferometry (PSInSAR™) are the techniques most widely used to determine surface displacements. Whatever the surveying technique, the detection of millimeter-level surface deformation is required to monitor small surface displacement rates that could impact risk evaluation and land use planning. Depending on depth and reservoir/overburden rheology, volumetric changes in reservoirs due to fluid extraction and injection can induce either subsidence or uplift that could trigger fault reactivation and threaten well integrity; deformation may also be detectable at the surface. Mapping surface effects accurately requires hundreds of observation points per km<sup>2</sup> which cannot be delivered by traditional monitoring methods without unacceptably large expenditure. PSInSAR™ is one of the most promising and cost-effective techniques capable of providing high precision and high areal density displacement measurements over long periods of time. Moreover, the availability of PS data for both ascending and descending orbits enables the estimation of both vertical and E–W horizontal displacement fields. Two case histories will be presented to illustrate the advantages of PSInSAR™ technology for the detection of surface deformation induced by reservoir exploitation and monitoring of its evolution through time.” **A. Tamburini, M. Bianchi, C. Giannico, and F. Novali**, *International Journal of Greenhouse Gas Control*, Available online January 22, 2010, doi:10.1016/j.ijggc.2009.12.009, <http://www.sciencedirect.com/science/article/B83WP-4Y71D6B-2/2/fb4a76cf64da734c00707e45ae4c1d4a>. (Subscription may be required.)

### “Reactive Transport Modeling to Study Changes in Water Chemistry Induced by CO<sub>2</sub> Injection at the Frio-I Brine Pilot.”

The following is the Abstract of this article: “To demonstrate the potential for geologic storage of CO<sub>2</sub> in saline aquifers, the Frio-I Brine Pilot was conducted, during which 1,600 tons of CO<sub>2</sub> were injected into a high-permeability sandstone and the resulting subsurface plume of CO<sub>2</sub> was monitored using a variety of hydrogeological, geophysical, and geochemical techniques. Fluid samples were obtained before CO<sub>2</sub> injection for baseline geochemical

characterization, during the CO<sub>2</sub> injection to track its breakthrough at a nearby observation well, and after injection to investigate changes in fluid composition and potential leakage into an overlying zone. Following CO<sub>2</sub> breakthrough at the observation well, brine samples showed sharp drops in pH, pronounced increases in HCO<sub>3</sub><sup>-</sup> and aqueous [iron (Fe)], and significant shifts in the isotopic compositions of [water (H<sub>2</sub>O)] and dissolved inorganic carbon. Based on a calibrated 1-D radial flow model, reactive transport modeling was performed for the Frio-I Brine Pilot. A simple kinetic model of Fe release from the solid to aqueous phase was developed, which can reproduce the observed increases in aqueous Fe concentration. Brine samples collected after half a year had lower Fe concentrations due to carbonate precipitation, and this trend can be also captured by the modeling. The paper provides a method for estimating potential mobile Fe inventory, and its bounding concentration in the storage formation from limited observation data. Long-term simulations show that the CO<sub>2</sub> plume gradually spreads outward due to capillary forces, and the gas saturation gradually decreases due to its dissolution and precipitation of carbonates. The gas phase is predicted to disappear after 500 years. Elevated aqueous CO<sub>2</sub> concentrations remain for a longer time, but eventually decrease due to carbonate precipitation. For the Frio-I Brine Pilot, all injected CO<sub>2</sub> could ultimately be sequestered as carbonate minerals.” **Tianfu Xu, Yousif K. Kharaka, Christine Doughty, Barry M. Freifeld, and Thomas M. Daley**, *Chemical Geology*, Available online January 18, 2010, doi:10.1016/j.chemgeo.2010.01.006, <http://www.sciencedirect.com/science/article/B6V5Y-4Y65SG8-1/2/9e4348c1a102c85b485d8e071c82c52b>. (Subscription may be required.)



## TERRESTRIAL

### “Soil organic carbon changes in the cultivation of energy crops: Implications for GHG balances and soil quality for use in LCA.”

The following is the Abstract of this article: “The environmental impact of different land-use systems for energy, up to the farm or forest ‘gate,’ has been quantified with life cycle assessment (LCA). Four representative crops are considered: oilseed rape (OSR), *Miscanthus*, short-rotation coppice (SRC) willow and forest residues. The focus of the LCA is on changes in soil organic carbon (SOC) but energy use, emissions of GHGs, acidification and eutrophication are also considered. In addition to providing an indicator of soil quality, changes in SOC are shown to have a dominant effect on total GHG emissions. *Miscanthus* is the best land-use option for GHG emissions and soil quality as it sequesters [carbon] at a higher rate than the other crops, but this has to be weighed against other environmental impacts where *Miscanthus* performs worse, such as acidification and eutrophication. OSR shows the worst performance across all categories. Because forest residues are treated as a by-product, their environmental impacts are small in all categories. The analysis highlights the need for detailed site-specific modeling of SOC changes, and for consequential



# TERRESTRIAL (CONTINUED)

LCAs of the whole fuel cycle including transport and use.” **Miguel Brandão, Llorenç Milà i Canals, and Roland Clift**, *Biomass and Bioenergy*, Available online January 12, 2010, doi:10.1016/j.biombioe.2009.10.019, <http://www.sciencedirect.com/science/article/B6V22-4Y4XCMW-1/2/26051898140dc493640a7c3fe71df0fb>. (Subscription may be required.)

## Carbon Market Update, February 18, 2010

CCX-CFI 2010 (\$/tCO <sub>2</sub> ) \$0.10 (Vintage 2010)	EU ETS-EUA DEC 2010 (\$/tCO <sub>2</sub> ) \$17.38
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(Converted from € to US\$)

# TRADING

“An overview of current research on EU ETS: Evidence from its operating mechanism and economic effect.”

The following is the Abstract of this article: “The European Union Emissions Trading Scheme (EU ETS) is supposed to be an important mechanism for addressing climate change. Up to now, the theoretical foundation of EU ETS has been widely acknowledged, but empirical research on its current situation has only been published recently or is forthcoming. Therefore, this paper is aimed to summarize the main arguments of empirical studies on the EU ETS, in terms of two aspects, i.e., the operating mechanism and economic effect of the EU ETS, which are two crucial topics and have been attached much attention. Based on the shortcomings of current research and future requirements of the EU ETS evolution, finally, [the authors] also present some further directions of the EU ETS research. Overall, the research overview here may be helpful to recognize the features of the EU ETS and its effect on others.” **Yue-Jun Zhang and Yi-Ming Wei**, *Applied Energy*, Available online January 21, 2010, doi:10.1016/j.apenergy.2009.12.019, <http://www.sciencedirect.com/science/article/B6V1T-4Y6T82B-6/2/646c17a9b105b72dae5b9a6d624ba61d>. (Subscription may be required.)

## RECENT PUBLICATIONS

### Carbon Capture and Sequestration.

The following is a summary of this document: “The last five years have seen a burst of activity around the prospective CCS industry, driven by concerns about the effects of CO<sub>2</sub> emissions on the Earth’s climate. Because emissions from large point sources are a primary source of global climate change, CCS is considered a required set of technologies to mitigate, if not eliminate, the likely rise in the Earth’s temperature. However, to date, no commercial-scale integrated power plant with CCS exists. What’s more, the addition of CCS systems to both existing and future power plants will likely add between 50 [percent] and 70 [percent] to the cost of producing electricity. One fundamental cause of uncertainty for the emerging CCS economy is the lack of a clear price for carbon emissions. While the obstacles to full-scale implementation of CCS are significant, however, there is no doubt that the CCS industry will grow rapidly over the next two decades. This report examines the market issues, technological issues, and opportunities for players in all phases of the CCS industry, from capture technology to transport and storage. It also provides detailed market forecasts for all the major regions of the world, including costs and revenues. While the authors believe that most of the targets for CCS deployments between now and 2030 are optimistic, the industry will grow, under the most aggressive scenario, to reach annual revenues of \$221.5 billion in 2030.” The complete document is available for purchase at: [http://www.researchandmarkets.com/reportinfo.asp?cat\\_id=0&report\\_id=1191502&q=CO2&p=3](http://www.researchandmarkets.com/reportinfo.asp?cat_id=0&report_id=1191502&q=CO2&p=3).

### Carbon Capture and Storage in North East England.

The following is from the Executive Summary of this document: “North East England is the birthplace of modern energy innovation, famous for the development of the steam turbine and electrical lighting. Industry, technologies and coal from the North East powered the global industrial revolution of the last century and the North East now wishes to lead the world in the next low carbon technology revolution. The Regional Development Agency One North East, the Association of North East Councils (ANEC), industrial partners and regional universities are working together to respond to this challenge. The region aims to lead the world in the development of next generation CCS technology responding to the combined challenges of carbon pricing, climate change, rising energy costs and concerns over future security of supply. This North East CCS prospectus has developed from a recognition of the challenges and opportunities for industry and for the UK economy from both industrial process capture and clean coal power generation. The prospectus drivers for this technology on an international level and the urgent requirement for the development of this technology. The prospectus gives an overview of the leading expertise and assets of the region for CCS, the strategic risks and benefits of CCS for the region and the UK and current status of key and next steps.” To view the entire prospectus, click: <http://www.onenortheast.co.uk/lib/liReport/15938/carbon%20capture%2032pp%20A4%207%20aw%20web.pdf>.

## RECENT PUBLICATIONS (CONTINUED)

### Policy Brief: Carbon Dioxide Accounting in Carbon Capture and Sequestration.

The following is from the Introduction of this document: “Accounting for the amount of CO<sub>2</sub> that is captured and sequestered is necessary to demonstrate the effectiveness of CCS as an emissions mitigation tool, and to protect the integrity of a GHG emission reduction program. This will require not only careful accounting of the amount of CO<sub>2</sub> injected in geologic sequestration (GS) projects, but also accounting to ensure that captured CO<sub>2</sub> is ultimately sequestered. In addition, any CO<sub>2</sub> that escapes to the atmosphere across the CCS chain will have to be properly quantified and accounted for under the regime. While accounting for CO<sub>2</sub> in each step in the CCS chain – capture, transport, and sequestration – is important, accounting at the sequestration site is perhaps the most difficult issue to address because it involves monitoring for and measurement of leakage...This brief deals with accounting across the entire CCS chain, but focuses primarily on accounting at GS sites, and hence addresses monitoring at these sites for the purpose of GHG accounting. Accounting for possible emissions from leakage at GS sites involves a range of technical and policy questions. Policy choices are bounded by technological feasibility as well as other considerations such as cost, measurement accuracy and precision, funding stability, and intergenerational equity. In developing [their] recommendations [the authors] analyzed the status of CCS under a GHG emission reduction program, GHG accounting policy options, and leakage monitoring technology. The underlying goal of these recommendations is to design policies and institutions that will ensure CCS supports the integrity of a carbon cap. This is critical for both industry and regulators to justify investment in CCS.” To view the complete document, written for Carnegie Mellon University’s (CMU) CCSReg Project, go to: [http://www.ccsreg.org/pdf/GHG%20Accounting%20Policy%20Brief\\_01042010.pdf](http://www.ccsreg.org/pdf/GHG%20Accounting%20Policy%20Brief_01042010.pdf).

## LEGISLATIVE ACTIVITY

### *Forbes*, “New Mexico Senate Panel Approves Pore Space Bill.”

A Senate committee in New Mexico approved legislation that establishes ownership rights for pore space located beneath New Mexico. SB 145 would provide further certainty for CCS projects in the state by vesting pore space ownership with the surface owner, unless the pore space has been previously severed from the surface owner. The surface estate holder would retain pore space ownership for “all matters relating to the mineral estate” where the pore space has been severed. The proposed legislation specifies that injected CO<sub>2</sub> “shall remain the property and responsibility of the person owning it at the time of injection, unless and until transferred to and accepted by another person.” The bill is considered the first step toward establishing a carbon storage market in New Mexico. SB 145 is available at: <http://legis.state.nm.us/Sessions/10%20Regular/bills/senate/SB0145.pdf>. February 4, 2010, [http://www.forbes.com/feeds/ap/2010/02/04/business-financial-impact-us-the-space-beneath-new-mexico\\_7331916.html?boxes=Homepagebusinessnews](http://www.forbes.com/feeds/ap/2010/02/04/business-financial-impact-us-the-space-beneath-new-mexico_7331916.html?boxes=Homepagebusinessnews).

### *Indianapolis Business Journal*, “Bill Would Give CO<sub>2</sub> Pipeline Firms Right to Take Private Land,” and *Chicago Tribune*, “Indiana Carbon Dioxide Pipeline Bill Advances.”

A bill filed in the Indiana General Assembly would give companies that build CO<sub>2</sub> pipelines the right to obtain private land in their path. According to SB 115, transporting CO<sub>2</sub> via pipeline “is declared to be a public use and service, in the public interest, and a benefit to the welfare of Indiana.” The measure, which cites the potential to reduce CO<sub>2</sub> emissions and promote economic development, could potentially grant eminent domain powers to numerous firms that plan to transport CO<sub>2</sub> through pipelines. SB 115 is available at: <http://www.in.gov/legislative/bills/2010/PDF/SB/SB0115.2.pdf>. January 25, 2010, <http://www.ibj.com/bill-would-give-co2-pipeline-firms-right-to-take-private-land/PARAMS/article/15967>, and January 30, 2010, <http://archives.chicagotribune.com/2010/jan/30/business/chi-ap-in-carbondioxidepipe> (Subscription may be required).



## EVENTS

March 5-6, 2010, **2010 MIT Energy Conference**, *Sheraton Boston Hotel, Boston, Massachusetts, USA*. This student-run conference brings together leaders in the fields of technology, policy, industry, and finance to develop solutions for the world’s energy challenges. Fundamental changes in the way energy is produced and consumed will be explored and technology and policy pathways that have potential to make a significant impact on energy solutions across the global energy landscape will be presented. To learn more, visit the conference website at: <http://www.mitenergyconference.com/index.php>.



## EVENTS (CONTINUED)

March 15-16, 2010, **Platts 18<sup>th</sup> Annual Coal Properties and Investment**, *Habor Beach Marriott Resort and Spa, Ft. Lauderdale, Florida, USA*. This event will cover the challenges facing the coal industry, such as political and regulatory issues, rising costs, and volatile international markets. It also includes in-depth information on international coal demand and supply, coal transportation and logistics, and the financial outlook for coal. For more information, click: <http://www.platts.com/ConferenceDetail.aspx?xmlpath=2010/pc010/index.xml>.

March 23-24, 2010, **The Wall Street Green Trading Summit**, *The Times Center, New York, USA*. The longest running environmental market event in the industry, this summit brings its attendees up-to-date with the latest developments in fields such as carbon trading and finance and renewable energy market opportunities. To learn more, visit the conference website at: <http://www.wsgts.com/>.

March 29-30, 2010, **Future of Coal Combustion Products**, *Jackson Walker LLP Offices, Houston, Texas, USA*. EPA's proposed rules on coal combustion product (CCP) disposal, with regard to technical design and management standards, will be the focus of this conference, as will the industry perspective on the EPA rules and pressing technical and legal issues. Also part of the agenda is a session focused on CCP's contributing role in the reduction of CO<sub>2</sub> emissions. To view the full agenda, visit the conference website at: <http://www.euci.com/conferences/0310-ccp/index.php?ci=936>.

March 29-April 1, 2010, **Sixth IMA Conference on Modeling Permeable Rocks**, *The University of Edinburgh, Edinburgh, Scotland, UK*. Hosted by the Institute of Mathematics and its Applications (IMA), this conference will focus on modeling requirements of permeable and fractured rocks for the geological storage of CO<sub>2</sub>. For more information, visit the conference website at: [http://www.ima.org.uk/Conferences/modelling\\_permeable\\_rocks.html/index.html](http://www.ima.org.uk/Conferences/modelling_permeable_rocks.html/index.html).

April 15-16, 2010, **IGCC Outlook China 2010**, *Ramada Plaza Pudong Shanghai, China*. This conference will focus on the development of Integrated Gasification Combined Cycle (IGCC) technologies in China, including the integration of IGCC with CCS and international cooperation in terms of equipment and solutions. To learn more, visit the conference website at: <http://www.igvision.com/igcc/>.

April 20-21, 2010, **Coal Power Plant Fundamentals**, *Hyatt Regency Chicago, Chicago, Illinois, USA*. This event provides its attendees with basic engineering concepts needed to better understand the workings of a coal-fired power plant. A general overview of a power plant layout will be presented, as will the operating principles. To download a brochure, visit the conference website at: <http://www.euci.com/conferences/0410-coal-power/index.php?ci=957>.

May 10-13, 2010, **9<sup>th</sup> Annual Conference on Carbon Capture & Sequestration**, *Hilton Pittsburgh, Pittsburgh, Pennsylvania, USA*. Following in the footsteps of the previous eight events, this annual, DOE-hosted conference will focus on the potential of present and future CCS technologies deployed in the United States and North America. Members from the U.S. and international scientific and engineering communities will be present to share experiences on such technologies and systems. For more information, visit the conference website at: <http://www.carbonsq.com/>.

May 13-14, 2010, **CO<sub>2</sub> Shipping Conference 2010**, *Millennium Gloucester Hotel and Conference Centre London, London, England*. This conference was developed as a forum to discuss the future potential of CO<sub>2</sub> transportation and its significance as a new market opportunity for gas carrier operators. Attendees will discuss the challenges that face CO<sub>2</sub> transport and the progress that has been made to date. To learn more, visit the conference website at: <http://www.rivieramm.com/events/CO2-Shipping-Conference-24/Event-Home-257>.



## EVENTS (CONTINUED)

May 23-28, 2010, **Energy, Water, and Global Climate Change as a Regional Agenda of the Americas**, *San Diego, California, USA*. The focus of this Pan-American Advanced Studies Institute (PASI) conference is to discuss the current state of research linking energy, water, and global climate change in the Americas. Topics to be covered during this conference include: climate and energy; climate and water; and climate and sustainability. For more information, visit the conference website at: <http://www-rohan.sdsu.edu/~energy/pasi/index.htm>.

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To learn more about DOE's Carbon Sequestration Program, please contact Sean Plasynski at [sean.plasynski@netl.doe.gov](mailto:sean.plasynski@netl.doe.gov), or Dawn Deel at [dawn.deel@netl.doe.gov](mailto:dawn.deel@netl.doe.gov).