

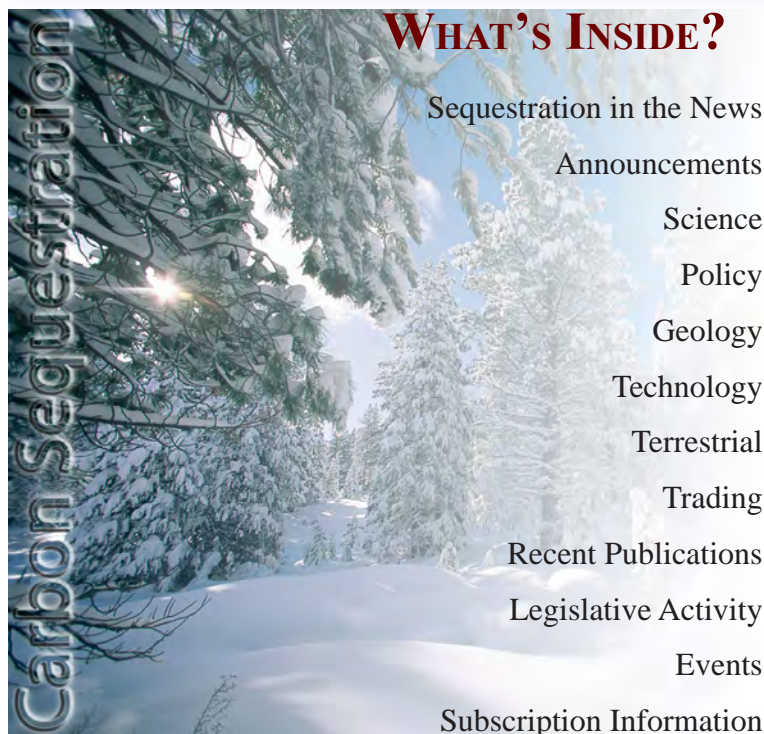


# Carbon Sequestration Newsletter



see page 3

FEBRUARY 2010



## WHAT'S INSIDE?

- Sequestration in the News
- Announcements
- Science
- Policy
- Geology
- Technology
- Terrestrial
- Trading
- Recent Publications
- Legislative Activity
- Events
- Subscription Information

guidance on designing and conducting effective public outreach activities. The primary lesson learned from the Regional Carbon Sequestration Partnerships' (RCSP) experience is that public outreach should be an integrated component of project management; conducting effective public outreach will not necessarily ensure project success, but underestimating its importance can potentially contribute to project delays, increased costs, and lack of community acceptance. In addition to the finding that public outreach should be an integral component of project management, the manual outlines an additional nine best practices. In combination, these 10 practices represent a framework for designing an outreach program that is tailored to the specific characteristics of a planned project, the project developers, and the community in which the project is planned. The recommendations are based on lessons learned by DOE's seven RCSPs during the first six years of the program. Nearly two dozen CO<sub>2</sub> storage field tests are in progress or have been completed by the RCSPs to date. (See Recent Publications section for a portion of the Executive Summary and a link to DOE's "Best Practices for Public Outreach and Education for Carbon Storage Projects.") January 13, 2010, [http://www.fossil.energy.gov/news/techlines/2010/10002-DOE\\_Publishes\\_Best\\_Practices\\_Manua.html](http://www.fossil.energy.gov/news/techlines/2010/10002-DOE_Publishes_Best_Practices_Manua.html).

## INTRODUCTION

This Newsletter is created by the National Energy Technology Laboratory and represents a summary of carbon sequestration news covering the past month. Readers are referred to the actual article(s) for complete information. It is produced by the National Energy Technology Laboratory to provide information on recent activities and publications related to carbon sequestration. It covers domestic, international, public sector, and private sector news.

## HIGHLIGHTS

**Fossil Energy Techline, "DOE Publishes Best Practices Manual for Public Outreach and Education for Carbon Storage Projects."**

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) released a new manual, titled, "Best Practices for Public Outreach and Education for Carbon Storage Projects." The publication is intended to assist project developers in understanding and applying best outreach practices for siting and operating carbon dioxide (CO<sub>2</sub>) storage projects. The manual provides practical, experience-based

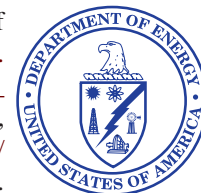
## SEQUESTRATION IN THE NEWS

**Air Products News Release, "Air Products and DOE Sign Agreement for Carbon Capture and Storage Project in Texas."**

On December 17, 2010, Air Products and DOE signed a cooperative agreement to conduct an engineering study and project plant to capture, concentrate, and purify CO<sub>2</sub> emitted from industrial operations for use in enhanced oil recovery (EOR). DOE



will move forward on Phase I of the potential two-phase program, which proposes to design and construct a state-of-the-art system to capture CO<sub>2</sub> from Air Products' steam methane reformers (SMRs) located at a refinery in Port Arthur, Texas; Phase II would recover and purify the CO<sub>2</sub> for delivery via pipeline for EOR in Texas. Valued at \$901,874, the Phase I funding will also further define the method of CO<sub>2</sub> delivery to the pipeline. For more information about similar American Recovery and Reinvestment Act of 2009 (ARRA) projects, click: [http://www.netl.doe.gov/publications/press/2009/09072-DOE\\_Announces\\_Industrial\\_CCS.html](http://www.netl.doe.gov/publications/press/2009/09072-DOE_Announces_Industrial_CCS.html). December 17, 2010, <http://www.airproducts.com/PressRoom/CompanyNews/Archived/2009/17Dec2009.htm>.



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## SEQUESTRATION IN THE NEWS (CONTINUED)

**IFP Press Release, "Transporting CO<sub>2</sub> – Launch of the European COCATE Project Led by IFP:"**

A European research project called "COCATE" will examine the creation of a transportation infrastructure capable of connecting various medium-sized, CO<sub>2</sub>-emitting industrial facilities located within a close proximity to geological storage sites. The project stems from the idea that smaller CO<sub>2</sub>-emitting facilities must pool a CO<sub>2</sub> capture and transportation system in order to reduce costs (major industrial facilities can be fitted with their own CO<sub>2</sub> capture and transport technologies). The Le Havre region of France and the Port of Rotterdam in the Netherlands have been selected as potential test sites. The project will examine two types of transportation infrastructure networks: (1) a local, low-pressure network that collects CO<sub>2</sub> emitted by various Le Havre-based industrial companies and transport it to various capture centers, and (2) a high-pressure network to transport CO<sub>2</sub> to the Port of Rotterdam for storage in depleted North Sea oil and gas fields. Within this construct, the project will review the technical limitations specific to each of the networks; with respect to the upstream low-pressure collection network, the flue gases will be transported as they are to the treatment unit, while the high-pressure network will focus on the effect(s) of the impurities contained in the captured CO<sub>2</sub>. In addition, two CO<sub>2</sub> transportation scenarios will be investigated: (1) by pipeline (CO<sub>2</sub> in supercritical state above 74 bars), and (2) by boat (CO<sub>2</sub> transported in refrigerated liquid form [-50°C, 7 bar or -30°C, 15 bar]). This three-year project includes a risk analysis and a total budget of \$6.5 million, of which nearly \$4.3 million is derived from the European Commission. December 8, 2009, <http://www.ifp.com/actualites/communiqués-de-presse/lancement-du-projet-europeen-cocate>.



***The Regina Leader-Post, "Canadian Government Invests \$[3.8] Million in Carbon Capture and Storage Research," and Western Economic Diversification Canada News Release, "Government of Canada Supports CO<sub>2</sub> Assessment Centre."***

On Friday, January 15, 2010, the Canadian Government announced a \$3.8 million Federal investment in carbon capture and sequestration (CCS) research for the International Performance Assessment Centre for Geological Storage of CO<sub>2</sub> (IPAC-CO<sub>2</sub>) at the University of Regina. The funding will allow IPAC-CO<sub>2</sub> to purchase analytical equipment to better understand CO<sub>2</sub> in the subsurface and provide improved data on storage sites. IPAC-CO<sub>2</sub> will also conduct modeling of carbon capture systems and work with the Canadian Standards Association (CSA) and the International Standards Organization (ISO) to develop the first international standards for geological storage. The \$3.8 million Federal investment comes from the Canada-Saskatchewan Western Economic Partnership Agreement (WEPA), in which both levels of government are contributing \$23.6 million each over four years. January 15, 2010, <http://www.leaderpost.com/technology/Canadian+government+invest+s+million+carbon+capture+storage+research/2447550/story.html>, and January 15, 2010, [http://www.wd.gc.ca/eng/77\\_11804.asp](http://www.wd.gc.ca/eng/77_11804.asp).



# SEQUESTRATION IN THE NEWS (CONTINUED)

*Carbon Capture Journal*, “EU Demonstrates CCS Projects at DNV.”

In December 2009, the European Commission held its first preparatory meeting to discuss how the European network of CCS will provide industry with a vehicle for coordination and exchanging information and experience. The network is coordinated by DNV,

which will provide input to the European Commission for establishing and facilitating the collection and sharing of information within the CCS network. DNV will organize events to help focus the policies and actions that are needed in order to establish a long-term CO<sub>2</sub> value chain. In particular, DNV recently initiated a web-based platform in collaboration with the European Commission. In addition, DNV will launch three CCS guidelines in the near future. For more information about DNV’s CCS activities, go to: [http://www.dnv.com/industry/energy/segments/carbon\\_capture\\_storage/index.asp](http://www.dnv.com/industry/energy/segments/carbon_capture_storage/index.asp). December 21, 2010, <http://www.carboncapturejournal.com/displaynews.php?NewsID=498&PHPSESSID=jk3arpcprh87o507tpqjifob74>.

## ANNOUNCEMENTS

### Total Inaugurates CCS Demonstration Facility.

On January 11, 2010, Total inaugurated its CCS demonstration facility in Lacq, southwestern France. The demonstration facility uses an oxy-combustion carbon capture technology, then pipes the CO<sub>2</sub> approximately 17 miles to the Rouse geological storage site where it is injected into a depleted natural gas reservoir located 4,500 meters underground. Approximately 120,000 metric tons of CO<sub>2</sub> will be captured and stored over the next two years, followed by three years of monitoring. For more information, visit: <http://www.total.com/en/about-total/news/news-940500.html&idActu=2265>.

### CCS Website Launched.

The Zero Emission Resource Organization (ZERO) launched a CCS website aimed at providing comprehensive and transparent information on CCS, including answers to questions related to CCS, a map, and facts on the world’s various CCS projects. The website can be accessed at: <http://www.zeroco2.no/>.

### Call for Papers.

The 9<sup>th</sup> Annual Carbon Capture and Sequestration Conference, scheduled for May 10-13, 2010, at the Hilton Pittsburgh in Pittsburgh, Pennsylvania, is currently accepting papers and poster presentations. Abstracts must be submitted online by February 22, 2010. For more information on the requirements and guidelines, visit: <http://www.carbonsq.com/pdf/2010/call%20for%20papers.pdf>.

### 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>.

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

On March 19, 2010, the German Geophysical Society (DGG) and the Society of Exploration Geophysicists (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>.

## SCIENCE

*Science Daily*, “African Leaf-Eating Primates ‘Likely to Be Wiped Out’ by Climate Change.”

New research has revealed that some monkey species have an increasing risk of extinction due to potential climate change. The study claims that populations of monkeys and apes in Africa that are largely

dependent upon a diet of leaves may be wiped out by a rise of two degrees Celsius in annual temperatures. The study also states that Old World monkey populations in Africa will be most affected by a two degree Celsius increase in global mean temperature, while New World monkeys in South America will largely be unaffected. However, if temperatures rise as much as four degrees Celsius (the most extreme prediction), the South American species will be affected as suitable habitats could diminish (small, fragmented populations are more susceptible to the risks of extinction). The study, published in the online journal *Animal Behaviour*, bases the

## SCIENCE (CONTINUED)

predictions on analyses of the ecological constraints that determine how much time animals are forced to rest, which is influenced by three factors: the percentage of leaves in the animals' diet, the temperature variation, and the mean annual temperature. When the three effects mesh, vulnerable species could be unable to cope, potentially leading to the extinction of their populations. To view the study, titled, "Resting time as an ecological constraint on primate biogeography," click: <http://www.sciencedirect.com/science/article/B6W9W-4XWD01N-1/2/8c3bcc941a58cb713278decb0c34b2e8>. December 21, 2009, <http://www.sciencedaily.com/releases/2009/12/091220174210.htm>.



### **Lamont-Doherty Earth Observatory News Release, "Scientists Target East Coast Rocks for CO<sub>2</sub> Storage."**

Scientists from Columbia University's Lamont-Doherty Earth Observatory (LDEO) believe that basalt formations along the coasts of New York, New Jersey, New England, and further south could serve as reservoirs to store CO<sub>2</sub> emissions from power plants and other industrial point sources. Earlier research shows that CO<sub>2</sub> injected into basalt undergoes natural chemical reactions that will eventually turn it into a solid mineral similar to limestone. The scientists used prior research and seismic and gravity measurements to determine possible offshore basalt formations, including four areas of more than 620 square miles located offshore of northern New Jersey, Long Island, and Massachusetts. In addition, the scientists estimate that the small Sandy Hook basin near New Jersey may contain approximately 4.3 cubic miles of basalt, with the potential to store close to 1 billion tons of CO<sub>2</sub>. According to the authors, the undersea basalt formations are beneficial because: (1) the depth would provide natural pressure to keep the CO<sub>2</sub> from reverting to a gas; (2) the sediments on top would form impermeable caps; and (3) the formations contain porous layers to absorb CO<sub>2</sub> by displacing seawater. Previous research has identified other areas of basalt throughout the Appalachians; the largest appears to extend offshore of Georgia and South Carolina. The study, titled, "Potential on-shore and off-shore reservoirs for CO<sub>2</sub> sequestration in Central Atlantic magmatic province basalts," is available at: <http://www.pnas.org/content/early/2009/12/28/0913721107.abstract?sid=fd113be3-513d-4895-9da9-547a30621ae2>. January 4, 2010, <http://www.ldeo.columbia.edu/news-events/scientists-target-east-coast-rocks-co2-storage>.

## POLICY

**Taiwan Today, "Government Sets Carbon Emission Reduction Goals,"** and **Commodity Online, "Taiwan Sets Goal to Cut CO<sub>2</sub> Emission Levels."**

The Executive Yuan (Executive Branch) of Taiwan announced that it has set short-, medium-, and long-term goals to reduce CO<sub>2</sub> emissions by 87 million metric tons by 2020. The short-term range

is from now until 2020, at which point CO<sub>2</sub> emission levels will be approximately 257 million metric tons, the same as they were in 2005; the medium-term range lasts until 2025, at which point carbon levels should be reduced to 2000 levels; and the long-term range is through 2050, at which point emission levels should be reduced to half of 2000 levels. The newly set goals are expected to accelerate the Taiwanese Government's efforts to reduce CO<sub>2</sub> emissions while benefitting businesses, and to speed up the development of Taiwan's green energy sector. The largest source for CO<sub>2</sub> reduction is expected to be through the use of clean energy, which could potentially reduce emissions by 41 million metric tons. Another 26.7 million metric tons of CO<sub>2</sub> emissions can be reduced by the purchase of CO<sub>2</sub> credits. January 19, 2010, <http://taiwantoday.tw/ct.asp?xItem=92315&CtNode=413>, and January 19, 2010, <http://www.commodityonline.com/news/Taiwan-sets-goal-to-cut-Co2-emission-levels-24882-3-1.html>.

### **"Assessing innovation in emerging energy technologies: Socio-technical dynamics of carbon capture and storage (CCS) and enhanced geothermal systems (EGS) in the USA."**

The following is the Abstract of this article: "This study applies a socio-technical systems perspective to explore innovation dynamics of two emerging energy technologies with potential to reduce [GHG] emissions from electrical power generation in the United States: CCS and enhanced geothermal systems (EGS). The goal of the study is to inform sustainability science theory and energy policy deliberations by examining how social and political dynamics are shaping the struggle for resources by these two emerging, not-yet-widely commercializable socio-technical systems. This characterization of socio-technical dynamics of CCS and EGS innovation includes examining the perceived technical, environmental, and financial risks and benefits of each system, as well as the discourses and actor networks through which the competition for resources – particularly public resources – is being waged. CCS and EGS were selected for the study because they vary considerably with respect to their social, technical, and environmental implications and risks, are unproven at scale and uncertain with respect to cost, feasibility, and life-cycle environmental impacts. By assessing the two technologies in parallel, the study highlights important social and political dimensions of energy technology innovation in order to inform theory and suggest new approaches to policy analysis." **Jennie C. Stephens and Scott Justo**, *Energy Policy*, Available online December 29, 2009, doi: 10.1016/j.enpol.2009.12.003, <http://www.sciencedirect.com/science/article/B6V2W-4Y1W8RX-2/2/847cf28a312ee71c15a8fa0e462e0c48>. (Subscription may be required.)

## GEOLOGY

### **"Buoyant dispersal of CO<sub>2</sub> during geological storage."**

The following is the Abstract of this article: "[CCS] is currently the only technology that may allow significant reductions in CO<sub>2</sub> emissions from large point sources. Seismic images of geological CO<sub>2</sub> storage show the rise of CO<sub>2</sub> is influenced by horizontal shales. The buoyant CO<sub>2</sub> spreads beneath impermeable barriers until a gap allows its upward migration. The large number and small scale of these barriers makes the prediction of the CO<sub>2</sub> migration path and hence the magnitude of CO<sub>2</sub> trapping very challenging. [The authors]

## GEOLOGY (CONTINUED)

show that steady buoyancy dominated flows in complex geometries can be modeled as a cascade of flux partitioning events. This approach allows the analysis of two-dimensional plume dispersal from a horizontal injection well. [The authors] show that the plume spreads laterally with height  $y$  above the source according to  $(y/h)^{1/2} L$ , where  $L$  is the width of the shales and  $h$  is their vertical separation. The fluid volume below successive shale layers, and therefore the magnitude of trapped  $\text{CO}_2$ , increase as  $(y/h)^{5/4}$  above the source, so that every additional layer of barriers traps more  $\text{CO}_2$  than the one below. Upscaling small-scale flow barriers by reducing the vertical permeability, common in numerical simulations of  $\text{CO}_2$  storage, does not capture the dispersion and trapping of the  $\text{CO}_2$  plume by the flow barriers.” **M.A. Hesse and A.W. Woods**, *Geophysical Research Letters*, Available online January 9, 2010, doi: 10.1029/2009GL041128, <http://www.agu.org/pubs/crossref/2010/2009GL041128.shtml>. (Subscription may be required.)

### “Pore-Scale Investigation of the Matrix–Fracture Interaction During $\text{CO}_2$ Injection in Naturally Fractured Oil Reservoirs.”

The following is the Abstract of this article: “Sequestration of  $\text{CO}_2$  into oil and gas reservoirs gains respect as an economically and environmentally convenient way of reducing emissions of [GHG] and increasing hydrocarbon production at the same time. Because the naturally fractured reservoirs (NFRs) constitute a great portion of current and potential  $\text{CO}_2$  injection applications, it is essential to understand the matrix-fracture interaction during such applications to maximize the efficiency of the process, maximizing incremental oil production with maximum  $\text{CO}_2$  storage. Visualization of the phase behavior and flow patterns to/from the fracture and from/to the matrix is critical in understating the process and discovering ways to co-optimize the oil production-[GHG] gas storage process. Hence, pore-scale behavior of the  $\text{CO}_2$ -oil interaction was investigated experimentally using homo- and heterogeneous fractured micromodels. Glass-etched microfluidic models were employed to investigate the pore-scale interaction between the matrix and fracture. Models were prepared by etching homo- and heterogeneous microscale pore patterns with a fracture in the middle of the model on glass sheets bonded together and then saturated with colored n-decane as the oleic phase.  $\text{CO}_2$  was injected at miscible and immiscible conditions. The focus of the study was on visual pore-scale analysis of miscibility, breakthrough of  $\text{CO}_2$ , and oil/ $\text{CO}_2$  transfer between the matrix and fracture under different miscibility conditions. More specifically, the  $\text{CO}_2$ -oil interaction near the fracture region inside the matrix was visualized, and its impacts on the further transport of  $\text{CO}_2$  inside the matrix by diffusion, transfer of oil from the matrix to the fracture and its flow in the fracture, and  $\text{CO}_2$  storage inside the matrix during these processes were analyzed visually.” **Vahapcan Er, Tayfun Babadagli, and Zhenghe Xu**, *Energy Fuels*, Available online December 8, 2009, doi: 10.1021/ef901038v, <http://pubs.acs.org/doi/abs/10.1021/ef901038v>. (Subscription may be required.)

### “Analytical solution for estimating storage efficiency of geologic sequestration of $\text{CO}_2$ .”

The following is the Abstract of this article: “During injection of  $\text{CO}_2$  into deep saline aquifers, the available pore volume of the aquifer may be used inefficiently, thereby decreasing the effective capacity of

the repository for  $\text{CO}_2$  storage. Storage efficiency is the fraction of the available pore space that is utilized for  $\text{CO}_2$  storage, or, in other words, it is the ratio between the volume of stored  $\text{CO}_2$  and the maximum available pore volume. In this note, [the authors] derive and present simple analytical expressions for estimating  $\text{CO}_2$  storage efficiency under the scenario of a constant-rate injection of  $\text{CO}_2$  into a confined, homogeneous, isotropic, saline aquifer. The expressions for storage efficiency are derived from models developed previously by other researchers describing the shape of the  $\text{CO}_2$ -brine interface. The storage efficiency of  $\text{CO}_2$  is found to depend on three dimensionless groups, namely: (1) the residual saturation of brine after displacement by  $\text{CO}_2$ ; (2) the ratio of  $\text{CO}_2$  mobility to brine mobility; (3) a dimensionless group (which [the authors] call a ‘gravity factor’) that quantifies the importance of  $\text{CO}_2$  buoyancy relative to  $\text{CO}_2$  injection rate. In the particular case of negligible residual brine saturation and negligible buoyancy effects, the storage efficiency is approximately equal to the ratio of the  $\text{CO}_2$  viscosity to the brine viscosity. Storage efficiency decreases as the gravity factor increases, because the buoyancy of the  $\text{CO}_2$  causes it to occupy a thin layer at the top of the confined formation, while leaving the lower part of the aquifer under-utilized. Estimates of storage efficiency from our simple analytical expressions are in reasonable agreement with values calculated from simulations performed with more complicated multi-phase-flow simulation software. Therefore, [the authors] suggest that the analytical expressions presented herein could be used as a simple and rapid tool to screen the technical or economic feasibility of a proposed  $\text{CO}_2$  injection scenario.” **Roland T. Okwen, Mark T. Stewart, and Jeffrey A. Cunningham**, *International Journal of Greenhouse Gas Control*, Available online December 8, 2009, doi: 10.1016/j.ijggc.2009.11.002, <http://www.sciencedirect.com/science/article/B83WP-4XWD05C-3/2/aafaa64550f6ed0bff1107cd771de75f>. (Subscription may be required.)

## TECHNOLOGY

### “Near-surface soil carbon detection for monitoring $\text{CO}_2$ seepage from a geological reservoir.”

The following is the Abstract of this article: “The promise of the Brookhaven National Laboratory (BNL) Inelastic Neutron Scattering (INS) System was evaluated for use as a long-term, in-field monitor to detect cumulative changes in belowground carbon resulting from the leakage of  $\text{CO}_2$  stored in deep geological reservoirs. This system underwent



tests at a facility constructed specifically for testing, under controlled conditions, various detection systems for monitoring near-surface transport and accumulations of  $\text{CO}_2$  fluxes emanating from a shallow buried, slotted horizontal well. The INS System was assessed by comparing the results from placing it above the horizontal well at a spot with a known high  $\text{CO}_2$  leak identified and quantified the previous years, with those obtained from background readings adjacent to the well. At two different ‘Hot Spots’, a suppression of about 14 [percent] in 2008 and about [seven percent] in 2009 in carbon content above the well in comparison to the background signal was observed. An overview of these results is presented.” **Lucian Wielopolski and**



## TECHNOLOGY (CONTINUED)

**Sudeep Mitra**, *Environmental Earth Sciences*, Available online December 9, 2009, doi: 10.1007/s12665-009-0397-6, <http://www.springerlink.com/content/a01601q6044u7448/?p=dc01a3c69f88414596b4a8254398d113&pi=10>. (Subscription may be required.)

### “Sharp Front Capturing Method for Carbon Dioxide Plume Propagation during Injection into a Deep Confined Aquifer.”

The following is the Abstract of this article: “An in-depth understanding of patterns and evolutionary characteristics of [CO<sub>2</sub>] plume has significant implications to optimize operational strategies and manage [CO<sub>2</sub>] during and after injection into saline aquifers for long-term geological storage. A sharp-interface mathematical model that describes the displacement process and its interfacial dynamics of [CO<sub>2</sub>]-brine flow in a deep confined saline aquifer was proposed for predicting the propagation of the [CO<sub>2</sub>] plume. On the basis of a conservative level set method (LSM), the governing equation of interfacial dynamics for capturing time-dependent fronts of the [CO<sub>2</sub>] plume was established. It features a unified relationship between the properties of fluids and the saturations in both the single-phase fluid regions, and the interfacial region in the computational domain was derived by the approximation of linear fraction functions. The model equations numerically solved under different operational conditions after the effects of two adjustable parameters in the interfacial dynamics equation that determine stable and convergent interfaces in the simulations were illustrated and analyzed. A comprehensive comparison to the similarity solutions to a benchmark problem was made to illustrate the reliability and accuracy of the proposed approach. The simulation results show that the maximum migration distances predicted by the proposed approach are shorter than those of the similarity solutions, and the patterns and evolutionary characteristics of [CO<sub>2</sub>] plume are intensively dependent upon both injection durations and injection rates at the injection well. The results also show the importance of the effect of vertical mass flux in modeling the migrations of [CO<sub>2</sub>] plume in saline aquifers regardless of injection rates. Moreover, the influences of the underlying assumptions on the interfacial dynamics of the migration of [CO<sub>2</sub>] were analyzed and discussed in detail. The proposed approach and the simulation results will provide insights into the determination of optimal operational strategies and rapid identification of the consequences of [CO<sub>2</sub>] injection into deep confined saline aquifers.”

**Yongzhong Liu, Le Wang, and Bo Yu**, *Energy Fuels*, Available online January 5, 2010, doi: 10.1021/ef9010498, <http://pubs.acs.org/doi/abs/10.1021/ef9010498>. (Subscription may be required.)

### “Integration of post-combustion capture and storage into a pulverized coal-fired power plant.”

The following is the Abstract of this article: “Post-combustion CCS presents a promising strategy to capture, compress, transport and store CO<sub>2</sub> from a high volume–low pressure flue gas stream emitted from a fossil fuel-fired power plant. This work undertakes the simulation of CO<sub>2</sub> capture and compression integration into an 800-MWe, supercritical, coal-fired power plant

using chemical process simulators. The focus is not only on the simulation of full load of flue gas stream into the CO<sub>2</sub> capture and compression, but also, on the impact of a partial load. The result reveals that the energy penalty of a low capture efficiency, for example, at 50 [percent] capture efficiency with 10 [percent] flue gas load is higher than for 90 [percent] flue gas load at the equivalent capture efficiency by about 440 kWh/tonne CO<sub>2</sub>. The study also addresses the effect of CO<sub>2</sub> capture performance by different coal ranks. It is found that lignite pulverized coal (PC)-fired power plant has a higher energy requirement than subbituminous and bituminous PC-fired power plants by 40.1 and 98.6 MWe, respectively. In addition to the investigation of energy requirement, other significant parameters including energy penalty, plant efficiency, amine flow rate and extracted steam flow rate, are also presented. The study reveals that operating at partial load, for example at half load with 90 [percent] CO<sub>2</sub> capture efficiency, as compared with full load, reduces the energy penalty, plant efficiency drop, amine flow rate and extracted steam flow rate by 9.9 [percent], 24.4 [percent], 50.0 [percent] and 49.9 [percent], respectively. In addition, the effect of steam extracted from different locations from a series of steam turbine with the objective to achieve the lowest possible energy penalty is evaluated. The simulation shows that a low extracted steam pressure from a series of steam turbines, for example at 300 kPa, minimizes the energy penalty by up to 25.3 [percent].” **Teerawat Sanpasertparnich, Raphael Idem, Irene Bolea, David deMontigny, and Paitoon Tontiwachwuthikul**, *International Journal of Greenhouse Gas Control*, Available online January 6, 2010, doi: 10.1016/j.ijggc.2009.12.005, <http://www.sciencedirect.com/science/article/B83WP-4Y3K1B8-1/2/c13d269971cc909d9dac16c236c223de>. (Subscription may be required.)



## TERRESTRIAL

### “The spatial variability of CO<sub>2</sub> storage and the interpretation of eddy covariance fluxes in central Amazonia.”

The following is the Abstract of this article: “The landscape of central Amazonia is composed of plateaus and valleys. Previous observations have shown preferential pooling of CO<sub>2</sub> in the valleys, suggesting that the change in CO<sub>2</sub> storage in the canopy air space (*S*) will be spatially variable at the scale



of the topography. This may affect the interpretation of the net ecosystem CO<sub>2</sub> exchange (*NEE*) rates measured on the plateaus if they have used one single atmospheric CO<sub>2</sub> concentration ([CO<sub>2</sub>]) vertical profile measurement system. [The authors] have measured the diel, spatial and seasonal variation of *S* along the topography by using a set of automated [CO<sub>2</sub>] vertical profile measurement systems. In addition, *NEE*, the above-canopy turbulent exchange of CO<sub>2</sub> (*F<sub>c</sub>*) and meteorological variables were also measured on a micrometeorological tower located on the plateau. The nocturnal

# TERRESTRIAL (CONTINUED)

accumulation of CO<sub>2</sub> was larger on the slopes and in the valleys than on the plateau and was larger in the dry period than in the wet period. In addition, the release of this CO<sub>2</sub> occurred later in the day on the slopes and in the valleys than on the plateau. Differences in the flow regime above the canopy along the topographical gradient, lateral drainage of respired CO<sub>2</sub> downslope, and temporal, spatial, and seasonal variation of soil CO<sub>2</sub> efflux ( $R_{soil}$ ) are thought to have contributed to this. These conditions cause  $S$  to be higher in magnitude on the slopes and in the valleys than on the plateau during midmorning hours. [The authors] demonstrate that there is a larger underestimation of  $R_{eco}$  by nighttime eddy covariance (EC) measurements in the dry period than in the wet period. In addition,  $R_{eco}$  – as derived from measurements only on the plateau ( $F_c + S_p$ ) – does not agree with that derived by an independent method. Yet  $S$  fluxes peaked at about 18:00-20:00 on the slopes and in the valleys, following a continuous decrease after this period until reaching a minimum just after dawn.  $NEE$  derived from  $F_c$  measured on the plateau and  $S$  measured on the plateau, slope and valley increased the estimates of  $R_{eco}$  on the plateau by about 30 [percent] and 70 [percent] in the wet and dry periods, respectively. Particularly for flux-tower sites over complex terrain, we recommend measuring the spatial variability of CO<sub>2</sub> at, at least two, more points along the topography to determine to what extent horizontal gradients and storage changes may contribute to tower fluxes. Finally, for sites that present topographical characteristics similar to that described in this study, care must be taken with the use of single in-canopy profiles of [CO<sub>2</sub>] to correct EC fluxes.” **A.C. de Araújo, A.J. Dolman, M.J. Waterloo, J.H.C. Gash, B. Kruijt, F.B. Zanchi, J.M.E. de Lange, R. Stoevelaar, A.O. Manzi, A.D. Nobre, R.N. Looftens, and J. Backer**, *Agricultural and Forest Meteorology*, Available online December 16, 2009, doi: 10.1016/j.agrformet.2009.11.005, <http://www.sciencedirect.com/science/article/B6V8W-4XY4S9M-2/2/dc702470e037abfb8d2583fb638091c8>. (Subscription may be required.)

## Carbon Market Update, January 11, 2010

CCX-CFI 2009 (\$/tCO<sub>2</sub>)  
\$0.10 (Vintage 2009)

EU ETS-EUA DEC 2009  
(\$/tCO<sub>2</sub>) \$19.18

(Converted from € to US\$)

## TRADING

### **RGGI News Release, “States Initiate Bidding Process for March 2010 CO<sub>2</sub> Allowance Auction.”**

On January 12, 2010, the 10 states participating in the Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice and application materials for their seventh CO<sub>2</sub> allowance auction, scheduled for March 10, 2010. The materials provide potential auction participants the information needed to submit a Qualification Application and signify their intent to bid in RGGI Auction 7. According to the Auction Notice for RGGI Auction 7, 40,612,408 CO<sub>2</sub> allowances for the current control period (2009 and [mostly] 2010 vintages), and 2,137,992 CO<sub>2</sub> allowances for the future control period (2013 vintage), will be offered for sale; states will continue to use a reserve price of \$1.86 for all allowances in Auction 7. In addition, the participating states released the auction schedule for 2010; the schedule includes dates for the four quarterly auctions to be held in 2010 and projected quantities of CO<sub>2</sub> allowances to be offered in auctions in 2010 and 2011. The final allowance quantities are published in the Auction Notice prior to each quarterly auction ([www.rggi.org/co2-auctions/upcoming\\_auctions](http://www.rggi.org/co2-auctions/upcoming_auctions)). The March 10, 2010, auction will be the seventh held since the debut of the RGGI auctions on September 25, 2008, and the fifth since compliance obligations under each participating state’s CO<sub>2</sub> Budget Trading Program took effect on January 1, 2009. To date, RGGI has auctioned more than 170 million CO<sub>2</sub> allowances; additional information about previous auction results is available at: [http://www.rggi.org/co2-auctions/market\\_monitor](http://www.rggi.org/co2-auctions/market_monitor). January 12, 2010, [http://www.rggi.org/docs/Auction\\_7\\_notice\\_news\\_release.pdf](http://www.rggi.org/docs/Auction_7_notice_news_release.pdf).

## RECENT PUBLICATIONS

### **Best Practices for Public Outreach and Education for Carbon Storage Projects.**

The following is from the Executive Summary of this document: “This manual represents a distillation of best practices for public outreach and education to support CO<sub>2</sub> storage projects; it is derived from the experiences of the seven RCSPs. Within the scope of the RCSP initiative, the partnerships have recognized the importance of conducting public outreach in tandem with the pilot-scale field tests. The goal of these field tests is to validate CO<sub>2</sub> storage opportunities in each of the RCSP regions. Results obtained from these efforts are providing the foundation for future commercialization efforts – and even more extensive outreach efforts. The best practices highlighted in this manual add a valuable perspective by addressing the practical implications of implementing CO<sub>2</sub> storage projects across a variety of U.S. geologic and cultural settings. The objective of the Public Outreach and Education for Carbon Storage Projects Best Practices Manual is to communicate the lessons learned and to recommend best practices emerging from the first six years of public outreach conducted by the seven RCSPs. The manual is intended to assist project developers in understanding and adopting best practices in outreach to support CO<sub>2</sub> storage projects. Although project developers are the primary audience for this document, other stakeholders may find the contents of this document of interest.” To view this NETL document, visit: [http://www.netl.doe.gov/technologies/carbon\\_seq/refshelf/BPM\\_PublicOutreach.pdf](http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM_PublicOutreach.pdf).

## RECENT PUBLICATIONS (CONTINUED)

### **Guidelines for Public Consultation and Participation in CCS Projects.**

The following is from the Introduction of this document: “The implementation of CCS projects is challenging not only from a technical perspective, but also due to the way that CCS technology touches on controversial subjects. These include human health and safety, climate change, power plant construction, use of fossil fuel resources, risk perception, and several social issues that do not necessarily relate directly to CCS technology. Companies looking to move forward with large-scale demonstration projects face difficult choices regarding when, how and where to begin a public outreach program. A CCS project is a local project but is carried out within the context of national and even international debate. This means that the group of stakeholders or potentially interested parties is considerably broad. This social process of creating support for a CCS project moreover, must occur in parallel with that of storage site selection. Knowledge of regional geology and social factors within local communities is required to execute projects successfully. A proactive approach to education and an outreach program designed to identify real and perceived risks, whilst engaging stakeholders, can build public trust through transparency and information delivery. Although the type of risks involved will vary at each stage of a CCS project, the main challenge from a community engagement perspective lies in the storage component. Nevertheless, understanding all the technologies - capture, transport, and storage - is important from a public education standpoint and it is not advisable to isolate storage when communicating with the public.” To view the full document, click: [http://www.bellona.org/filearchive/fil\\_Guidelines\\_public\\_support\\_for\\_CCS\\_Bellona.pdf](http://www.bellona.org/filearchive/fil_Guidelines_public_support_for_CCS_Bellona.pdf).

### **Carbon Capture, Sequestration, and Emissions Trading: The Outlook for Global Carbon Markets.**

The following is a summary of this document: “Human-generated [CO<sub>2</sub>] and other [GHGs] are acknowledged by the scientific community as having a contributing effect on global climate change. Two major avenues for controlling the spread of carbon are being explored: CCS, in which [CO<sub>2</sub>] is caught at the point of production and piped to a secure facility for long-term storage, and carbon emissions trading, in which producers are allocated allowances for their anticipated carbon production, and can sell any that they do not use (or buy what they need to compensate for any over-production of carbon). This study examines both CCS and the carbon emissions trading market, delineating major drivers and issues (technical, regulatory, and business) for each sector.” The complete document is available for purchase at: [http://www.abiresearch.com/research/1004439-Carbon\\_Capture%2c\\_Sequestration\\_and\\_Emissions\\_Trading](http://www.abiresearch.com/research/1004439-Carbon_Capture%2c_Sequestration_and_Emissions_Trading).

## LEGISLATIVE ACTIVITY

### **Yahoo News, “France Adapts Carbon Tax Climate Plan.”**

On January 20, 2010, France outlined a new, government-proposed carbon tax, which would reduce CO<sub>2</sub> emissions while protecting businesses. The legislation amends a previously rejected effort that aimed at encouraging French consumers to conserve energy. The French government said it planned to maintain a tax of 17 Euros per tonne of CO<sub>2</sub>

with compensation for households. There will be sector-specific measures, as certain “sensitive and energy-intensive sectors” will receive special exemptions. In addition, the government plans to consult with businesses and environmentalists in February 2010 on how to structure the tax. The French Government also said it will push for a European Union (EU)-wide carbon tax that would also apply to imports. The new bill is expected to be submitted to parliament on July 1, 2010. January 20, 2010, [http://news.yahoo.com/s/afp/20100120/sc\\_afp/franceenvironmentclimatepoliticstax\\_20100120152737](http://news.yahoo.com/s/afp/20100120/sc_afp/franceenvironmentclimatepoliticstax_20100120152737).



## EVENTS

February 19-22, 2010, **International Conference on Climate Change and Developing Countries**, Kottayam, Kerala, India. The first major international conference on climate change in the southern part of India, this event is aimed at bringing attention to concerns related to climate change. Topics to be covered include low carbon technologies, impacts and mitigation, and climate change policies. For more information, visit: <http://www.ceetindia.org/ccdc/>.





## EVENTS (CONTINUED)

February 23-24, 2010, **4<sup>th</sup> Annual European Carbon Capture and Storage**, *Hilton Park Lane, London, UK*. This event will provide an update on Europe's developing CCS market, funding allocation, policy changes, lessons learned from European and international case studies, and practical solutions to the challenges of commercialization. For more information, visit the conference website at: <http://www.platts.com/ConferenceDetail.aspx?xmlpath=2010/pc065/index.xml>.

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>.

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/>.

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/>.

## FOR SUBSCRIPTION DETAILS...

Please visit <http://listserv.netl.doe.gov/mailman/listinfo/sequestration>, enter your email address, and create a password. This will enable you to receive a pdf version of the Carbon Sequestration Newsletter at no cost.

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

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