



# Carbon Sequestration Newsletter

SEPTEMBER 2009



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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, “Regional Partner Announces Plans for Carbon Storage Project Using CO<sub>2</sub> Captured from Coal-Fired Power Plant.”**

The Southeast Regional Carbon Sequestration Partnership (SECARB), one of seven members of the U.S. Department of Energy’s (DOE) Regional Carbon Sequestration Partnership (RCSP) Program, and Southern Company have announced plans to store carbon dioxide (CO<sub>2</sub>) captured from an existing coal-fired power plant located in the

Citronelle Oil Field north of Mobile, Alabama. The project will capture approximately 150,000 tons of CO<sub>2</sub> per year from Alabama Power’s Plant Barry (a total equivalent to the emissions from 25 megawatts of the plant’s generating capacity) and inject the CO<sub>2</sub> into a deep saline reservoir 9,000 feet beneath the surface. Under the plan, the CO<sub>2</sub> will be transported by pipeline and injected into the saline formation, which has oil-bearing formations both above and below its location. A monitoring, verification, and accounting (MVA) program will be conducted to track the movement of the injected CO<sub>2</sub> and ensure that it is safely and permanently stored. The project will commence in 2011 and is expected to last up to four years. This test site was selected by SECARB because it is believed to be representative of similar saline formations that possess high potential for CO<sub>2</sub> storage. To learn more about DOE’s RCSP Program, visit: <http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html>, or click: <http://www.secARB.org/> for further information about SECARB. July 20, 2009, [http://www.fossil.energy.gov/news/techlines/2009/09047-SECARB\\_Announces\\_CCS\\_Plans.html](http://www.fossil.energy.gov/news/techlines/2009/09047-SECARB_Announces_CCS_Plans.html).

**Fossil Energy Techline, “Department of Energy Awards \$20 Million for Project to Advance Industrial Carbon Capture and Storage.”**

DOE has awarded Ramgen Power Systems, LLC \$20 million in funding from the American Recovery and Reinvestment Act (ARRA) to advance the commercial deployment of a novel CO<sub>2</sub> compressor, called the Rampressor, which can be used for carbon capture and storage (CCS) in industrial settings.



The Rampressor uses supersonic shockwaves to compress CO<sub>2</sub> for capture and storage and employs a technology that reduces the cost of compressing CO<sub>2</sub>. The device achieves supersonic compression effects in a stationary environment due to a rotating disk in the center that spins at the necessary speed. Also, compared to conventional CO<sub>2</sub> compressors, the Rampressor has fewer parts, a smaller footprint, and lower overall system costs. Current CO<sub>2</sub> compression technologies are costly; too large for many retrofits; and require substantial maintenance costs, including additional electricity needed to run the compressors. For more information on DOE’s Carbon Sequestration Research Program, click: <http://www.fossil.energy.gov/programs/sequestration/index.html>. August 10, 2009, [http://www.fossil.energy.gov/news/techlines/2009/09055-DOE\\_Announces\\_Ramgen\\_Power\\_Systems.html](http://www.fossil.energy.gov/news/techlines/2009/09055-DOE_Announces_Ramgen_Power_Systems.html).



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## SEQUESTRATION IN THE NEWS

*Denbury Resources Inc. News Release*, "Denbury Undertakes Midwest CO<sub>2</sub> Pipeline Feasibility Study," and *Pipelines International*, "Denbury Studies Midwest Carbon Dioxide Pipelines."

Denbury Resources has begun a feasibility study of a possible CO<sub>2</sub> pipeline project that would connect several proposed gasification plants to existing pipeline infrastructure in the Mississippi-Louisiana region. The study will determine the most likely pipeline route(s), estimated construction costs, and regulatory requirements. Denbury's initial estimates suggest a 500- to 700-mile pipeline system with a preliminary cost estimate of approximately \$1.0 billion. The potential pipeline project is projected to take four to five years to complete. The study coincides with two proposed Midwestern gasification plants, both of which have CO<sub>2</sub> purchase contracts with Denbury, being selected to proceed to the term sheet negotiation phase under the DOE loan guarantee program. The program also selected a third proposed gasification plant that will be built along the Gulf Coast of Mississippi and could connect to the existing Free State Pipeline. July 13, 2009, <http://phx.corporate-ir.net/phoenix.zhtml?c=72374&p=irol-newsArticle&ID=1307101&highlight=>, and July 28, 2009, [http://pipelinesinternational.com/news/denbury\\_studies\\_midwest\\_carbon\\_dioxide\\_pipelines/004171/](http://pipelinesinternational.com/news/denbury_studies_midwest_carbon_dioxide_pipelines/004171/).



*University of Kentucky News Release*, "Deep Well Begins CO<sub>2</sub> Sequestration Test."

The Kentucky Geological Survey (KGS) began injecting CO<sub>2</sub> into an 8,126-foot deep well at a test site in Hancock County, Kentucky, in July. The project will store the CO<sub>2</sub> deep underground to demonstrate the feasibility of carbon storage in deep, western Kentucky geologic formations. KGS and industry scientists and engineers have already used brine to confirm that the Knox Dolomite section will sequester CO<sub>2</sub> at depths in the range of 3,800 to 7,400 feet. Funding for the project is provided from a \$1.5 million allocation from a grant by the Kentucky General Assembly in 2007, as well as a total of \$6.5 million in grants from the National Energy Technology Laboratory (NETL), the Western Kentucky Carbon Storage Foundation, and the Illinois Office of Coal Development and Marketing. Peabody Energy, ConocoPhillips, E.ON U.S., and the Tennessee Valley Authority created the Western Kentucky Carbon Storage Foundation to provide funding and technical assistance to the project. August 18, 2009, [http://news.uky.edu/news/display\\_article.php?category=8&artid=4958](http://news.uky.edu/news/display_article.php?category=8&artid=4958).



# SEQUESTRATION IN THE NEWS

## (CONTINUED)

### ***Encore Acquisition Company Press Release, “Encore Acquisition Company Announces CO<sub>2</sub> Supply Agreement and Planned Tertiary Recovery Project in its Bell Creek Field.”***

On July 28, 2009, Encore Acquisition Company announced that it had agreed to acquire a CO<sub>2</sub> supply that will be used for an enhanced oil recovery (EOR) project in Encore’s Bell Creek Field. Under the

agreement, Encore will purchase all of the volumes available from the Lost Cabin Gas Plant located in Fremont County, Wyoming. Encore plans to build compression facilities near the plant and construct a 206-mile pipeline to transport the compressed CO<sub>2</sub>, which is estimated at approximately 50 million cubic feet per day, to the Bell Creek Field. The project is expected to yield an incremental 30.1 million barrels of oil. With 100 percent of the available CO<sub>2</sub> volumes being utilized, production is estimated to exceed 6,500 barrels of oil per day by 2015. The project will be divided into seven phases and is expected to cost approximately \$425 million. July 28, 2009, <http://www.encoreacq.com/releasedetail.cfm?ReleaseID=399604>.

## ANNOUNCEMENTS

### **NETL Technologies Earn Prestigious R&D 100 Awards.**

The Office of Fossil Energy (FE) has captured four 2009 Research and Development (R&D) 100 Awards for technologies developed at NETL. Since 2000, NETL researchers and NETL-supported technologies have won more than 30 R&D 100 Awards, which are presented to the 100 most technically significant products to enter the marketplace in the past year. For more information on the four winning technologies, click: [http://www.fossil.energy.gov/news/techlines/2009/09048-NETLTechnologies\\_Earn\\_Prestigious\\_.html](http://www.fossil.energy.gov/news/techlines/2009/09048-NETLTechnologies_Earn_Prestigious_.html).

### **WESTCARB Annual Meeting.**

The West Coast Regional Carbon Sequestration Partnership (WESTCARB) will hold the WESTCARB 2009 Annual Business Meeting at the FireSky Resort and Spa in Scottsdale, Arizona, on September 15-16, 2009. Meeting topics include: Phase II geologic and terrestrial field projects, improved characterization of regional CO<sub>2</sub> storage opportunities, progress for the Phase III large-volume geologic storage test, and national and state legislative/regulatory developments. More information is available at: [http://www.westcarb.org/AnnualMtg\\_scottsdale\\_announcement.html](http://www.westcarb.org/AnnualMtg_scottsdale_announcement.html).

### **BSCSP Annual Meeting.**

The Big Sky Carbon Sequestration Partnership (BSCSP) will hold its annual meeting at the Gallatin Gateway Inn in Bozeman, Montana, on September 23-24, 2009. Experts will discuss carbon sequestration technologies; CCS economics, costs, and opportunities; Federal and state regulatory procedures; energy policies; and carbon sequestration site development. Registration is free and open to the public until September 11, 2009; audience members will have an opportunity to ask questions following panel presentations. Registration information is available at: [http://www.bigskyco2.org/annual\\_meeting09](http://www.bigskyco2.org/annual_meeting09), or to view the agenda, go to: [http://www.bigskyco2.org/files/pdfs/Annual\\_Agenda\\_2009.pdf](http://www.bigskyco2.org/files/pdfs/Annual_Agenda_2009.pdf).

### **Call for U.S. Participation in European Commission’s FP7 on CCS.**

Through its Seventh Framework Programme (FP7), the European Commission has issued calls for R&D proposals related to CCS that are open to U.S. organizations. This opportunity has been made possible under the “Implementing Agreement Between the Department of Energy of the United States of America and the European Commission for Non-Nuclear Energy Scientific and Technological Cooperation.” For information on the proposals, go to: [http://www.fossil.energy.gov/international/ec\\_call\\_for\\_us\\_participation.pdf](http://www.fossil.energy.gov/international/ec_call_for_us_participation.pdf).

### **EUCI Web Conferences.**

Electric Utility Consultants, Inc. (EUCI) is conducting two web seminars covering a wide range of CCS topics. The first seminar, “CO<sub>2</sub> Technical Webinar,” will be held on September 18 and discuss the simulation and seismic monitoring of CO<sub>2</sub>, EOR, and sequestration. The second seminar, “Regulatory Future of Carbon Capture and Sequestration,” will be held on October 2 and present the legal, legislative, and strategic policy issues confronted by state legislatures in addressing CCS issues and solutions. To learn more, visit the EUCI website at: [http://www.euci.com/web\\_conferences.php](http://www.euci.com/web_conferences.php).

## SCIENCE

### **Fossil Energy Techline, “Bees, Balloons, Pollen Used as Novel CO<sub>2</sub> Monitoring Approach.”**

Bees, helium-filled balloons, and pollen can now be used to verify that there is no CO<sub>2</sub> released at carbon sequestration sites, according to researchers from NETL. Researchers believe this discovery will help to determine the environmental impact without disrupting habitats surrounding sequestration sites, while ensuring the effectiveness of carbon storage. The technique involves co-injecting chemical tracers at low levels to “fingerprint” the CO<sub>2</sub> during storage, allowing it to be differentiated from neutral CO<sub>2</sub>. In cooperation with bee experts at Montana State University (MSU), NETL researchers conducted several detailed tests to determine if pollen collected by bees contains measurable quantities of the tracer, or if bees bring back the tracer from direct contact with foliage. Atmospheric tracer levels were also monitored using an extensive grid of monitors and a light detection and ranging system was employed by MSU researchers to correlate field tracer levels with bee foraging locations. Apogee Scientific was contracted by NETL researchers to use a large, helium-filled balloon to elevate a carousel containing sealed sorbent tubes for sequential exposure at known times and elevations to determine if atmospheric plume monitoring of tracer would be a feasible approach. The studies were conducted at the Center for Zero Emissions Research and Technology research site at MSU. July 29, 2009, [http://www.fossil.energy.gov/news/techlines/2009/09049-Bees%2C\\_Balloons%2C\\_Pollen\\_Monitor\\_CO2.html](http://www.fossil.energy.gov/news/techlines/2009/09049-Bees%2C_Balloons%2C_Pollen_Monitor_CO2.html).



### **Science Daily, “Higher Carbon Dioxide May Give Pine Trees A Competitive Edge.”**

A team of Duke University researchers have found that pine trees grown for 12 years in air that is one-and-a-half times richer in CO<sub>2</sub> than today’s levels can produce twice as many seeds of at least the same quality as those growing under normal conditions. It was previously found that grasses and other herbaceous plants can also produce more seeds under higher levels of CO<sub>2</sub>, but the seeds are of inferior quality. To come to their conclusions, researchers collected, counted, and analyzed seeds produced at the Duke Free Air CO<sub>2</sub> Enrichment (FACE) site in Duke Forest, where growing parcels of loblolly pine trees have been receiving elevated amounts of CO<sub>2</sub> since 1997 as part of a DOE-funded project designed to simulate natural growing conditions. The results showed that the high-CO<sub>2</sub> loblolly seeds were similar in nutrient content, germination, and growth potential to the seeds produced from trees growing under present-day CO<sub>2</sub> concentrations. These findings were presented during the Ecological Society of America’s 2009 annual meeting in Albuquerque, New Mexico, on August 3, 2009. August 4, 2009, <http://www.sciencedaily.com/releases/2009/08/090803173246.htm>.



## POLICY

### **Reuters, “U.S. and China Sign Memorandum on Climate Change.”**

The United States and China signed a Memorandum of Understanding (MOU) on July 28, 2009, that states the nations agree to cooperate on climate change, energy, and environment issues. During the talks, U.S. and Chinese officials discussed how to reduce GHG emissions before the United Nations (U.N.) conference in Copenhagen later this year that aims to set new global goals for climate change. The MOU, which was released by the State Department, also created a new climate change policy “dialogue,” which lists 10 areas of cooperation, including energy efficiency, renewable energy, cleaner use of coal, and R&D. The two countries also launched a \$15 million joint project – a portion of this funding will be used to study the development of clean coal technologies. July 28, 2009, <http://www.reuters.com/article/vcCandidateFeed1/idUSN28530225>.

### **Newsday.com, “NY Governor Signs Order Setting Emissions Goal.”**

The Governor of New York signed an executive order on August 6, 2009, that sets a statewide goal of cutting GHG emissions to 80 percent below 1990 levels by mid-century. The economic impacts will be examined by a new council that represents various state agencies and a plan to reach the target levels will be prepared by September 2010. The 1990 baseline for New York’s emissions is 277 million tons; currently, the state’s emission levels are approximately 290 million tons. Under the order, New York’s state emissions are expected to be reduced to 55 million tons by 2050. The state also has joined the Regional Greenhouse Gas Initiative (RGGI) for capping power plant emissions and auctioning carbon allowances. To view the 2009 State Energy Plan Draft, visit: <http://www.scribd.com/doc/18375962/Draft-Energy-Plan-Final>. August 6, 2009, <http://www.newsday.com/ny-governor-signs-order-setting-emissions-goal-1.1352587>.

### **“Policy interactions, risk and price formation in carbon markets.”**

The following is the Abstract of this article: “Carbon pricing is an important mechanism for providing companies with incentives to invest in carbon abatement. Price formation in carbon markets involves a complex interplay between policy targets, dynamic technology costs, and market rules. Carbon pricing may under-deliver investment due to R&D externalities, requiring additional policies which themselves affect market prices. Also, abatement costs depend on the extent of technology deployment due to learning-by-doing. This paper introduces an analytical framework based on marginal abatement cost (MAC) curves with the aim of providing an intuitive understanding of the key dynamics and risk factors in carbon markets. The framework extends the usual static MAC representation of the market to incorporate policy interactions and some technology cost dynamics. The analysis indicates that supporting large-scale deployment of mature abatement technologies suppresses the marginal cost of abatement, sometimes to zero, whilst increasing total abatement costs. However, support for early stage R&D may reduce both total abatement cost and carbon price

## POLICY (CONTINUED)

risk. An important aspect of the analysis is in elevating risk management considerations into energy policy formation, as the results of the stochastic modeling indicate wide distributions for the emergence of carbon prices and public costs around the policy expectations.” **William Blyth, Derek Bunn, Janne Kettunen, and Tom Wilson**, *Energy Policy*, Available online August 18, 2009, doi:10.1016/j.enpol.2009.07.042, <http://www.science-direct.com/science/article/B6V2W-4X1GG38-4/2/6a0c0cb0486ce6420adedd912b40f914b>. (Subscription may be required.)

## GEOLOGY

“Greenhouse gas mitigation in a carbon constrained world: The role of carbon capture and storage.”

The following is the Abstract of this article: “CCS promises to allow for low-emissions fossil-fuel-based power generation. The technology is under development; a number of technological, economic, environmental and safety issues remain to be solved. CCS may prolong the prevailing coal-to-electricity regime and countervail efforts in other mitigation categories. Given the need to continue using fossil-fuels for some time, however, it may also serve as a bridging technology towards a renewable energy future. In this paper, [the authors] analyze the structural characteristics of the CCS innovation system and perform an energy-environment-economic analysis of the potential contribution of CCS, using a general equilibrium model for Germany. [The authors] show that a given climate target can be achieved at lower marginal costs when the option of CCS is included into the mix of mitigation options. [The authors] conclude that, given an appropriate legal and policy framework, CCS, energy efficiency and some other mitigation efforts are complementary measures and should form part of a broad mix of measures required for a successful CO<sub>2</sub> mitigation strategy.” **Barbara Praetorius and Katja Schumacher**, *Energy Policy*, Available online August 8, 2009, doi: 10.1016/j.enpol.2009.07.01, <http://www.sciencedirect.com/science/article/B6V2W-4WYCT88-2/2/2069a4623c20490a71b2ca55b5abf1c3>. (Subscription may be required.)

“New Trapping Mechanism in Carbon Sequestration.”

The following is the Abstract of this article: “The modes of geologic storage of CO<sub>2</sub> are usually categorized as structural, dissolution, residual, and mineral trapping. Here [the authors] argue that the heterogeneity intrinsic to sedimentary rocks gives rise to a fifth category of storage, which we call local capillary trapping. Local capillary trapping occurs during buoyancy-driven migration of bulk phase CO<sub>2</sub> within a saline aquifer. When the rising CO<sub>2</sub> plume encounters a region (10–2 to 10+1m) where capillary entry pressure is locally larger than average, CO<sub>2</sub> accumulates beneath the region. This form of storage differs from structural trapping in that much of the accumulated saturation will not escape, should the integrity of the seal overlying the aquifer be compromised. Local capillary trapping differs from residual trapping in that the accumulated saturation can be much larger than the residual saturation for the rock. [The authors] examine local capillary trapping in a series of numerical simulations. The essential feature is that the drainage curves (capillary pressure versus saturation for CO<sub>2</sub>

displacing brine) are required to be consistent with permeabilities in a each grid block has its own drainage curve, scaled from a reference curve to the permeability and porosity in that block. [The authors] find that capillary heterogeneity controls the path taken by rising CO<sub>2</sub>. The displacement front is much more ramified than in a homogeneous domain, or in a heterogeneous domain with a single drainage curve. Consequently, residual trapping is overestimated in simulations that ignore capillary heterogeneity. In the cases studied here, the reduction in residual trapping is compensated by local capillary trapping, which yields larger saturations held in a smaller volume of pore space. Moreover, the amount of CO<sub>2</sub> phase remaining mobile after a leak develops in the caprock is smaller. Therefore, the extent of immobilization in a heterogeneous formation exceeds that reported in previous studies of buoyancy-driven plume movement.” **Eshan Saadatpoor, Steven L. Bryant, and Kamy Sepehrnoori**, *Transport in Porous Media*, Available online August 4, 2009, doi: 10.1007/s11242-009-9446-6, <http://www.springerlink.com/content/r0703xn633632u15/?p=97d3dd493d0f4afc88a0d87441ba7f26&pi=3>. (Subscription may be required.)

“Basin-scale hydrogeologic impacts of CO<sub>2</sub> storage: Capacity and regulatory implications.”

The following is the Abstract of this article: “Industrial-scale injection of CO<sub>2</sub> into saline formations in sedimentary basins will cause large-scale fluid pressurization and migration of native brines, which may affect valuable groundwater resources overlying the deep sequestration aquifers. In this paper, we discuss how such basin-scale hydrogeologic impacts (1) may reduce current storage capacity estimates, and (2) can affect regulation of CO<sub>2</sub> storage projects. Our assessment arises from a hypothetical future carbon sequestration scenario in the Illinois Basin, which involves twenty individual CO<sub>2</sub> storage projects (sites) in a core injection area most suitable for long-term storage. Each project is assumed to inject five million tonnes of CO<sub>2</sub> per year for 50 years. A regional-scale three-dimensional simulation model was developed for the Illinois Basin that captures both the local-scale CO<sub>2</sub>–brine flow processes and the large-scale groundwater flow patterns in response to CO<sub>2</sub> storage. The far-field pressure buildup predicted for this selected sequestration scenario support recent studies in that environmental concerns related to near- and far-field pressure buildup may be a limiting factor on CO<sub>2</sub> storage capacity. In other words, estimates of storage capacity, if solely based on the effective pore volume available for safe trapping of CO<sub>2</sub>, may have to be revised based on assessments of pressure perturbations and their potential impacts on caprock integrity and groundwater resources. Our results suggest that (1) the area that needs to be characterized in a permitting process may comprise a very large region within the basin if reservoir pressurization is considered, and (2) permits cannot be granted on a single-site basis alone because the near- and far-field hydrogeologic response may be affected by interference between individual storage sites. We also discuss some of the challenges in making reliable predictions of large-scale hydrogeologic impacts related to CO<sub>2</sub> sequestration projects.” **Jens T. Birkholzer and Quanlin Zhou**, *International Journal of Greenhouse Gas Control*, Available online August 8, 2009, doi:10.1016/j.ijggc.2009.07.002, <http://www.sciencedirect.com/science/article/B83WP-4WYCTC4-1/2/9119c6c4c48060cc95cbc729f959cced>. (Subscription may be required.)

# TECHNOLOGY

## “A Phase-Partitioning Model for CO<sub>2</sub>-Brine Mixtures at Elevated Temperatures and Pressures: Application to CO<sub>2</sub>-Enhanced Geothermal Systems”

The following is the Abstract of this article: “Correlations are presented to compute the mutual solubilities of CO<sub>2</sub> and chloride brines at temperatures 12-300°C, pressures 1-600 bar (0.1-60 MPa), and salinities 0-6 m [sodium chloride (NaCl)]. The formulation is computationally efficient and primarily intended for numerical simulations of CO<sub>2</sub>-water flow in carbon sequestration and geothermal studies. The phase-partitioning model relies on experimental data from literature for phase partitioning between CO<sub>2</sub> and NaCl brines, and extends the previously published correlations to higher temperatures. The model relies on activity coefficients for the [water (H<sub>2</sub>O)]-rich (aqueous) phase and fugacity coefficients for the CO<sub>2</sub>-rich phase. Activity coefficients are treated using a Margules expression for CO<sub>2</sub> in pure water, and a Pitzer expression for salting-out effects. Fugacity coefficients are computed using a modified Redlich-Kwong equation of state and mixing rules that incorporate asymmetric binary interaction parameters. Parameters for the calculation of activity and fugacity coefficients were fitted to published solubility data over the P-T range of interest. In doing so, mutual solubilities and gas-phase volumetric data are typically reproduced within the scatter of the available data. An example of multiphase flow simulation implementing the mutual solubility model is presented for the case of a hypothetical, enhanced geothermal system where CO<sub>2</sub> is used as the heat extraction fluid. In this simulation, dry supercritical CO<sub>2</sub> at 20°C is injected into a 200°C hot-water reservoir. Results show that the injected CO<sub>2</sub> displaces the formation water relatively quickly, but that the produced CO<sub>2</sub> contains significant water for long periods of time. The amount of water in the CO<sub>2</sub> could have implications for reactivity with reservoir rocks and engineered materials.” **Nicolas Spycher and Karsten Pruess**, *Transport in Porous Media*, Available online July 17, 2009, doi: 10.1007/s11242-009-9425-y, <http://www.springerlink.com/content/t1h0744x531x4105/?p=f92985fed6f4ef3abfe1f855b86ff7c&pi=15>. (Subscription may be required.)

## “CO<sub>2</sub> capture and sequestration source-sink match optimization in Jing-Jin-Ji region of China.”

The following is the Abstract of this article: “CCS is considered to be an important option for climate change mitigation. A key problem for the implementation of CCS technology is the source-sink match design and optimization when considering both economic and environmental requirement. This paper presents a generic-optimization-based model for the strategic planning and design of future CCS source-sink matching. The features and capabilities of the model are illustrated through a detailed case study for the Jing-Jin-Ji (Beijing, Tianjin, and Hebei Province) region in China. It shows how the model helps make a compromise in arriving at a strategic decision for CCS source-sink matching by providing the tradeoff frontiers between economic and environmental performance, and the features of match solutions with the best economic performance or with the best environmental performance.” **Zhong Zheng, Dan Gao, Linwei Ma, Zheng Li, and Weidou Ni**, *Frontiers of Energy and Power Engineering in China*, Available

online July 21, 2009, doi: 10.1007/s11708-009-0053-6, <http://www.springerlink.com/content/m677h0p704722132/?p=97d3dd493d0f4afc88a0d87441ba7f26&pi=9>. (Subscription may be required.)



# TERRESTRIAL

## “A review of applications of model-data fusion to studies of terrestrial carbon fluxes at different scales.”

The following is the Abstract of this article: “Model-data fusion is defined as matching model prediction and observations by varying model parameters or states using statistical estimation. In this paper, [the authors] review the history of applications of various model-data fusion techniques in studies of terrestrial carbon fluxes in two approaches: top-down approaches that use measurements of global CO<sub>2</sub> concentration and sometimes other atmospheric constituents to infer carbon fluxes from the land surface, and bottom-up approaches that estimate carbon fluxes using process-based models. [The authors] consider applications of model-data fusion in flux estimation, parameter estimation, model error analysis, experimental design and forecasting. Significant progress has been made by systematically studying the discrepancies between the predictions by different models and observations. As a result, some major controversies in global carbon cycle studies have been resolved, robust estimates of continental and global carbon fluxes over the last two decades have been obtained, and major deficiencies in the atmospheric models for tracer transport have been identified. In the bottom-up approaches, various optimization techniques have been used for a range of process-based models. Model-data fusion techniques have been successfully used to improve model predictions, and quantify the information content of carbon flux measurements and identify what other measurements are needed to further constrain model predictions. However, [the authors] found that very few studies in both top-down and bottom-up approaches have quantified the errors in the observations, model parameters and model structure systematically and consistently. [The authors] therefore suggest that future research will focus on developing an integrated Bayesian framework to study both model and measurement errors systematically.” **Ying-Ping Wang, Cathy M. Trudinger, and Ian G. Enting**, *Agricultural and Forest Meteorology*, Available online August 15, 2009, doi: 10.1016/j.agrformet.2009.07.009, <http://www.sciencedirect.com/science/article/B6V8W-4X0W4H0-1/2/4ac b106f0b982a481f5094b3e700764a>. (Subscription may be required.)

## Carbon Market Update, August 14, 2009

CCX-CFI 2009 (\$/tCO<sub>2</sub>)  
\$0.25 (Vintage 2009)

EU ETS-EUA DEC 2009  
(\$/tCO<sub>2</sub>) \$20.27

(Converted from € to US\$)

# TRADING

**RGGI News Release, “RGGI Participating States Open Fifth Auction Cycle with Release of Application Materials.”**

## TRADING (CONTINUED)

The 10 states participating in RGGI released the Auction Notice and application materials for the fifth regional CO<sub>2</sub> allowance auction scheduled for Wednesday, September 9, 2009. The materials provide the information needed to submit a qualification application. In Auction 5, the states will continue to employ a reserve price of \$1.86 for all allowances; 28,408,945 allowances for the future control period (all for the 2012 vintage) will be auctioned. Auction 5 will be the third auction held since compliance obligations under each participating state's CO<sub>2</sub> Budget

Trading Program took effect on January 1, 2009 (RGGI's participating states also held two "pre-compliance" auctions in September 2008 and December 2008). To date, the states participating in RGGI have auctioned more than 110 million allowances. Under RGGI protocols, the power sector in participating states caps CO<sub>2</sub> emissions at current levels through 2014; the cap will then be reduced by 2.5 percent each year from 2015 to 2018, totaling a 10 percent reduction. For more information, visit: <http://www.rggi.org/>, or click: <http://www.rggi.org/co2-auctions/information> to download the auction materials. July 15, 2009, [http://www.rggi.org/docs/Auction\\_5\\_notice\\_release.pdf](http://www.rggi.org/docs/Auction_5_notice_release.pdf).

## RECENT PUBLICATIONS

### **"Near-Term Technologies for Retrofit CO<sub>2</sub> Capture and Storage of Existing Coal-fired Power Plants in the United States."**

The following is the Summary of this White Paper: "Coal-fired power plants, as large point sources of CO<sub>2</sub>, are the logical choice for CO<sub>2</sub> mitigation, via CCS and other options. However, continuing life extension of the relatively old and inefficient fleet of existing U.S. coal power plants undermines potential CO<sub>2</sub> mitigation efforts. New coal power plants, with CO<sub>2</sub> capture and geologic storage will slow the rate of growth of CO<sub>2</sub> emissions but the large existing fleet of coal power plants needs to be replaced with lower CO<sub>2</sub> power sources or retrofitted with CCS to significantly lower CO<sub>2</sub> emissions. In the near term, and perhaps medium term, there are inadequate non-coal, low-CO<sub>2</sub> emitting alternatives to replace the existing 50 [percent] coal-based electricity in the U.S. and 40 [percent] worldwide. Therefore to become serious about major CO<sub>2</sub> reductions, consideration should be given to CCS retrofits of existing coal power plants. Existing coal plants represent approximately 33 [percent] of total U.S. CO<sub>2</sub> emissions. As such, the retrofit or rebuild of U.S. existing coal power plants with CCS represents significant opportunities for major CO<sub>2</sub> reductions. Retrofits and rebuilds, however, face many technical, economic and political challenges. The low cost electricity from these mostly paid-off (fully amortized) existing coal plants leads to very high CO<sub>2</sub> avoidance costs. In addition, the simpler and less capital-intensive retrofit add-on for post-combustion CCS leads to large net efficiency and capacity losses. This type of retrofit will likely favor the newer supercritical steam cycle coal units that already have good [sulfur dioxide (SO<sub>2</sub>)] and [nitrogen oxide (NO<sub>x</sub>)] controls. Rebuilds of the older subcritical steam cycle coal units have added advantages and flexibility. Due to the lower efficiency and generally higher SO<sub>2</sub>, NO<sub>x</sub>, [mercury (Hg)] and particulate emissions of the older existing subcritical coal units, rebuilds can avoid most net efficiency and capacity losses while reducing all emissions to near zero. This is an important advantage. Rebuilds can come in the form of a state-of-the-art supercritical coal boiler steam cycle of post- or oxy-combustion CCS or an integrated gasification combined cycle (IGCC) for pre-combustion CCS. Combined cycle repower rebuilds can also be fueled with natural gas (without CCS) or off-site CCS based on coal gasification to synthetic natural gas or [hydrogen (H<sub>2</sub>)]. This enables major repowering capacity increases and CO<sub>2</sub> reductions at old coal plant sites considered hopeless for retrofit CCS." To view this White Paper, visit: <http://web.mit.edu/mitei/docs/reports/simbeck-near-term.pdf>.

### **"Carbon Capture and Storage: Full-Scale Demonstration Progress Update."**

The following is from the Background of this document: "Secure, reliable and affordable energy supplies are needed for sustainable economic growth, but increases in associated CO<sub>2</sub> emissions, and the associated risk of climate change, are a cause of major concern. The IEA analysis in Energy Technology Perspectives 2008 (ETP) projects that the CO<sub>2</sub> emissions attributable to the energy sector will increase by 130 [percent] by 2050 in the absence of new policies or supply constraints as a result of increased fossil fuel usage. To address this increase will require an energy technology revolution involving greater energy efficiency, increased renewable energies and nuclear power, and the near-decarbonization of fossil fuel-based power generation. Nonetheless, fossil fuel usage is expected to continue to play a major role in delivering global energy supply, with the latest IEA projections showing a global increase in fossil fuel usage through 2030. The only technology available to mitigate GHG emissions from large-scale fossil fuel usage is CCS. The ETP BLUE scenario, which assessed strategies for reducing GHG emissions by one-half in 2050, concluded that CCS will need to contribute one-fifth of the necessary emissions reductions to achieve stabilization in the most cost-effective manner. CCS is therefore an essential part of the portfolio of technologies that is needed to achieve deep global emission reductions." This International Energy Agency (IEA) document is available at: [http://www.iea.org/G8/docs/ccs\\_g8july09.pdf](http://www.iea.org/G8/docs/ccs_g8july09.pdf).

## RECENT PUBLICATIONS (CONTINUED)

### “WCI Regional Emissions Database Options White Paper.”

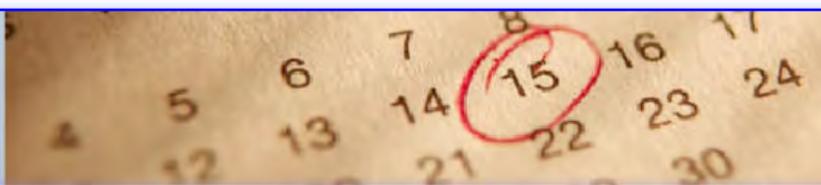
The following is from the Purpose and Background of this White Paper: “The purpose of the Options White Paper is to present the fundamental design choices for the [Western Climate Initiative (WCI)] Regional Emissions Database (RED). The RED will be a system of database components developed by The Climate Registry (The Registry) for collecting, transferring, storing and analyzing GHG emissions data from facilities and entities in WCI states and provinces. This White Paper will explore numerous options for managing data and designing database functions in order to provide guidance to The Registry. A key function of the RED will be to meet WCI partner jurisdiction data collection, recovery and analysis needs while at the same time minimizing the burden of satisfying WCI partner jurisdictions’ collective and individual GHG reporting requirements as well as the Federal GHG reporting requirements. After engaging in internal review and discussion of, and receiving stakeholder comments on, the White Paper, WCI will provide The Registry with guidance and direction on how it should proceed in defining detailed specifications for the RED. The options that are suggested throughout the White Paper are based on realistic expectations for the cost and schedule of the project.” To download WCI’s Regional Emissions Database Options White Paper, go to: <http://www.westernclimateinitiative.org/component/remository/func-startdown/129/>.

## LEGISLATIVE ACTIVITY

### *Oregon Governor Ted Kulongoski Press Release, “Governor Kulongoski Signs Climate Change Legislation into Law.”*

Oregon Governor Ted Kulongoski signed a series of bills on July 22, 2009, aimed at reducing GHG emissions, ensuring low carbon fuel, investing in green technology and jobs, and increasing energy efficiency in homes and businesses across the state. The series of bills signed into law include: (1) Senate Bill 38, which will expand the reporting requirements for GHG emissions to imported electricity, natural gas,

and transportation fuel and enhance the state’s ability to track the amount of GHGs emitted in Oregon; (2) Senate Bill 101, which requires that new electricity sources must be as least as clean as natural gas plants; (3) Senate Bill 79, which increases energy efficiency in building codes by 10 to 15 percent for residential structures and by 15 to 25 percent for commercial structures; (4) House Bill 2186, which authorizes the Environmental Quality Commission (EQC) to develop a low carbon fuel standard; and (5) House Bill 2626, which provides local governments with the authority to issue bonds for residential and business energy efficiency projects. These bills are available at: <http://www.leg.state.or.us/>. July 22, 2009, [http://governor.oregon.gov/Gov/P2009/press\\_072209.shtml](http://governor.oregon.gov/Gov/P2009/press_072209.shtml).



## EVENTS

September 1-4, 2009, **COAL-GEN Europe**, *Expo Silesia, Katowice, Poland*. COAL-GEN Europe offers attendees two parallel conference tracks to examine the latest clean coal technology developments and discuss the issues facing the European coal-fired power generation sector. To view the conference topics, registration information, and the two-track agenda, go to: <http://cge09.events.pennnet.com/fl/content.cfm?NavId=8523&Language=Engl>.

September 13-19, 2009, **8<sup>th</sup> International Carbon Dioxide Conference**, *Friedrich-Schiller-University, Jena, Germany*. This conference provides a multidisciplinary forum for all aspects of modern carbon cycle research relevant to understanding the natural and anthropogenic controls of atmospheric CO<sub>2</sub> and its interactions in the global ecosystem. For registration information, visit the conference website at: <http://www.conventus.de/icdc8/>.

September 14-15, 2009, **Carbon Capture and Sequestration Summit**, *Omni Shoreham Hotel, Washington, DC, USA*. The goal of this summit is to develop a greater understanding of current and future needs for the commercialization of CCS. Topics to be discussed include: current Federal and state legal and regulatory environments; CCS economics and business models; and the challenges facing CO<sub>2</sub> transportation and storage. To learn more, click: <http://www.americanconference.com/energy/Energy.htm?PageMode=Search>.

September 14-15, 2009, **Platts 2<sup>nd</sup> Annual Carbon Capture & Sequestration**, *Westin Grand Hotel in Washington, D.C, USA*. This two-day conference has three main focuses: new policy directions and economic challenges for large-scale deployment; jurisdiction and regulatory framework; and CCS economics. To view the full agenda, visit the conference website by clicking: <http://www1.platts.com/Events/2009/pc919/index.xml>.



## EVENTS (CONTINUED)

September 22-24, 2009, **Carbon Capture and Storage World Summit**, *Hotel Palomar Arlington, Arlington, Virginia, USA*. This summit will provide a comprehensive look at CCS by examining the most up-to-date information on CCS policy and funding, as well as technology and industry updates. For more information, visit the summit website at: <http://www.carboncaptureandstorageconference.com/>.

September 29-30, 2009, **South African Carbon Capture & Storage Conference**, *The Sandton Sun, Johannesburg, South Africa*. This conference provides an entry level introduction to CCS aimed at developing a basic understanding of the various technical, economic, political, and regulatory aspects involved. There will also be presentations on results from several existing CCS facilities. For more information, visit the conference website at: <http://www.ccsconference.co.za/index.html>.

September 30-October 2, 2009, **5<sup>th</sup> Conference on Carbon Credit Market and Carbon Capture and Storage**, *Rome Fair Centre, Rome, Italy*. The only Italian event specializing in GHG emissions and the technology used for GHG reductions, this conference will take place in conjunction with CCS EXPO, the first event for the Mediterranean area focused on CCS. To learn more information, click: [http://www.zeroemissionrome.eu/en/index\\_co2.asp](http://www.zeroemissionrome.eu/en/index_co2.asp).

October 4-7, 2009, **Gasification Technologies Conference**, *Colorado Springs, Colorado, USA*. This conference will provide participants with information, analysis, and networking opportunities to better understand the gasification market. One of the major topical sessions will include a discussion on carbon management, liability, incentives, and regulations. For more information, visit: [http://www.gasification.org/conferences/annual\\_conferences.aspx](http://www.gasification.org/conferences/annual_conferences.aspx).

October 27-28, 2009, **2009 Clean Carbon Policy Summit**, *AT&T Conference Center - UT Austin, Austin, Texas, USA*. Government officials and industry leaders from Texas will gather for this event to take an in-depth look at the issues involved with ultra clean technology. Included on the schedule is a session focused on CO<sub>2</sub> capture, transportation, and cleanup. To download the full agenda, visit the conference website at: <http://www.iemshows.com/cleancarbon/>.

November 5-6, 2009, **3<sup>rd</sup> International Symposium: Capture and Geological Storage of CO<sub>2</sub> - Accelerating Deployment**, *Paris, France*. This symposium takes a global and cross-disciplinary approach that focuses on the industrial deployment of CCS. Included in the agenda is a discussion on DOE's RCSPs. For more information, including a detailed program, visit the conference website at: <http://www.co2symposium.com/>.

November 9-11, 2009, **Carbon Capture and Storage for Utilities**, *Omni Hotel at CNN Center, Atlanta, Georgia*. This conference will discuss and review how to accurately estimate reliable capacities of CO<sub>2</sub> storage; examine developing pore space ownership issues from leading law firms; interpret strategies from current CCS project developers; and analyze critical public outreach, water issues, technological advancements and MVA best practices. For more information, go to: <http://www.euci.com/conferences/1109-ccs/index.php?ci=824>.

## 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).