



Office of Fossil Energy

# Carbon Sequestration Newsletter

MARCH 2012

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storage of carbon dioxide (CO<sub>2</sub>). DE-FOA-0000652, titled, “Technologies to Ensure Permanent Geologic Carbon Storage,” addresses key geologic storage challenges and uncertainties that include improving and validating containment, improving injection operations, increasing reservoir storage efficiency, and mitigating potential releases of CO<sub>2</sub> from the engineered containment system. The following four technical areas of interest are addressed: *Area of Interest 1* – Studies of Existing Wellbores Exposed to CO<sub>2</sub>; *Area of Interest 2* – Advanced Wellbore Integrity Technologies; *Area of Interest 3* – Field Methods to Optimize Capacity and Ensure Storage Containment; and *Area of Interest 4* – Enhanced Simulation Tools to Improve Predictions and Enhance Performance of Geologic Storage. The FOA was posted on March 6, 2012, and applications must be received by April 17, 2012. The FOA can be accessed at: <http://www.grants.gov/search/search.do;jsessionid=NFJqPXtBQGC57zbP0701H6cygPFBRhn40510jmgGNGtB15RqpTNM!-2135146600?oppId=150113&mode=VIEW>.

### **EPA News Release, “EPA Proposes First Carbon Pollution Standard for Future Power Plants.”**

On March 27, the U.S. Environmental Protection Agency (EPA) proposed the first Clean Air Act (CAA) standard for carbon emissions from new power plants. EPA’s rule creates a path forward for new technologies to be deployed at future facilities that will allow companies to burn coal, while emitting less carbon. The rulemaking proposed concerns new generating units that will be built in the future, and does not apply to existing units already operating or units that will start construction over the next 12 months. For more information, visit: <http://epa.gov/carbonpollutionstandard/>. The proposed rule can be viewed at: <http://epa.gov/carbonpollutionstandard/pdfs/20120327proposal.pdf>. March 27, 2012, <http://yosemite.epa.gov/opa/advpress.nsf/bd4379a92ceceac8525735900400c27/9b4e8033d7e641d9852579ce005ae957!OpenDocument>.

## 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

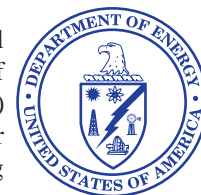
**DOE/NETL’s Carbon Storage Program, “Funding Opportunity Announcement DE-FOA-0000652.”**

In support of the Carbon Storage Program, the U.S. Department of Energy’s (DOE) National Energy Technology Laboratory (NETL) has issued a Funding Opportunity Announcement (FOA) to request applications that develop technologies and simulation tools to ensure geologic

## SEQUESTRATION IN THE NEWS

**Carbon Capture Journal, “Duke Energy & China Huaneng Sign CCS Research Agreement.”**

Duke Energy and China Huaneng Group will expand their research cooperation in the areas of advanced coal and carbon capture and storage (CCS) technologies as part of a recently signed three-year agreement. A Memorandum of Understanding



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## SEQUESTRATION IN THE NEWS (CONTINUED)

(MOU) on several renewable and clean-energy fronts was originally signed in 2009, when Huaneng Group developed a facility that captured 120,000 tons of CO<sub>2</sub> per year from the 1,320-megawatt (MW), coal-fired Shidongkou power station in China. The expanded agreement includes an engineering study to determine the potential feasibility of applying Huaneng Group's carbon capture process on Duke Energy's Gibson Station Unit 3. A Joint Working Group will be created to coordinate the project, which will be funded by the U.S.-China Clean Energy Research Center (CERC). February 18, 2012, <http://www.carboncapturejournal.com/displaynews.php?NewsID=898>.

### ***Mywesttexas.com*, "Kinder Morgan CO<sub>2</sub> Readies Doe Canyon Expansion, adds St. Johns Field."**

Kinder Morgan CO<sub>2</sub> announced plans to increase enhanced oil recovery (EOR) operations at two fields. The Colorado Doe Canyon field, which currently supplies 105 mmcf/day of CO<sub>2</sub> into the Cortez pipeline, is expected increase to 170 mmcf/day. The company's current total throughput in the Cortez pipeline is 1.25 bcf/day and the new production will increase this total to 1.3 to 1.31 bcf/day. Kinder Morgan's Katz field, which produced 200 to 250 barrels per day before CO<sub>2</sub> injection, is now pumping 1,300 barrels per day. In addition, a possible expansion of Kinder Morgan's McElmo Dome production is in the engineering feasibility study phase. Kinder Morgan CO<sub>2</sub> also recently purchased the St. Johns CO<sub>2</sub> field in eastern Arizona (Apache County) and western New Mexico (Catron County); early studies estimate the field's CO<sub>2</sub> reserves at 12 trillion cubic feet. Kinder Morgan plans to drill 4 to 6 test wells in addition to the 8 to 12 wells already in place. February 24, 2012, [http://www.mywesttexas.com/business/oil/top\\_stories/article\\_3143d85f-8ad8-5997-9702-4373aea5a3d9.html](http://www.mywesttexas.com/business/oil/top_stories/article_3143d85f-8ad8-5997-9702-4373aea5a3d9.html).

### ***Reuters*, "UK Government Files Plans to Build Carbon Capture Plans," and *Reuters*, "Government Publishes Details of Carbon Capture Tender."**

The UK government called for proposals to build at least one CCS power plant in a notice of contract published in the European Union's (EU) official journal. The notice document also called for proposals for a wide range of engineering projects for CCS, including construction of a power plant, gas storage, and pipelines. Participants are invited to make proposals by April 13, 2012; the notification is one step short of launching the official tender, which the Department of Energy and Climate Change (DECC) anticipates to be released shortly. The EU will raise money to fund CCS or renewable energy projects through its New Entrant Reserve 300 (NEW300) Program by selling 300 million EU Allowances (EUAs). According to the notice document, DECC expects Britain's first CCS project to begin operation in the 2016 to 2020 timeframe. February 24, 2012, <http://www.reuters.com/article/2012/02/24/us-britain-ccs-notice-idUSTRE81N1BY20120224>, and February 24, 2012, <http://uk.reuters.com/article/2012/02/24/uk-britain-ccs-notice-idUKTRE81N1CD20120224>.

# SEQUESTRATION IN THE NEWS (CONTINUED)

## **Government of Saskatchewan News Release, “Saskatchewan Partners with Research Groups in The Netherlands.”**

The government of Saskatchewan’s Advanced Education, Employment, and Immigration Minister signed an MOU with the Petroleum Technology Research Centre (PTRC) of Regina, the University of Regina, and CATO-2 of The Netherlands to encourage the sharing of information on CCS through student exchange, research collaboration, and technology transfer. PTRC, a non-profit R&D organization that manages the Weyburn-Midale CO<sub>2</sub> Project, and the government of Saskatchewan also signed an MOU with INCAS<sup>3</sup>, a Netherlands-based sensor technology institution, giving Saskatchewan access to critical sensor technologies needed to deploy new EOR technologies. March 6, 2012, <http://www.gov.sk.ca/news?newsId=9a5e05de-4e3a-470c-baaa-78eb47f5b1e7>.

## **ABC News, “Carbon Capture Trial Drilling Begins.”**

The Government of Western Australia Department of Mines and Petroleum has begun drilling in Harvey, Western Australia, to determine the feasibility of storing carbon underground. The \$8.5-million South West Hub project will collect data from as deep as 1.9 miles underground at the Harvey One Well. The first non-commercial one of its kind in Western Australia and the second in Australia, the project is expected to take up to three years to complete. February 22, 2012, <http://www.abc.net.au/news/2012-02-22/carbon-capture-trial-drilling-begins/3844882?section=wa>.

## **GreenCareer, “Research Project to Test Geosequestration of CO<sub>2</sub>.”**

Researchers from Curtin University have been awarded a \$1.4-million grant from the Australian National Low Emissions Coal (ANLEC) R&D Program, which will be used to assess the injection capacity of CO<sub>2</sub> at selected sites. The two-year study will test eight cores from a range of potential CO<sub>2</sub> storage sites to determine their suitability for injectivity. February 14, 2012, <http://www.greencareer.net.au/news-articles/research-project-to-test-geosequestration-of-co2>.

## **ANNOUNCEMENTS**

### **Big Sky Annual Meeting.**

The Big Sky Carbon Sequestration Partnership (BSCSP) will host their annual meeting at the Best Western Heritage Inn in Great Falls, Montana, April 18-19, 2012. Key issues related to the science, policy, and technology of CCS will be addressed. For registration information, visit: <http://www.bigskyco2.org/content/annual-meeting-april-18-19-2012>.

### **Netherlands Storage Site Suitable for Carbon Capture.**

The EU announced that an approximately 1.9-mile deep storage site off the coast of The Netherlands is suitable for a carbon capture project. Under the European Energy Program for Recovery, the EU awarded the project \$242 million in funding. To read the European Commission’s statement, visit: [http://ec.europa.eu/clima/news/articles/news\\_2012022901\\_en.htm](http://ec.europa.eu/clima/news/articles/news_2012022901_en.htm). For more information, go to: <http://www.bloomberg.com/news/2012-02-29/eu-says-netherlands-storage-site-is-suitable-for-carbon-capture.html>.

### **CCS Training Courses.**

CCS Through Life Management (TLM), in partnership with the Nottingham Centre for Carbon Capture and Storage (NCCCS), is offering two CCS training courses: (1) “Carbon, Capture and Storage – A Field-Based Masterclass,” on April 30-May 3, 2012, in Wareham, Dorset, United Kingdom, and (2) “Simplifying CCS” on May 9-10, 2012, in Calgary, Canada. More information is available at: [http://www.ccstlm.com/content\\_187\\_academy](http://www.ccstlm.com/content_187_academy).

### **IEAGHG 2012 Summer School.**

The 6<sup>th</sup> International Energy Agency Greenhouse Gas Program (IEAGHG) Summer School will be held at Tsinghua University, in Beijing, China, on August 12-18, 2012. Led by international experts in the CCS field, the program will cover the full chain of CCS and provide up-to-date information in each field, including technical information on capture technologies, storage site selection, capacity and modelling, wellbore integrity, and transport, as well as other issues such as regulations, health and safety, and public communication. Interested students can go to: <http://www.ieaghg.org/index.php?/20111222270/summer-school-2012.html> for application information.

### **Carbon Permits to Be Auctioned for Germany.**

The European Energy Exchange (EEX) won a tender to auction up to 85 million EUAs on behalf of Germany in the third phase (2013-2020) of the EU Emissions Trading Scheme (EU ETS). In the second phase (2008-2012), the majority of the carbon permits are free; beginning in 2013, approximately half of the EUAs will be sold via auctions. For more information, visit: <http://www.reuters.com/article/2012/02/29/eex-carbon-idUSL5E8DT2J220120229>.

# SCIENCE

## **ScienceDaily, “Earliest Horses Show Past Global Warming Affected Body Size of Mammals.”**

A group of scientists have discovered a correlation between temperature and body size in mammals from approximately 56 million years ago. In a study published in the journal “Science,” researchers analyzed the evolution of the earliest horses, the *Sifrhippus sandrae*, and found that as temperatures increased, their body size decreased. During the Paleocene-Eocene Thermal Maximum – a 175,000-year climate event in which increased concentrations of CO<sub>2</sub> in the atmosphere and oceans led to an average global temperature increase of approximately 10 to 20 degrees – researchers traced the evolution of the *Sifrhippus*. They found that during a 130,000-year period, the mammals shrank approximately 30 percent, from 12 pounds to 8.5 pounds. Over the next 45,000 years, they increased to approximately 15 pounds. Researchers also analyzed the correlations with aridity and CO<sub>2</sub> levels, but found temperature to be the most likely factor in determining body size. February 23, 2012, <http://www.sciencedaily.com/releases/2012/02/120223142634.htm>.

## **Oak Ridge National Laboratory News Release, “ORNL-Led Team Advances Science of Carbon Accounting.”**

A team of researchers at ORNL have developed a method to determine the carbon balance of North America. Using inventory records from the United States, Canada, and Mexico that track changes in the amount of carbon in various reservoirs, such as plants, soils, and wood, the researchers generated estimates of the current rate of atmospheric CO<sub>2</sub> storage over North America, which then allowed them to calculate the state of the science in determining North America’s carbon balance. The data showed that storage is neither permanent nor fixed, and that much of the current carbon storage in North America is associated with the forest sector in the Northwest and Southeast. The research paper, titled, “Reconciling estimates of the contemporary North American carbon balance among terrestrial biosphere models, atmospheric inversions, and a new approach for estimating net ecosystems exchange from inventory-based data,” is available at: <http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2011.02627.x/abstract>. March 6, 2012, [http://www.ornl.gov/info/press\\_releases/get\\_press\\_release.cfm?ReleaseNumber=mr20120306-00](http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20120306-00).

# POLICY

## **Dubai Chronicle, “Dubai to Reduce Carbon Dioxide and Greenhouse Gas Emissions.”**

Dubai will develop a strategy to reduce greenhouse gas (GHG) emissions and implement a carbon trading scheme. The Dubai Supreme Council of Energy (DSCE) signed an MOU with the Dubai Carbon Centre of Excellence (DCCE) to verify preliminary studies on CO<sub>2</sub> emissions. The initiative, part of the Dubai Integrated Energy Strategy 2030, will include research on GHG emissions and the development of frameworks for introducing a comprehensive CO<sub>2</sub> abatement program. In addition, DCCE will complete a detailed inventory of Dubai’s GHG emissions

in line with International Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC) requirements, as well as recommend viable targets for reducing CO<sub>2</sub> and GHGs and a methodology to monetize emissions. The strategy would also examine the best options to build a “Clean Energy Fund” linked to CO<sub>2</sub> reduction and dedicated to new investment in energy-related projects in Dubai. February 26, 2012, <http://www.dubaichronicle.com/2012/02/26/dubai-carbon-dioxide-greenhouse-gas-emissions/>.

## **“Overall environmental impacts of CCS technologies – A life cycle approach.”**

The following is the Abstract of this article: “In the last decade the environmental performance of climate effective CCS considering also other environmental effects has become focus of several studies. With various technological CCS options under development, the field of possible technical solutions is hardly covered yet. This paper identifies technologies whose environmental effects have been [analyzed] from a life cycle perspective. Life Cycle Assessment (LCA) has proved to be a helpful tool to investigate the environmental consequences associated with the introduction of CCS. Even though, big differences in underlying assumptions of existing studies make comparison difficult, some general effects can be described. In general the intended reduction in [global warming potential (GWP)] by introducing CO<sub>2</sub> capture (up to – 85 [percent] hard coal oxyfuel, – 95 [percent] lignite oxyfuel, – 80 [percent] natural gas post-combustion) is combined with an increase of other environmental effects, regardless of capture technology, time horizon or fuel considered. Performing the [normalization] step shows that acidification and human toxicity potential have to be watched as well. Additionally, three parameter sets have been identified, which have a significant impact on the effects: (a) development of plant efficiencies and energy penalties; (b) capture efficiency; (c) fuel origin and composition.” **Petra Zapp, Andrea Schreiber, Josefine Marx, Mike Haines, Jurgen-Friedrich Hake, and John Gale**, *International Journal of Greenhouse Gas Control*, Available online February 24, 2012, doi:10.1016/j.ijggc.2012.01.014, <http://www.sciencedirect.com/science/article/pii/S175058361200028X>. (Subscription may be required.)

## **“[Characterizing] CCS learning: The role of quantitative methods and alternative approaches.”**

The following is the Abstract of this article: “A number of energy scenario studies have suggested that CCS could make a significant contribution to reducing global CO<sub>2</sub> emissions. This would require efforts to ensure rapid development and deployment. Since there is limited experience of CCS systems, it is hard to define ‘business as usual’ development. This leads to significant uncertainty for policy makers and other stakeholders with regard to [characterizing] potential CCS pathways and assessing the scope for and risks of acceleration. Quantitative analytical approaches to projecting costs and other parameters typically depend on best current estimates of critical input data, as well as implicit or explicit assumptions about technology development pathways and contextual factors such as evolving regulatory requirements. There are significant limitations in current quantitative (and qualitative) data on CCS that lead to significant difficulties in identifying robust assumptions. One way to handle this is to develop multiple scenarios to illustrate the uncertainty. Another strategy is to make more use of qualitative methods for [analyzing] CCS innovation processes. This latter approach could help to

## POLICY (CONTINUED)

avoid some of the issues associated with CCS cost uncertainty and instead re-focus attention on understanding critical aspects of innovation processes.” **Nils Markusson and Hannah Chalmers**, *Technological Forecasting and Social Change*, Available online February 28, 2012, doi:10.1016/j.techfore.2011.12.010, <http://www.sciencedirect.com/science/article/pii/S0040162511002885>. (Subscription may be required.)

## GEOLOGY

### “Studies of pH buffer systems to promote carbonate formation for CO<sub>2</sub> [storage] in brines.”

The following is the Abstract of this article: “Carbon dioxide [storage] using brines is significantly dependent on pH for the formation of carbonates. This study evaluated a series of buffer solutions and then selected the optimal one to promote the precipitation of mineral carbonates (mainly calcium carbonates) for above-ground and to help to understand the pH effect on both above-ground and underground carbonation. Five organic or inorganic buffer solutions (pH > 9.0) were selected in this study. pH stability studies were conducted to compare the buffering ability amongst those five buffer solutions for 15 days in both closed and open atmospheres. Buffer solution Bf 1 (boric buffer solution, pH = 10.0) and Bf 2 (0.3 M Tris buffer solution) were selected as the optimal buffers to conduct carbonation experiments due to their strong buffering ability to maintain the pH above 9.0. Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) analysis showed that the concentration of Ca decreased considerably after each carbonation experiments with buffer Bf 1 or Bf 2. The results from X-ray diffraction (XRD) analysis of the precipitates formed from carbonation reactions confirmed the predominant presence of calcite (CaCO<sub>3</sub>). Finally, the buffers studied here were compared to biocatalysts previously reported for rising pH of brines.” **Qi Liu and M. Mercedes Maroto-Valer**, *Fuel Processing Technology*, Available online February 20, 2012, doi:10.1016/j.fuproc.2012.01.023, <http://www.sciencedirect.com/science/article/pii/S0378382012000409>. (Subscription may be required.)

### “The effect of mechanical rock properties on CO<sub>2</sub> storage capacity.”

The following is the Abstract of this article: “One of the most important issues when estimating CO<sub>2</sub> storage capacity, especially in the case of the storage into deep saline aquifers, is the mechanical integrity of rock, i.e. estimate of cap rock fracture pressure. In the case of storage into mature oil and gas reservoirs, reservoir pressure should not present an issue since it was significantly decreased due to hydrocarbon production, so it is reasonable to assume that the rock integrity would not be disturbed by injecting CO<sub>2</sub> to the initial reservoir pressure. Because estimates of fracture pressure are necessary, but not convenient for regional aquifers, the analysis of pore volume changes due to pressure buildup for the chosen CO<sub>2</sub> site in Croatia has been made. Pressure buildup depends on reservoir fluid (brine) compressibility, CO<sub>2</sub> compressibility at given reservoir conditions before CO<sub>2</sub> injection and on rock compressibility i.e. pore compressibility. Implementing the simple method for analysis of pressure buildup considering elastic properties of fluids and rock,

larger CO<sub>2</sub> storage capacity estimate was achieved than by using storage efficiency coefficient (E), as defined by U.S. DOE and which was used for estimating storage capacities in regional deep saline aquifers in Croatia as the part of EU GeoCapacity project.” **Domagoj Vulin, Tomislav Kurevija, Iva Kolenkovic**, *Energy*, Available online February 23, 2012, doi:10.1016/j.energy.2012.01.059, <http://www.sciencedirect.com/science/article/pii/S0360544212000643>. (Subscription may be required.)

### “Ensemble based co-optimization of carbon dioxide [storage] and enhanced oil recovery.”

The following is the Abstract of this article: “[Storage] of CO<sub>2</sub> in depleted or partially depleted oil reservoirs is a plausible option to reduce CO<sub>2</sub> emissions into the atmosphere. Carbon dioxide has been used as the injection fluid in EOR operations. The goal of such projects is to improve the profitability by maximizing the oil production (to increase the revenue) and minimizing the CO<sub>2</sub> injection (to decrease the costs). However, in [storage] projects, subsurface storage of the injected CO<sub>2</sub> needs to be maximized. The objective of this study is to develop a framework to co-optimize the oil extraction and CO<sub>2</sub> [storage]. In [the authors’] work, factors such as the cost of capturing the produced CO<sub>2</sub>, CO<sub>2</sub> transportation and recycling are taken into account. In the proposed framework, the net present value (NPV) of the project is selected as the optimization objective function. The ensemble-based optimization (EnOpt) algorithm has been chosen as the optimization algorithm and the well injection patterns and rates as the controlling variables. A synthetic case is used to demonstrate the applicability of the developed technique. [The authors’] results show that the oil recovery and the NPV can be increased significantly. The proposed methodology is fairly robust as it does not require adjoint programming and can be readily used with any reservoir simulator. The workflow presented in this work can be used to design and co-optimize the coupled CO<sub>2</sub> [storage] and EOR.” **Hamid Reza Jahangiri and Dongxiao Zhang**, *International Journal of Greenhouse Gas Control*, Available online February 24, 2012, doi:10.1016/j.ijggc.2012.01.013, <http://www.sciencedirect.com/science/article/pii/S1750583612000278>. (Subscription may be required.)

## TECHNOLOGY

### “The Cost of Carbon Capture and Storage for Natural Gas Combined Cycle Power Plants.”

The following is the Abstract of this article: “This paper examines the cost of CCS for natural gas combined cycle (NGCC) power plants. Existing studies employ a broad range of assumptions and lack a consistent costing method. This study takes a more systematic approach to analyze plants with an amine-based [post-combustion] CCS system with 90 [percent] CO<sub>2</sub> capture. [The authors] employ sensitivity analyses together with a probabilistic analysis to quantify costs for plants with and without CCS under uncertainty or variability in key parameters. Results for new baseload plants indicate a likely increase in levelized cost of electricity (LCOE) of \$20–32/MWh (constant 2007\$) or \$22–40/MWh in current dollars. A risk premium

## TECHNOLOGY (CONTINUED)

for plants with CCS increases these ranges to \$23–39/MWh and \$25–46/MWh, respectively. Based on current cost estimates, [the authors'] analysis further shows that a policy to encourage CCS at new NGCC plants via an emission tax or carbon price requires (at 95 [percent] confidence) a price of at least \$125/t CO<sub>2</sub> to ensure NGCC-CCS is cheaper than a plant without CCS. Higher costs are found for [non-baseload] plants and CCS retrofits.” **Edward S. Rubin and Haibo Zhai**, *Environ. Sci. Technol.*, Available online February 14, 2012, doi:10.1021/es204514f, <http://pubs.acs.org/doi/abs/10.1021/es204514f>. (Subscription required.)

### “Potential restrictions for CO<sub>2</sub> [storage] sites due to shale and tight gas production.”

The following is the Abstract of this article: “[CCS] is the only available technology that both allows continued use of fossil fuels in the power sector and reduces significantly the associated CO<sub>2</sub> emissions. Geological [storage] requires a deep permeable geological formation into which captured CO<sub>2</sub> can be injected, and an overlying impermeable formation, called a caprock, that keeps the buoyant CO<sub>2</sub> within the injection formation. Shale formations typically have very low permeability and are considered to be good caprock formations. Production of natural gas from shale and other tight formations involves fracturing the shale with the explicit objective to greatly increase the permeability of the shale. As such, shale gas production is in direct conflict with the use of shale formations as a caprock barrier to CO<sub>2</sub> migration. [The authors] have examined the locations in the United States where deep saline aquifers, suitable for CO<sub>2</sub> [storage], exist, as well as the locations of gas production from shale and other tight formations. While estimated [storage] capacity for CO<sub>2</sub> [storage] in deep saline aquifers is large, up to 80 [percent] of that capacity has areal overlap with potential shale-gas production regions and, therefore, could be adversely affected by shale and tight gas production. Analysis of stationary sources of CO<sub>2</sub> shows a similar effect: about two-thirds of the total emissions from these sources are located within 20 miles of a deep saline aquifer, but shale and tight gas production could affect up to 85 [percent] of these sources. These analyses indicate that co-location of deep saline aquifers with shale and tight gas production could significantly affect the sequestration capacity for CCS operations. This suggests that a more comprehensive management strategy for subsurface resource utilization should be developed.” **Thomas Elliot and Michael Celia**, *Environ. Sci. Technol.*, Available online February 21, 2012, doi:10.1021/es2040015, <http://pubs.acs.org/doi/abs/10.1021/es2040015>. (Subscription required.)



## TERRESTRIAL

### Oak Ridge National Laboratory News Release, “Final FACE Harvest Reveals Increased Soil Carbon Storage Under Elevated Carbon Dioxide.”

According to a 12-year free-air CO<sub>2</sub>-enrichment (FACE) experiment at Oak Ridge National Laboratory (ORNL), elevated concentrations

of CO<sub>2</sub> can increase carbon storage in soil, helping slow down rising atmospheric concentrations. The experiment, sponsored by DOE, ended in 2009, but the conclusion and final harvest provided researchers the opportunity to cut down trees and dig into the soil to quantify the effect of elevated CO<sub>2</sub> concentrations on plant and soil carbon; the effects were quantified by excavating soil from large pits that were approximately three feet deep. Researchers found an increase in soil carbon storage under elevated CO<sub>2</sub> concentrations – a finding different from other FACE experiments in forests. March 5, 2012, [http://www.ornl.gov/info/press\\_releases/get\\_press\\_release.cfm?ReleaseNumber=mr20120305-00](http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20120305-00).

### “Long-and short-term precipitation effects on soil CO<sub>2</sub> efflux and total belowground carbon allocation.”

The following is the Abstract of this article: “Soil CO<sub>2</sub> efflux ( $E_{soil}$ ), the main pathway of C movement from the biosphere to the atmosphere, is critical to the terrestrial C cycle but how precipitation and soil moisture influence  $E_{soil}$  remains poorly understood. Here, [the authors] irrigated a longleaf pine wiregrass savanna for six years; this increased soil moisture by 41.2 [percent]. [The authors] tested how an altered precipitation regime affected total belowground carbon allocation (TBCA), root growth, soil carbon, and  $E_{soil}$ . [The authors] used two methods to quantify  $E_{soil}$ : daytime biweekly manual measurements and automated continuous measurements for one year. [The authors] hypothesized that the low-frequency manual method would miss both short- and long-term (i.e., subdaily to annual, respectively) effects of soil moisture on  $E_{soil}$  while the high-frequency data from the automated method would allow the effects of soil moisture to be discerned. Root growth was significantly higher in irrigated plots, particularly at 0–20 cm depth. Irrigated annual  $E_{soil}$  was significantly greater than that of the control when estimated with the continuous measurements but not when estimated from biweekly measurements. The difference in annual  $E_{soil}$  estimates is likely due to (1) the delayed increase in  $E_{soil}$  following irrigation pulses of soil moisture (i.e., variation that the biweekly manual measurements missed) and (2) the diel timing of biweekly manual measurements (they were completed early to mid-day before peak efflux). With irrigation, estimates of TBCA increased almost two-fold with automated measurements but only 36 [percent] with intermittent measurements. Relative to controls, irrigated treatments stored almost 2 Mg C ha<sup>-1</sup> year<sup>-1</sup> more in soils and 0.26 Mg C ha<sup>-1</sup> year<sup>-1</sup> more in roots. High-frequency measurements of  $E_{soil}$  were essential to estimate total belowground carbon allocation. With irrigation, soil carbon pools were not at steady-state, so shifts in soil carbon storage must be considered in TBCA estimates.” **Chelcy R. Ford, Jason McGee, Francesca Scandellari, Erik A. Hobbie, Robert J. Mitchell**, *Agricultural and Forest Meteorology*, Available online January 24, 2012, doi:10.1016/j.agrformet.2011.12.008, <http://www.sciencedirect.com/science/article/pii/S0168192312000020>. (Subscription may be required.)

### “Responses of trees to elevated carbon dioxide and climate change.”

The following is the Abstract of this article: “The enhancement in photosynthesis at elevated concentration of [CO<sub>2</sub>] level than the ambient level existing in the atmosphere is widely known. However, many of the earlier studies were based on instantaneous responses of plants grown in pots. The availability of field chambers for growing

## TERRESTRIAL (CONTINUED)

trees, and long-term exposure studies of tree species to elevated [CO<sub>2</sub>], has changed [many of the] views on [CO<sub>2</sub>] acting as a [fertilizer]. Several tree species showed acclimation or even down-regulation of photosynthetic responses while a few of them showed higher photosynthesis and better growth responses. Whether elevated levels of [CO<sub>2</sub>] can serve as a fertilizer in a changed climate scenario still remains an unresolved question. Forest-Air-Carbon dioxide-Enrichment (FACE) sites monitored at several locations have shown lately, that the acclimation or down regulation as reported in chamber studies is not as wide-spread as originally thought. FACE studies predict that there could be an increase of 23–28 [percent] productivity of trees at least till 2050. However, the increase in global temperature could also lead to increased respiration, and limitation of minerals in the soil could lead to reduced responses in growth. Elevated [CO<sub>2</sub>] induces partial closure of leaf stomata, which could lead to reduced transpiration and more economical use of water by the trees. Even if the [CO<sub>2</sub>] acts as a fertilizer, the responses are more pronounced only in young trees. And if there are variations in species responses to growth due to elevated [CO<sub>2</sub>], only some species are going to dominate the natural vegetation. This will have serious implications on the biodiversity and the structure of the ecosystems. This paper reviews the research done on trees using elevated CO<sub>2</sub> and tries to draw conclusions based on different methods used for the study. It also discusses the possible functional variations in some tree species due to climate change.” **Jose Kallarackal and T.J. Roby**, *Biodiversity and Conservation*, Available online February 1, 2012, doi:10.1007/s10531-012-0254-x, <http://www.springerlink.com/content/qu694535138mj285/>. (Subscription required.)

## TRADING

**Reuters, “South Africa to Introduce Carbon Tax.”**

The South African Treasury announced plans to introduce a carbon tax next year to reduce GHG emissions. Under the plan, nearly two-thirds of emissions will be tax-exempt until 2020 in an attempt to lessen the impact on industry; in its 2012/2013 budget, the treasury proposed a 60 percent tax-free threshold on annual emissions for all sectors, who, with the exception of electricity, would be able to claim additional relief of at least 10 percent. In addition, the draft policy, which is expected to be published later this year, proposed a carbon tax of 120 rand per ton

of CO<sub>2</sub> equivalent for emissions above the threshold; the levy would come into effect in 2013/2014, increasing by 10 percent each year until 2020. February 22, 2012, <http://www.reuters.com/article/2012/02/22/safrica-budget-carbon-idAFL5E8DM4VA20120222>.

**Reuters, “UK to Auction Extra EU Carbon Permits in 2012.”**

Government officials announced that Britain will auction more EU carbon permits than planned this year due to a surplus of permits for the second phase (2008-2012) trading period of the EU ETS. Since November 2008, the UK government has raised \$1.8 billion from the sale of 99 million permit sources from a new entrant reserve for Phase II. The last scheduled auction, conducted on March 8, 2012, sold 3.5 million EUAs; according to DECC, more Phase II auctions will be held this year. DECC also said they will auction 125-130 million EUAs annually from 2013 to 2020. The EU ETS, the world’s largest cap-and-trade scheme, sets a cap on CO<sub>2</sub> emissions for approximately 12,000 power and industrial plants. February 24, 2012, <http://www.reuters.com/article/2012/02/24/carbon-uk-idUSL5E8DO76720120224>.

**“Electric-power systems planning and greenhouse-gas emission management under uncertainty.”**

The following is the Abstract of this article: “In this study, a multistage interval-stochastic integer programming model is formulated for managing GHG emissions and planning electric-power systems under uncertainty. The developed model can reflect dynamic, interactive, and uncertain characteristics of energy systems. Besides, the model can be used for answering questions related to types, times, demands and mitigations of energy systems planning practices, with the objective of minimizing system cost over a long-time planning horizon. The solutions can help generate electricity-generation schemes and capacity-expansion plans under different GHG-mitigation options and electricity-demand levels. Tradeoffs among system cost, energy security, and emission management can also be tackled. A high system cost will increase renewable energy supply and reduce GHG emission, while a desire for a low cost will run into risks of a high energy deficiency and a high GHG emission.” **Y.P. Li and G.H. Huang**, *Energy Conversion and Management*, Available online January 31, 2012, doi:10.1016/j.enconman.2011.12.018, <http://www.sciencedirect.com/science/article/pii/S0196890411003724>. (Subscription may be required.)

## RECENT PUBLICATIONS

**“Global Opportunity in Carbon Capturing & Storage Technology Market (2011 – 2016).”**

The following is a description of this document: “The report contains an elaborative description of the Global [CCS] technology market. The report casts various developments and plans in respective field across the geographies along with the influential factors for this market. It provides the current market scenario and future market forecasts for major markets. The report provides a deep insight to the initiatives taken by governments across the globe which is one of the major driving forces for this market. The major players in this global technology market have been covered as company profiles.” To view the full report, go to: [http://www.researchandmarkets.com/research/2e260c/global\\_opportunity](http://www.researchandmarkets.com/research/2e260c/global_opportunity). (Subscription required.)

## RECENT PUBLICATIONS (CONTINUED)

### **“A Greenhouse Gas Accounting Framework for Carbon Capture and Storage Projects.”**

The following is from the Executive Summary of this document: “The Greenhouse Gas Accounting Framework for Carbon Capture and Storage (CCS) Projects—CCS Accounting Framework—provides methods to calculate emissions reductions associated with capturing, transporting, and safely and permanently storing anthropogenic CO<sub>2</sub> in geologic formations. It aims for consistency with the principles and procedures from ISO 14064-2:2006. *Greenhouse gases—Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements*, which represents best practice guidance for the quantification of project-based GHG emission reductions. Ultimately, the objective of the CCS Accounting Framework is to inform and facilitate the development of a common platform to account for GHG emissions reductions due to capturing and geologically storing CO<sub>2</sub>. It also contributes to the public discussion about the viability of CCS to serve as a feasible CO<sub>2</sub> mitigation solution... The emissions accounting procedures in the CCS Accounting Framework apply to multiple CO<sub>2</sub> source types, including electric power plants—equipped with pre-combustion, [post-combustion], or oxy-fired technologies—and industrial facilities (for example, natural gas production, fertilizer manufacturing, and ethanol production). For CO<sub>2</sub> transport, the calculation methodology in this document applies only to pipelines because while other methods of transport, (e.g., truck transport) are possible, they are typically not considered viable options for large-scale CCS endeavors. With respect to the geological storage of CO<sub>2</sub>, the CCS Accounting Framework applies to saline aquifers, depleted oil and gas fields, and enhanced oil and gas recovery sites. The CCS Accounting Framework provides a comprehensive set of GHG accounting procedures within a single methodology. The quantification approach includes equations to calculate emissions reductions by comparing baseline emissions to project emissions—the difference between the two represents the GHG reductions due to capturing and [storing] CO<sub>2</sub>, which would have otherwise entered the atmosphere.” To view the entire Center for Climate and Energy Solutions (C2ES) document, click: <http://www.c2es.org/docUploads/CCS-framework.pdf>.

### **“Geomechanical [modeling] as part of the site investigation for CO<sub>2</sub> injection in the onshore part of the Gippsland Basin, SE Australia.”**

The following is the Abstract of this document: “The storage of [CO<sub>2</sub>] into geological formations is responsible for a number of coupled chemical and mechanical processes. Injection of CO<sub>2</sub> results in pore-pressure gradients that give rise to a change of the in-situ stress state. These alterations cause expansion due to poro-elasticity and possible irreversible deformation of the reservoir (e.g. tensile fracture). In this work, as part of the site assessment, a first 2D numerical geomechanical model of the Seaspray Depression, located in the onshore part of the Gippsland Basin, SE Australia, is presented. The study aims to investigate short-term (10 [years]) local changes of the effective stress and the associated basin uplift for various total storage scenarios (7.81, 22.1 and 72.4Mt CO<sub>2</sub>). In the approach, using the Hashin-Shtrikman bounds theory for multiphase materials, the model accounts for flow of supercritical CO<sub>2</sub>, coupled with rock deformation, through a system with site specific mechanical and hydrological properties of a rock plus water mixture. The simulations show under the assumptions made that the ground vertical displacement for a total injection volume of 7.81Mt CO<sub>2</sub> results in 7.25cm uplift. This is in good agreement with recently published InSAR field data from the In Salah storage project, which show that an average injection rate of 0.5-1Mt/yr gives rise to 5-7mm/yr surface uplift. [The authors] also conclude that a larger total volume of 72.4Mt would result in an uplift of 23cm. Although this current work does not yet take into account rock plasticity and multiphase flow, the analyses demonstrate that our model approach is appropriate to conduct more simulation studies associated with CO<sub>2</sub> injection in the future.” The complete Global CCS Institute document is available at: <http://www.globalccsinstitute.com/publications/geomechanical-modelling-part-site-investigation-co2-injection-onshore-part-gippsland>.

## LEGISLATIVE ACTIVITY

### ***National Enhanced Oil Recovery Initiative Press Release, “Enhanced Oil Recovery Plan Draws Bipartisan Welcome in Congress.”***

Recommendations have been released by the National Enhanced Oil Recovery Initiative (NEORI) calling for Federal and state incentives to stimulate the expansion of EOR using CO<sub>2</sub> from power plants and industrial facilities. In the practice of CO<sub>2</sub>-EOR, which represents six percent of current U.S. domestic oil production, oil producers inject CO<sub>2</sub> into wells to draw more oil to the surface. However, limited supplies of CO<sub>2</sub> constrain the expansion of EOR – an issue that NEORI’s recommendations attempt to address. The centerpiece of the recommendations is a Federal tax incentive focused on companies

that capture and transport CO<sub>2</sub>. According to NEORI estimates, the tax credit, which would be administered by the U.S. Treasury Department, would quadruple U.S. oil production from EOR to 400 million barrels per year, while reducing CO<sub>2</sub> emissions by 4 billion tons over the next 40 years. In addition, NEORI calculates that the program would produce a net return of \$100 billion of 40 years, and reduce the trade deficit by saving the United States approximately \$610 billion on imported oil over the same time period. February 28, 2012, <http://neori.org/press-release-feb28/>.





## EVENTS

April 24-25, 2012, **Carbon Capture and Storage Conference**, *Venue to be Determined, Calgary, Alberta, Canada*. This event provides an opportunity for attendees to hear from regulators, scientists, and industry players on the latest in CCS-related legislation, overcoming geologic challenges, devising business models for commercialization, gaining public acceptance, and other topics. Visit: <http://www.canadianinstitute.com/2012/338/carbon-capture-and-storage-conference/> for more details.

April 30-May 2, 2012, **11<sup>th</sup> Annual Conference on Carbon Capture, Utilization, and Sequestration**, *David L. Lawrence Convention Center, Pittsburgh, Pennsylvania, USA*. The intent of this conference is to: (1) provide a forum for the exchange of experience among scientific and engineering communities working on such technologies and systems; (2) facilitate the necessary dialogue between technology developers/purveyors, industry, and the public on the development and deployment of viable technologies; and (3) share experience on developing the necessary capacity within the public and private sector to move the technology base forward. More information is available at: <http://www.carbonsq.com/>.

May 15, 2012, **3<sup>rd</sup> Annual Brussels Carbon Capture and Storage Summit 2012**, *Le Chatelain All Suite Hotel, Brussels, Belgium*. This event will feature industry professionals, EU policymakers, and other stakeholders debating the progress of CCS in Europe. Discussions will focus on the impact of global finances on the CCS commercialization; the state of play regarding CCS funding models, including future roles for public subsidies; and future CCS applications and uses that may help drive its commercialization potential. For more information, click: [http://www.eu-ems.com/summary.asp?event\\_id=102&page\\_id=744](http://www.eu-ems.com/summary.asp?event_id=102&page_id=744).

May 21-23, 2012, **Global Conference on Oceans, Climate, and Security**, *Seaport Hotel and World Trade Center, Boston, Massachusetts, USA*. This three-track conference will focus on mitigating the effects of potential climate change on coastal and ocean ecosystems, as well as the security interests of the Nation. Included is a Science and Technology Needs track, which will discuss, among other topics, technologies and innovations, modeling solutions and simulations, and emerging sciences. For more information, visit: <http://www.gcocs.org/>.

May 30-June 1, 2012, **Carbon Expo 2012**, *Koelnmesse, Cologne, Germany*. The ninth installment of this fair, "Carbon Expo 2012: The Interface Between Industry and Technology & Climate and Carbon Finance," will include discussions on the effects of the Durban Global Climate Conference and economic forecasts for the EU and their influence on emissions trading. In addition, this expo will cover topics such as trends in the global carbon and energy markets, energy and carbon market ecosystems, and the potential market impacts CCS could have on the Clean Development Mechanism (CDM). For more information, click: [http://www.carbonexpo.com/en/carbon\\_expo/home/index.php](http://www.carbonexpo.com/en/carbon_expo/home/index.php).

June 4-8, 2012, **7<sup>th</sup> Asia Clean Energy Forum**, *ADB Headquarters, Mandaluyong City, Philippines*. Participants of this forum will discuss successful strategies and mechanisms for accelerating access to affordable, low-carbon energy. The Pre-Forum, held the first two days of the event, includes a Regional Workshop on Greenhouse Gas Inventories and Accounting. The Main Forum, held the last three days of the event, will be made up of 32 plenary and breakout sessions. A full agenda has yet to be developed. To learn more, go to: <http://www.asiacleanenergyforum.org/>.

July 8-12, 2012, **Global Conference on Global Warming 2012**, *Istanbul Technical University, Maslak, Istanbul, Turkey*. The themes of this conference cover potential climate change across a broad range of disciplines, such as ecology, education, social sciences, economics, management, political sciences, and information technology. Among the topics to be discussed are carbon storage, carbon tax, climate change modeling and simulations, and GHGs. For more information, go to: <http://www.gcgw.org/gcgw12/index.php?conference=gcgw&schedConf=gcgw12>.

July 23-25, 2012, **Carbon Capture and Storage: Science, Technology, and Policy**, *MIT, Cambridge, Massachusetts, USA*. This energy short course covers the science, technology, and policy aspects of CCS, focusing on the role of CCS in the climate change mitigation portfolio; the technical approaches to CO<sub>2</sub> capture; the science behind geologic storage, site selection, and risk evaluation; and the role of policy in establishing a market and business opportunities for CCS. For more information, visit the course website at: [http://web.mit.edu/professional/short-programs/courses/carbon\\_capture\\_storage.html](http://web.mit.edu/professional/short-programs/courses/carbon_capture_storage.html).



## EVENTS (CONTINUED)

November 18-22, 2012, **International Conference on Greenhouse Gas Technologies 11 (GHGT-11)**, *Kyoto International Conference Center, Japan*. This will be the second visit to Kyoto by the GHGT conference series, with more than 1,600 delegates expected to attend. A formal agenda has not yet been developed; however, planning for GHGT-11 is underway. The call for papers has expired. Visit: <http://www.ghgt.info/index.php/Content-GHGT11/ghgt-11-overview.html> for more details.

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