



MARCH 2013

Carbon Storage Newsletter



HIGHLIGHTS

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[“Research Experience in Carbon Sequestration 2013 Now Accepting Applications.”](#)



Supported by the U.S. Department of Energy’s (DOE) Office of Fossil Energy (FE) and the National Energy Technology Laboratory (NETL), the Research Experience in Carbon Sequestration (RECS) Program is accepting applications for RECS 2013. Scheduled for June 2-12, 2013, in Birmingham, Alabama, RECS 2013 is an intensive science- and field-based program that combines background briefings with group exercises and field activities at an integrated carbon capture and storage (CCS) project. In addition, RECS 2013 includes visits to a power plant, core laboratory, and the National Carbon Capture Center (NCCC), and covers CCS deployment issue topics, with a particular focus on carbon dioxide (CO₂) enhanced oil recovery (EOR)/carbon storage. The graduate students and early career professionals who participate will gain hands-on experience modeling CO₂ injection and subsurface fluid flow, monitoring surface CO₂, and analyzing core and well logs, as well as capture technologies. Founded in 2004, RECS was the first program to offer an intensive program on CCS systems to young scientists and engineers. Applicants should be early career professionals, Ph.D., or Master’s level students with backgrounds in geology, chemistry, hydrology, physics, engineering, climate science, and related fields. For more information, as well as application instructions, visit the [RECS website](#).

ANNOUNCEMENTS

Breakthrough Large-Scale Industrial Project Begins Carbon Capture and Utilization.

A CCS project at Air Products and Chemicals hydrogen production facility in Port Arthur, Texas, has begun capturing CO₂ and piping it to an oilfield for use in EOR. The project is expected to capture approximately 1 million metric tons of CO₂ per year that would otherwise be released in the atmosphere, as well as recover 1.6 to 3.1 million additional barrels of domestic oil annually.

New Set of Computational Tools and Models Expected to Help Enable Rapid Development and Deployment of Carbon Capture Technologies.

A new suite of 21 computational tools and models to help enable rapid development and deployment of new carbon capture technologies has been developed and made available by the Carbon Capture Simulation Initiative (CCSI), a public-private partnership led by NETL. The toolset is expected to make it easier for U.S. utilities to meet carbon capture requirements if/when they are enacted and help technology companies doing business in countries where controls are already in place.



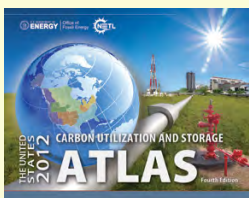
ANNOUNCEMENTS (CONTINUED)

NETL Director Anthony Cugini to Speak at 12th Annual CCS Conference.

NETL Director Anthony Cugini will speak at the 12th Annual CCS Conference scheduled for May 13-16, 2013, in Pittsburgh, Pennsylvania. At the conference, government decision makers and leaders from industry and academia will address the policy, program, and technology needs necessary to allow coal-fired power generation and other industrial processes to continue in a carbon-constrained environment and contribute to energy security. The 2013 Conference theme is advancing science, technology, and policy needed to meet near-term carbon reduction goals.

NETL's Carbon Capture, Utilization, and Storage Database – Version 4.

NETL has released the fourth version of the CCS Database, which includes active, proposed, canceled, and terminated CCS projects worldwide. As of November 2012, the database contained 268 CCS projects worldwide. The 268 projects include 68 capture, 61 storage, and 139 for capture and storage in more than 30 countries across 6 continents. Users can download the CCS Database as a [Google Earth layer](#) or download a copy in [Microsoft Excel](#) file format.



DOE Releases Carbon Utilization and Storage Atlas.

DOE's 2012 United States Carbon Utilization and Storage Atlas (Atlas IV) states that the United States has at least 2,400 billion metric tons of potential CO₂ storage resource in saline formations, oil and gas reservoirs, and unmineable coal. Atlas IV was created by NETL with input from DOE's Regional Carbon Sequestration Partnerships (RCSPs) and American Recovery and Reinvestment Act (ARRA)-funded site characterization projects. [Click here to access the NATCARB Viewer.](#)

NETL Research Results in New U.S. Patents.

Researchers at DOE's NETL received nine patents in 2012 for innovations that address the Nation's energy challenges. The patents include an integrated process for removing pollutants from fossil-fuel combustion systems; a metallurgical melting process to produce defective-free metal ingots; catalysts that make it easier to reform hydrocarbon fuels; stainless steel compositions and heat treatment processes to enhance stainless steel durability; a method to measure the circulation rate of coal solids in gasification reactors; and a process to separate and purify CO₂. Deployment of these technologies will enhance energy efficiency, improve metallurgical processes, and allow for better emissions monitoring and control.

2013 Midwest Carbon Sequestration Science Conference.

The Midwest Geological Sequestration Consortium (MGSC) will hold their annual Project Advisory Meeting on October 7, 2013, at the I Hotel and Conference Center in Champaign, Illinois. This conference will include a full day of Illinois Basin Decatur Project (IBDP) research presentations covering the MGSC Development Phase research activities. The conference will also include a Sequestration Training and Education Program (STEP)-sponsored workshop and an optional tour of the IBDP site. Full meeting details will be distributed in June, with registration opening in July.

12th International Conference on Greenhouse Gas Control Technologies.

GHGT-12 will be held on October 5-9, 2014, in Austin, Texas, USA. This will be the first visit by the conference series to Austin and more than 1,600 participants are expected to attend. The event will be hosted by the University of Texas at Austin and the IEA Greenhouse Gas R&D Programme (IEAGHG).

RGGI Auction 19 Results.

The nine states participating in the Regional Greenhouse Gas Initiative (RGGI) announced that 37,835,405 CO₂ allowances were sold at the 19th auction, held Wednesday, March 13, 2013, at a clearing price of \$2.80. The auction generated \$105.9 million for reinvestment in a variety of consumer benefit initiatives, including energy efficiency, renewable energy, direct bill assistance, greenhouse gas (GHG) abatement, and climate change adaptation programs. Allowances sold represent 100 percent of the allowances offered for sale. Bids for the CO₂ allowances ranged from \$1.98 to \$5.03 per allowance. The next RGGI auction is scheduled for June 5, 2013.

CARBON STORAGE IN THE NEWS

“CONSOL Energy, VCCER Announce Research Project Aimed at Identifying Coal Seam Carbon Storage Alternatives.”

CONSOL Energy and the Virginia Center for Coal and Energy Research (VCCER) at Virginia Tech will collaborate on a research project that will test the CO₂ storage potential of unmineable coal seams. CONSOL Energy’s CNX Gas Virginia operations will donate the use of three coalbed methane (CBM) wells in the pilot project to be conducted by VCCER and NETL in Virginia. Up to 20,000 tons of CO₂ will be injected and stored in coal seams. The injection, which will take place during the course of one year, builds upon a recently completed, 1,000-ton injection test that took place in a neighboring county in 2009. VCCER and NETL have established a comprehensive plan to monitor the injected CO₂ to understand the feasibility of CO₂ storage in unmineable coal seams and explore the potential of enhanced coalbed methane (ECBM) recovery. The test is part of a larger effort funded by NETL for CCS projects. From *CONSOL Energy News Release* on February 4, 2013.

“Summit Power & Linde Join Forces to Develop Projects Deploying Carbon Capture from Natural Gas.”

Summit Power Group and The Linde Group announced a partnership to develop commercial-scale, natural gas-fired power plants that will capture up to 90 percent of CO₂. The new power plants, which will combine natural gas-fired power plant technology with carbon capture technology, will produce approximately 250 megawatts (MW) of net electric power while capturing up to 750,000 tons of CO₂ annually. The companies have identified several U.S. locations for this type of plant where the ultra-low carbon electric power could be sold to utilities and large consumers, and where suitable geologic storage sites are available for CO₂ injection. Both Summit Power and Linde are already developing carbon capture projects for CO₂ storage or EOR. Summit is currently developing two major coal gasification projects that will capture 90 percent of the CO₂ they release: the Texas Clean Energy Project (TCEP) in the United States and the Captain Clean Energy Project (CCEP) in the United Kingdom. From *Summit Power* on February 7, 2013.

“DNV and PSE Report on Ship Carbon Capture and Storage.”

According to results released by Det Norske Veritas (DNV) and Process Systems Enterprise Ltd. (PSE), the Maritime CCS research and development (R&D) project successfully developed a concept design for onboard chemical CO₂ capture. The system consists of a chemical absorption plant to separate CO₂ from flue gases, a liquefaction unit to compress and condense the captured CO₂ using a refrigerant, and two storage tanks to temporarily store the liquid CO₂ until it is discharged into transmission and storage infrastructures at the next suitable port. Maritime CO₂ emissions are estimated at more than 1,000 million metric tons per year (three percent of total emissions) and are expected to reach 2,000 to 3,000 million metric tons by 2050. From *DNV Press Release* on February 12, 2013.

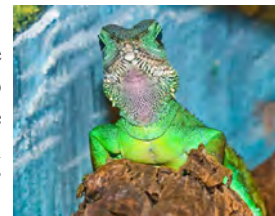
“UKCCSRC Offers Funding for 11 RAPID Research Projects.”

The UK CCS Research Center (UKCCSRC) will offer approximately \$2.5 million in funding for 11 research projects in the areas of CO₂ capture, CO₂ transport, and CO₂ storage. The four capture projects will develop approaches for chemical looping for low-cost oxygen production; oxy-fuel and exhaust gas recycling at gas-fired power plants; computational fluid dynamic (CFD) modeling of oxy-coal combustion; and post-combustion capture using membranes. The four transport projects will deliver important knowledge and understanding for safe and cost-effective design and operations of CCS networks, with projects analyzing the development of flexible CO₂ transport systems; the behavior of dense-phase CO₂ with impurities in pipelines; water solubility limits in CO₂ mixture; and generating equations of state for CO₂ mixtures relevant to CCS applications. Lastly, the three storage projects will contribute to improved characterization for CO₂ storage in the North Sea; the development of processes to monitor CO₂ storage; and a scoping project that will explore a follow-on project monitoring the transport of potential release from the subsurface. More information on the individual projects can be found on the [Projects Page](#). From *UKCCS Research Centre* on February 19, 2013.

SCIENCE

“Lizards Facing Mass Extinction from Climate Change.”

According to recently published research, dozens of lizard species could become extinct within the next 50 years due to potential climate change. Specifically, the study, which appears in the scientific journal “Global Ecology and Biogeography,” suggests that lizards with viviparous reproduction (retention of embryos within the mother’s body) are being threatened as global temperatures increase. Researchers investigated the hypothesis that historic invasions of cold climates by *Liolaemus* lizards have only been possible due to their evolution to viviparity (live birth) from oviparity (laying eggs). It was discovered that once the lizards evolve to viviparity, the process is irreversible and they remain restricted to cold climates. Thus, through analysis, scientists discovered that increasing temperatures in the species’ historically cold habitats could result in a reduction of their areas of distribution. As a result, viviparous lizards may face potential extinction in the next few decades if global temperatures continue to rise at the same rate. From *ScienceDaily* on March 6, 2013.



“Climate Change Could Affect Monarch Butterfly’s Migration, Study Says.”

According to a study published in the journal “Current Biology,” global climate change could have an impact on the migration pattern of the monarch butterfly. Researchers found that monarch butterflies, which fly 2,000 miles south from North America to Mexico every fall and back again in the spring, would keep flying south if they did not feel winter weather. Researchers said that



SCIENCE (CONTINUED)

without a thermal stimulus, the annual migration cycle would be broken. In a previous study, the researchers revealed the butterflies use skylight cues and an internal compass to guide them in their migration south, and the new study found these navigation tools also help the butterflies return north. In order to determine what causes the monarchs to change direction, researchers captured a sample of butterflies as they were about to begin their fall migration south. These butterflies then experienced the same changes in temperature and light they would experience naturally in the Mexican mountains, except in a laboratory. After 24 days in the laboratory, the butterflies were released and headed north and not south, but the butterflies that were captured and kept warm continued to fly south. The study's authors confirmed the change in the monarch's direction was because of the cold temperatures, not day length. From *U.S. News & World Report* on February 21, 2013.

POLICY

“DNV KEMA Launches CO2MPETENCY.”

DNV KEMA has launched a new knowledge management service for the CO₂ management and CCS industries to accelerate worldwide competency building. The new service supports: (1) learning in CO₂ management projects (developing and implementing lessons learned at key milestones and critical points on the project timeline); (2) learning between CO₂ management projects (enabling connections between projects and the identification, capture and sharing of good practices, joint problem solving, and exchange of lessons learned between concurrent projects); and (3) learning from CO₂ management projects (the targeted capture, validation, and dissemination of project knowledge to inform a wider community of practice and future projects). According to a DNV official, the new project learning service can help to reduce the risks by sharing how to manage the risks associated with CO₂ capture, transport, and storage and develop standards that define safe and economical industry practice. Also, the learning service can accelerate technology development through the sharing of effective practices, which can allow the CCS industry to advance more quickly through technology readiness levels in existing and new areas and build public confidence through the distribution of material about the feasibility and safety of CO₂ management strategies. The official also stated that the new service will build regulatory knowledge and address regulatory concerns while regulators learn from real industry knowledge and, in turn, provide industry with opportunities to address concerns and improve organizational efficiencies by promoting mutual problem solving. From *DNV* on February 19, 2013.

“Public perception, knowledge and policy support for mitigation and adaptation to Climate Change in Costa Rica: Comparisons with North American and European studies.”

The following is the Abstract of this article: “Over the past 20 years considerable efforts have been invested in exploring how the public understands climate change. However, the bulk of this research has been

conducted in Europe and North America and little is known about public perceptions of climate change in developing countries. This article presents the results of the first nationally representative study ($n=1473$) of public perceptions of climate change in Costa Rica. In Costa Rica, a large proportion of interviewees (i.e. over 85 percent) are highly concerned about climate change in general and feel, as noted in European and North American studies, that its impacts are more worrisome for people farthest away (e.g. in the developed countries or among future generations). At the local level, people feel that food (10.5 percent) and water (16.1 percent) shortages as well as poverty (11.3 percent) and heat waves (11.7 percent) are the most expected impacts of climate change. Analysis of adaptation behavior responses suggest that individuals have a relatively lower grasp of emergency and prevention disaster plans but are relatively more proactive in preventing hydro-meteorological extremes related to water scarcity or excess. A majority of respondents engage in mitigation behaviors largely for financial or contextual reasons. Finally, support for adaptation and mitigation policy responses is generally high (i.e. above 70 percent of interviewees supports them) except for the case of internalizing the cost of watershed protection increasing the water tariffs (52.5 percent). As discussions about mitigation and adaptation become increasingly common within developing countries, questions about public perceptions in that context are more pressing than ever. Work on climate perceptions needs to be carried out in specific countries to better understand which policies are most likely to resonate with public support, and which might be most difficult to implement.” **R. Vignola, S. Klinsky, J. Tam, and T. McDaniels**, *Mitigation and Adaptation Strategies for Global Change*. (Subscription may be required to view article.)

“India CCS scoping study: Final report.”

The following is a summary of this report: “The present report has been prepared as a part of a scoping study for CCS in India carried out by The Energy and Resources Institute (TERI), with support from the Global CCS Institute. The study was conducted to identify the potential role for CCS in India's GHG mitigation strategies through an examination of issues, opportunities and barriers to the deployment of CCS. The conclusions of the report should help in drawing a roadmap for CCS implementation in India.”

GEOLOGY

“Multimodel Predictive System for Carbon Dioxide Solubility in Saline Formation Waters.”

The following is the Abstract of this article: “The prediction of [CO₂] solubility in brine at conditions relevant to carbon [storage] (i.e., high temperature, pressure, and salt concentration [T-P-X]) is crucial when this technology is applied. Eleven mathematical models for predicting CO₂ solubility in brine are compared and considered for inclusion in a multimodel predictive system. Model goodness of fit is evaluated over the temperature range 304–433 K, pressure range 74–500 bar, and salt concentration range 0–7 m (NaCl equivalent), using 173 published CO₂ solubility measurements, particularly selected for those conditions. The performance of each model is assessed using various statistical methods, including the

GEOLOGY (CONTINUED)

Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Different models emerge as best fits for different subranges of the input conditions. A classification tree is generated using machine learning methods to predict the best-performing model under different T-P-X subranges, allowing development of a multimodel predictive system (MMoPS) that selects and applies the model expected to yield the most accurate CO₂ solubility prediction. Statistical analysis of the MMoPS predictions, including a stratified [five]-fold cross validation, shows that MMoPS outperforms each individual model and increases the overall accuracy of CO₂ solubility prediction across the range of T-P-X conditions likely to be encountered in carbon [storage] applications.” **Zan Wang, Mitchell J. Small, and Athanasios K. Karamalidis**, *Environ. Sci. Technol.* (Subscription may be required to view article.)

“Thermal Activation of Antigorite for Mineralization of CO₂.”

The following is the Abstract of this article: “This contribution demonstrates the sensitivity of antigorite dehydroxylation to treatment conditions and discusses the implications of the observations for scientific (i.e., dehydroxylation kinetics) and technological (i.e., energy efficient conditions and design of practical activation reactors) applications. At present, the energy cost of dehydroxylation of serpentinite ores represent the most important impediment for a large scale implementation of sequestering CO₂ by mineralization. [The authors] have analyzed changes in antigorite’s derivative thermogravimetric curves (DTG) and deduced factors affecting the mass loss profiles. The imposed heating rate, type of purge gas, type of comminution and sample mass all influence the dehydroxylation curve. However, the results show no influence of material of construction of the heating vessel and flow rate of the purge gas. [The authors] report an important effect of oxidation of Fe²⁺ under air purge gas that occurs prior to dehydroxylation and leads to formation of hematite skins on serpentinite particles, slowing down subsequent mass transfer and increasing the treatment temperature. From the process perspective, 75 μm particles afford optimal conditions of temperature and rate of dehydroxylation. Overall, the practical considerations, in thermally activating serpentinite ores for storing CO₂ by carbonation, comprise rapid heating, proper size reduction, prior demagnetisation, and fluidization of the powder bed.” **Reydyck D. Balucan and Bogdan Z. Dlugogorski**, *Environ. Sci. Technol.* (Subscription may be required to view article.)

“Interactions of Supercritical CO₂ with Coal.”

The following is the Abstract of this article: “Carbon dioxide [storage] on coal with CO₂-ECBM is acknowledged as a promising way to mitigate CO₂ emissions. For successfully understanding and implementing CO₂-ECBM process, the potential interactions of CO₂ with coal during CO₂ [storage] in coal seams were investigated. Research methods consisting of low-temperature nitrogen adsorption–desorption and chromatographic analysis were used to address the transformation of coal pore morphology and the capability of supercritical CO₂ extraction when coal contacts with high pressure CO₂. According to the test results, interaction of coal with high pressure CO₂ does not create a significant influence on pore shape and mesoporous volume distribution of any rank of coal. However, this causes the coal surface fractal dimension and

specific surface area to be changed, which implies that the coal’s pore morphology change due to CO₂ sorption is irreversible. The results also indicate that the injection of high-pressure CO₂ does not only change the pore morphology of coal but also has the ability to extract the hydrocarbons present in the coal matrix. The extracted hydrocarbons are of biological toxicity and can be mobilized with gas or water to other geologic structures and [formations]. Thus, the potential environmental safety and health issues (ES&H issues) related to CO₂ [storage] in deep coal seams require thorough assessment.” **Dengfeng Zhang, Lili Gu, Songgeng Li, Peichao Lian, and Jun Tao**, *Energy Fuels*. (Subscription may be required to view article.)

TECHNOLOGY

“Opportunities for Utilizing Anthropogenic CO₂ for Enhanced Oil Recovery and CO₂ Storage.”

The following is the Abstract of this article: “[Carbon dioxide]-EOR has emerged as a major option for productively utilizing CO₂ emissions captured from electric power and other industrial facilities as part of CCS operations. Not only can depleting oil fields provide secure, well characterized sites for storing CO₂, such fields can also provide a source of revenues to offset the costs of capturing CO₂ by producing incremental oil. This paper draws significantly on work by Advanced Resources, sponsored by DOE/NETL, and IEAGHG, that demonstrates that CO₂-EOR offers large CO₂ storage capacity potential, and could accommodate a major portion of the CO₂ captured from industrial facilities for the next 30 years. This work also demonstrates that CO₂ can be effectively and permanently stored when deployed in association with CO₂-EOR, with the amount stored depending on the priority placed on maximizing storage. In addition to showing that CCS benefits from CO₂-EOR by providing the revenues from sale of CO₂, overcoming other barriers, while producing oil with a lower CO₂ emissions ‘footprint.’ The report demonstrates that CO₂-EOR needs CCS; because large-scale future implementation of CO₂-EOR will be dependent on CO₂ supplies from industrial sources.” **Michael L. Godec, Vello A. Kuuskraa, and Phil Dipietro**, *Energy Fuels*. (Subscription may be required to view article.)

“Chemical and Mechanical Properties of Wellbore Cement Altered by CO₂-Rich Brine Using a Multianalytical Approach.”

The following is the Abstract of this article: “Defining chemical and mechanical alteration of wellbore cement by CO₂-rich brines is important for predicting the long-term integrity of wellbores in geologic CO₂ environments. [The authors] reacted CO₂-rich brines along a cement-caprock boundary at 60°C and pCO₂ = 3 MPa using flow-through experiments. The results show that distinct reaction zones form in response to reactions with the brine over the [eight]-day experiment. Detailed characterization of the crystalline and amorphous phases, and the solution chemistry show that the zones can be modeled as preferential portlandite dissolution in the depleted layer, concurrent calcium silicate hydrate (CSH) alteration to an amorphous zeolite and Ca-carbonate precipitation in the carbonate layer, and carbonate dissolution in the amorphous layer. Chemical reaction altered the mechanical properties of the core lowering the average Young’s moduli in the depleted, carbonate, and amorphous layers to approximately 75, 64, and 34

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[percent] of the unaltered cement, respectively. The decreased elastic modulus of the altered cement reflects an increase in pore space through mineral dissolution and different moduli of the reaction products.” **Harris E. Mason, Wyatt L. Du Frane, Stuart D.C. Walsh, Zurong Dai, Supakit Charnvanichborikarn, and Susan A. Carroll**, *Environmental Science and Technology*. (Subscription may be required to view article.)

“A Methodology for Phased Development of a Hypothetical Pipeline Network for CO₂ Transport During Carbon Capture, Utilization, and Storage.”

The following is the Abstract of this article: “If implemented on a commercial scale, [CCS] has the potential to significantly reduce CO₂ emissions. Moving the CO₂ from the point sources to the geologic storage locations will likely require a pipeline network. The Plains CO₂ Reduction (PCOR) Partnership developed a four-step methodology that can be used to estimate the length, cost, and time frame of a hypothetical pipeline network that would be built in phases. The methodology was tested during a case study in which a hypothetical phased pipeline network was estimated for the PCOR Partnership region. The hypothetical pipeline network consisted of trunk lines roughly 10,780 km in total length that could provide an overall CO₂ reduction for the region of about 555.6 M[metric tons] CO₂/yr by 2050. The results also indicate that an extensive pipeline network may not be required to transport to storage locations the quantity of CO₂ required to meet the emission reduction targets for the PCOR Partnership region.” **Melanie D. Jensen, Peng Pei, Anthony C. Snyder, Loreal V. Heebink, Lisa S. Botnen, Charles Gorecki, Edward N. Steadman, and John A. Harju**, *Energy Fuels*. (Subscription may be required to view article.)

“Effects of CO₂ and acid gas injection on enhanced gas recovery and storage.”

The following is the Abstract of this article: “[Storage] of CO₂ and other associated waste gases in natural gas reservoirs is an option to mitigate [GHGs] and enhanced gas recovery. This paper examines strategies to maximize enhanced gas recovery in a natural gas reservoir via subsurface storage of potential associated waste gases such as CO₂ and hydrogen sulfide (H₂S). Numerical simulations are performed with a compositional reservoir simulator ‘Tempest’ using experimental data initially produced by Clean Gas Technology Australia (CGTA) at Curtin University in 2009. The simulation results shows that additional gas is recovered by gas-gas displacement after injecting CO₂ and acid gas (CO₂-H₂S) in two separate scenarios. Importantly, when pure CO₂ is injected, CO₂ breakthrough at the production well occurred faster than the breakthrough under mixed CO₂-H₂S injection.” **Chawarwan Khan, Robert Amin, and Gary Madden**, *Journal of Petroleum Exploration and Production Technology*. (Subscription may be required to view article.)

“Porous Media Compressed-Air Energy Storage (PM-CAES): Theory and Simulation of the Coupled Wellbore-Reservoir System.”

The following is the Abstract of this article: “Expansion in the supply of intermittent renewable energy sources on the electricity grid can potentially benefit from implementation of large-scale compressed air energy storage in porous media systems (PM-CAES) such as [formations] and depleted hydrocarbon reservoirs. Despite a large government research program 30 years ago that included a test of air injection and production in a [formation], and an abundance of literature on CAES mostly relevant to caverns, there remain fundamental questions about the hydrologic and energetic performance of PM-CAES. [The authors] have developed rigorous simulation capabilities for PM-CAES that include modeling the coupled wellbore-reservoir system. Through consideration of a prototypical PM-CAES wellbore-reservoir system representing a depleted hydrocarbon reservoir, [the authors] have simulated 100 daily cycles of PM-CAES. [The authors] find that (1) PM-CAES can store energy but that pervasive pressure gradients in PM-CAES result in spatially variable energy storage density in the reservoir, (2) the wellbore-reservoir storage component of PM-CAES is very efficient, (3) [caprock] and hydrologic seals along with proper sizing of the PM-CAES reservoir prevent excess pressure diffusion from being a problem, and (4) injection and production of air does not significantly mobilize residual liquid water in the reservoir.” **Curtis M. Oldenburg and Lehua Pan**, *Transport in Porous Media*. (Subscription may be required to view article.)

TERRESTRIAL

“Modeling Interactions Between Economic Activity, Greenhouse Gas Emissions, Biodiversity and Agricultural Production.”

The following is the Abstract of this article: “In this article, [the authors] develop a modeling approach which examines selected drivers of ecosystem functioning and agricultural productivity. In particular, [the authors] develop linkages between land use and biodiversity and between biodiversity and agricultural productivity. [The authors] review the literature for quantitative estimates of key relationships and their parameters for modeling human consumption, land use, energy use, and [GHG] emissions on biodiversity and agricultural productivity. [The authors] assemble these specifications into an iterative causal model and carry out a number of scenario projections of country-level consumption, production, land use, energy use, [GHG] emissions, species diversity, and agricultural production up to 2050. Finally, [the authors] dissect the projections into key drivers using structural decomposition and sensitivity analyses.” **Manfred Lenzen, Christopher Dey, Barney Foran, Asaph Widmer-Cooper, Ralf Ohlemüller, Moira Williams, and Thomas Wiedmann**, *Environmental Modeling & Assessment*. (Subscription may be required to view article.)

TRADING

“California Holds Second Auction of Carbon Credits.”

The California Air Resources Board held its second auction on February 19, 2013, selling more than 22 million CO₂ emissions allowance. The minimum bid price for the auction was \$10.71 per

TRADING (CONTINUED)

ton. The state agency's first auction was held in November 2012 and raised \$290 million. Along with the cap-and-trade market, the auction is a centerpiece of AB 32, California's legislation to

address potential climate change. California has placed a ceiling on the total amount of CO₂ that can be released by industries each year; the ceiling, or cap, declines each year. Most allowances are available to companies for free; however, if additional allowances are needed, they can be purchased through the state's auction or on the open market. From *The Sacramento Bee* on February 20, 2013.

RECENT PUBLICATIONS

"The Global Status of CCS: Update, January 2013."

The following is a summary of this document: "This update [summarizes] the current status of large-scale integrated CCS projects (LSIPs) worldwide and outlines the major developments that have occurred since the Institute's [Global Status of CCS: 2012](#) report was published in October 2012. In brief, at the end of January 2013 the Institute identified that the number of LSIPs around the world had decreased from 75 to 72, with two Dutch projects put on hold and one in the United States cancelled. One project in Canada made a positive final investment decision, bringing the total number of projects operating or under construction to 17. Globally, eight operational projects are preventing 23 million [metric tons] of CO₂ per year from reaching the atmosphere. This is expected to increase to 37 million [metric tons] of CO₂ a year by 2015, by which time a further nine projects under construction—up from eight reported in the October 2012 Status Report—will be operating. In a significant setback to CCS demonstration targets in Europe, no CCS projects were awarded funding under the first round of the European Commission's NER300 competition."

"CO₂ Storage Atlas: Norwegian Sea."

The following is a summary of this document: "The Norwegian Sea may be able to store 5.5 gigatons of CO₂. This is more than 100 times Norway's total CO₂ discharge in 2012. The CO₂ Storage Atlas of the Norwegian Sea has been prepared by the Norwegian Petroleum Directorate, at the request of the Ministry of Petroleum and Energy. The studied areas are in opened parts of the Norwegian Continental Shelf (NCS). The main objectives have been to identify the safe and effective areas for long-term storage of CO₂ and to avoid possible negative interference with ongoing and future petroleum activity. This study is based on detailed work on all relevant geological formations and hydrocarbon fields in the Norwegian Sea. The work is based on several studies as well as data from more than 40 years of petroleum activity on the Norwegian Continental Shelf. A new geological study of the coastal-near [formations] in the Norwegian Sea, is included. A study of the CO₂ storage potential in relevant dry-drilled structures and mapped structures in the area is provided, together with a summary of the CO₂ storage potential in oil and gas fields. [Carbon dioxide] storage in [EOR] projects is also discussed. The methodology applied for estimating storage capacity is based on previous assessments, but the storage efficiency factor has been assessed individually for each [formation] based on simplified reservoir simulation cases. The assessed [formations] have been ranked according to guidelines developed for the CO₂ Storage Atlas of the Norwegian part of the North Sea (2011)."

"Communications for carbon capture and storage: Identifying the benefits, managing risk and maintaining the trust of stakeholders."

The following is a summary of this document: "This report reviews the communication approaches of five CCS projects and explores the common challenges and themes they have faced. It is not designed to be a 'template for success' or a 'how-to' guide because all projects are different and all sites have specific issues. It does, however, attempt to draw out communication strategies that have proven to be successful for some projects as they have attempted to earn and maintain stakeholders' trust and suggests measures which, project developers in general and CCS communicators in particular, might adopt if they are to mitigate the risk of failure on the engagement front."

"A deployment strategy for effective geophysical remote sensing of CO₂ sequestration: Final report."

The following is a summary of this document: "The report examines alternative geophysical methods to time-lapse seismic that might be deployed to monitor commercial volumes of stored CO₂. It uses simple geological models for the South Perth and Gippsland basins to simulate the resolution of various techniques or combinations of techniques. Topics covered include lowering noise levels in data processing workflows, estimate noise in a time-lapse sense for shallow well receivers as well as ambient noise imaging for ocean bottom receivers. Whilst no alternative method or combination of methods appears to have the sensitivity to adequately replace a time-lapse seismic approach, the added information could greatly improve the resolution and sensitivity of time-lapse geophysical methods alone."

LEGISLATIVE ACTIVITY

"Sanders, Boxer Propose Climate Change Bills."

U.S. Senator Bernie Sanders, chairman of the Senate Committee Environment and Public Works, and U.S. Senator Barbara Boxer

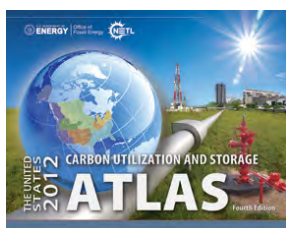
introduced comprehensive legislation that proposes a fee on carbon emissions to fund investments in energy efficiency and sustainable energy technologies. Under the legislation, rebates would be provided to consumers to offset efforts to raise prices by oil, coal, or gas companies. The proposal was drafted as two measures: the [Climate Protection Act](#) and the [Sustainable Energy Act](#). A [summary](#) of the legislation is also available. From *U.S. Senator Bernie Sanders News Release* on February 14, 2013.

About DOE's Carbon Storage Program

The [Carbon Storage Program](#) is implemented by the U.S. Department of Energy's Office of Fossil Energy and managed by the National Energy Technology Laboratory. The program is developing technologies to capture, separate, and store CO₂ in order to reduce greenhouse gas emissions without adversely influencing energy use or hindering economic growth. NETL envisions having a technology portfolio of safe, cost-effective, carbon dioxide capture, transport, and storage technologies that will be available for commercial deployment.

The [Carbon Storage Program Overview](#) webpage provides detailed information of the program's structure as well as links to the webpages that summarize the program's key elements.

Carbon Storage Program Resources



The U.S. Department of Energy's [2012 United States Carbon Utilization and Storage Atlas \(Atlas IV\)](#) shows that the United States has at least 2,400 billion metric tons of potential carbon dioxide storage resource in saline formations, oil and gas reservoirs, and unmineable coal. Data from Atlas IV is available via the [National Carbon Sequestration Database and Geographic Information System \(NATCARB\)](#), which is a geographic information system-based tool developed to provide a view of carbon capture and storage potential.

Newsletters, program fact sheets, best practices manuals, roadmaps, educational resources, presentations, and more are available via the [Carbon Storage Reference Shelf](#).

Get answers to your carbon capture and storage questions at NETL's [Frequently Asked Questions](#) webpage.

There are several ways to join the conversation and connect with NETL's Carbon Storage Program:



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About NETL's Carbon Storage Newsletter

Compiled by the National Energy Technology Laboratory, this newsletter is a monthly summary of public and private sector carbon storage news from around the world. The article titles are links to the full text for those who would like to read more.



National Energy Technology Laboratory

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