



Office of Fossil Energy

Carbon Sequestration Newsletter

NOVEMBER 2012

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Carbon Sequestration

CSLF, an international climate change initiative focused on cost-effective CCUS technologies, officially recognized the projects at a recent meeting in Perth, Australia, for making contributions to the development of global carbon dioxide (CO₂) mitigation technologies. With the recognition, all three projects will appear on the CSLF website in a yearly project portfolio to keep the global community updated on progress, enhancing the projects' global visibility and widespread knowledge sharing opportunities. The three DOE projects, which are managed by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL), are: the Illinois Basin Decatur Project (Decatur, Illinois), a large-scale CCUS demonstration project being conducted by the Midwest Geological Sequestration Consortium (MGSC), one of seven DOE Regional Carbon Sequestration Partnerships (RCSPs); Air Products & Chemicals, Inc. (Allentown, Pennsylvania), a large-scale industrial CCUS project funded by the American Recovery and Reinvestment Act of 2009 (ARRA); and the Illinois Industrial Carbon Capture and Storage Project (Decatur, Illinois), another ARRA-funded, large-scale industrial CCUS project. November 8, 2012, http://www.fossil.energy.gov/news/techlines/2012/12051-CSLF_Praises_DOE_Carbon_Storage_Pr.html.

Fossil Energy Techline, "Carbon Storage Partner Completes First Year of CO₂ Injection Operations in Illinois."

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, "International Carbon Storage Body Praises Department of Energy Projects."

The Carbon Sequestration Leadership Forum (CSLF) recognized three U.S. Department of Energy (DOE) projects as important advancements toward commercialization and large-scale deployment of carbon capture, utilization, and storage (CCUS) technologies.

Led by the Illinois State Geological Survey (ISGS), the Illinois Basin-Decatur Project has completed the first year of injecting CO₂ from an industrial plant at a large-scale test site in Illinois. The project is the first demonstration-scale project in the United States to use CO₂ from an industrial source and inject it into a saline formation. The CO₂, which is being captured from an ethanol production facility operated by the Archer Daniels Midland Company, is being injected in a compressed "supercritical" (dense phase) state into the Mount Simon Sandstone reservoir approximately 7,000 feet below the surface. Injection operations began November 17, 2011, with an average injection rate of 1,000 metric tons (1,100 short tons) per day; after approximately one year, a total of 317,000 metric tons of CO₂ have been injected – about one-third of the planned 1 million metric ton injection volume. The technologies applied and lessons learned from this project will support industry in the region looking to develop CO₂ capture and transport infrastructure, whether it is for carbon storage or enhanced oil recovery (EOR) in the depleted oilfields in the Illinois Basin. November 19, 2012, http://www.fossil.energy.gov/news/techlines/2012/12056-Carbon_Storage_Partner_Completes_F.html.



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HIGHLIGHTS (CONTINUED)

IPAC-CO₂ News Release, "Announcing the World's First Standard for Geologic Storage of CO₂."

CSA Group and the International Performance Assessment Center for Geologic Storage of Carbon Dioxide (IPAC-CO₂) have announced the CSA Z741 Geologic Storage of Carbon Dioxide Standard, the world's first bi-national carbon capture and storage standard for the geologic CO₂ storage for Canada and the United States. The standard, developed with a technical committee of more than 30 professionals from industry, regulators, researchers, and non-government organizations (NGOs) from both sides of the border, is intended to also be used as a basis for the international carbon capture and storage standards through the International Organization for Standardization (ISO). The standard provides essential guidelines for regulators, industry, and others around the world involved with scientific and commercial carbon capture and storage projects, establishing requirements and recommendations for the environmentally safe and long-term geological storage of CO₂ in a way that minimizes risks to the environment and human health. November 15, 2012, <http://ipac-co2.com/uploads/File/PDFs/CSA%20IPAC-CO2%20CCS%20Standard%202012%20Final%20News%20Release%20v1%20copy.pdf>.

Fossil Energy Techline, "Ohio State Develops Game-Changing CO₂ Capture Membranes in DOE-Funded Project."

Researchers from Ohio State University have developed a new hybrid membrane that combines the separation performance of inorganic membranes with the cost-effectiveness of polymer membranes. The technology, which was developed in a project managed by DOE/FE's Carbon Capture Program, has commercial potential for use at coal-fired power plants with CCUS. Ohio State's new hybrid membrane consists of a thin, inorganic "zeolite Y" layer between an inorganic intermediate and a polymer cover. The three layers sit atop a polymer support, which in turn rests on a woven backing. A first prototype was realized by researchers as they combined new nanotechnology characterization and fabrication methods with state-of-the-art manufacturing techniques. They were then able to slash the growth rate of the "zeolite Y" from eight hours to less than 15 minutes, also reducing the ceramic processing time from 43 hours to 20 minutes. November 15, 2012, http://www.fossil.energy.gov/news/techlines/2012/12053-OSU_Develops_Novel_Composite_Membr.html.

SEQUESTRATION IN THE NEWS

Western Australia Business News, "W. Australia CCS Plan Advances."

Following positive results from initial investigations, Western Australia's first onshore carbon capture and storage project, the South West Hub, has proceeded to the next step, as the Department of Mines and Petroleum is exploring the viability of capturing CO₂ from the Harvey region and transporting and storing it underground. The project is currently in the preparation phase and working to establish suitability of an underground reservoir for carbon storage. According to the project coordinators, the first

SEQUESTRATION IN THE NEWS (CONTINUED)

exploratory drilling program confirmed indications of the Lesueur reservoir, a sandstone reservoir approximately 4,900 feet in size and approximately 1.5 miles underground. The results enabled the project team to plan for the next drilling program and three-dimensional seismic mapping of the underground area, which would be undertaken next year. A total of \$330 million in Commonwealth funding has been contributed to the project; to date, \$52 million of it has been committed through the CCS National Flagships Program. October 25, 2012, [http://www.downstreamtoday.com/\(X\(1\)S\(54letw55nxxhy345m1d1s455\)\)/news/article.aspx?a_id=37553](http://www.downstreamtoday.com/(X(1)S(54letw55nxxhy345m1d1s455))/news/article.aspx?a_id=37553).

Bloomberg, “Chevron’s Gorgon Carbon Project on Track for Injection in 2015.”

According to the Australian energy minister, Chevron’s Gorgon liquified natural gas project, located off the northwest coast of Australia, is on track to begin CO₂ injections in 2015. The Gorgon project is designed to inject 3.5 million tons of CO₂ per year below Barrow Island off Western Australia at an approximate depth of 2,300 meters. Australia is aiming to reduce greenhouse gas (GHG) emissions at

least five percent below 2000 levels by 2020, with a long-term goal of cutting GHG emissions by 80 percent below 2000 levels by 2050. October 23, 2012, <http://www.businessweek.com/news/2012-10-23/chevron-s-gorgon-carbon-project-on-track-for-injection-in-2015>.

Bloomberg, “U.K. Shortlists Four Projects Bidding for \$1.6 Billion CCS Funds,” and Reuters, “U.K. Shortlists Projects for Carbon Capture Funding.”

Four projects have been named to a shortlist by the U.K. government for \$1.6 billion of funding for carbon capture and storage projects. The U.K. Department for Energy and Climate Change (DECC) narrowed a list of bids down to the following four projects: Drax’s 304-megawatt (MW) coal plan in North Yorkshire; Shell and SSE’s 1,180-MW combined cycle gas plant in Peterhead; National Grid and Petrofac’s 570-MW coal-gasification project in Grangemouth; and Progressive Energy and GDF Suez’s 330-MW coal-gasification project in Teesside. The U.K. government is expected to select the winner in 2013; the timetable will depend on the selected projects. October 30, 2012, <http://www.bloomberg.com/news/2012-10-30/u-k-shortlists-four-projects-bidding-for-1-6-billion-ccs-funds.html>, and October 30, 2012, <http://uk.reuters.com/article/2012/10/30/uk-britain-energy-ccs-idUKBRE89T0UT20121030?feedType=RSS&feedName=domesticNews>.

ANNOUNCEMENTS

DOE Announces Milestones for MGSC Project.

DOE announced that MGSC has made progress on construction of the Illinois Industrial Carbon Capture and Storage project’s storage facility and opened the National Sequestration Education Center to the public. The Illinois project will be able to store 1 million tons of CO₂ per year once fully operational in 2013, and will also help demonstrate the feasibility and reduce the cost of clean coal and CCUS technologies. For more information, visit: http://www.fossil.energy.gov/news/techlines/2012/12044-Sequestration_Education_Center_Ope.html.

NETL Researchers Chosen as Science & Engineering Ambassadors.

Four NETL researchers have been chosen as Science & Engineering Ambassadors, with the goal of increasing public understanding and engagement with energy issues. Chosen from NETL’s Office of Research and Development (ORD), the four researchers will serve as interpreters and communicators of scientific research to the non-technical public. For more information, visit: http://www.fossil.energy.gov/news/techlines/2012/12050-NETL_Researchers_Chosen_as_Energy_.html.

NETL Releases Accomplishments Document.

DOE/NETL has released a document, titled, “Carbon Storage Program 2010-2011 Accomplishments,” which highlights the accomplishments of the Carbon Storage Program during the 2010 and 2011 calendar years. The new publication shows that the program has achieved numerous accomplishments through the growth, expansion, and introduction of new concepts and opportunities as a result of an adapting effort that incorporates novel activities to resolve issues uncovered by research and development (R&D) activities and social demands. The document is available on the NETL website at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/CS-Program-2010-2011-Accomplishments.pdf.

SCIENCE

CO2CRC Media Release, “New Material Uses Trapdoors to Capture Carbon Dioxide.”

Researchers from the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) have developed a new material capable of separating CO₂ from other gases. The material, a synthesized chabazite

zeolite, uses a molecular “trapdoor” to separate molecules based on their properties rather than their size. The new material can separate the CO₂ from gas streams at a wide range of temperatures and pressures, and also has the potential to separate it from power station flue gases and natural gas production. The team of researchers included input from the Commonwealth Scientific and Industrial Research Organization (CSIRO), the Department of Materials Engineering and Mechanical Engineering at Monash University, and the Australian Synchrotron. The journal paper is available at:

SCIENCE (CONTINUED)

<http://pubs.acs.org/doi/abs/10.1021/ja309274y>. November 9, 2012, <http://www.co2crc.com.au/dls/media/12/Trapdoor%20Capture.pdf>. (Subscription may be required).

***Phys.Org*, “Dinosaur-Era Acoustics: Global Warming May Give Oceans the ‘Sound’ of the Cretaceous.”**

According to new research, potential climate change could be giving the Earth’s oceans the same hi-fi sound qualities they possessed during the Dinosaurs Era more than 100 million years ago. The acidity of the ocean, and in turn the acoustical properties of sea water, is directly affected by global temperatures. The new research predicts that potential climate change will acidify saltwater sufficiently enough by 2100 that low-frequency sound near the ocean surface will travel significantly farther (possibly twice as far) than current levels permit. The data was built on investigations by other researchers, who reconstructed ocean acidity for the past 300 million years by analyzing historic levels of boron in seafloor sediments. The researchers were then able to predict the soundscape of ancient oceans to conclude the low-frequency sound transmission in the ocean 300 million years ago was similar to conditions today. They also found that as the ocean became more acidic, transmission improved, reaching its largest transmission value approximately 110 million years ago, allowing low-frequency sound to travel twice as far. October 18, 2012, <http://phys.org/news/2012-10-dinosaur-era-acoustics-global-oceans-cretaceous.html>.

POLICY

***Businessweek*, “European Union to Propose 2030 Climate Framework by 2014.”**

By 2014, the European Union (EU) plans to propose a framework for reducing GHGs until 2030 to ensure the regulatory stability necessary for investment in clean technologies. According to the European Commission, the proposal will provide long-term perspective on how the EU will continue to move toward a low-carbon economy from its binding goal of cutting emissions by 20 percent in 2020 compared with 1990 levels and its political target of reducing GHGs by 80 percent to 95 percent in 2050. The planned 2030 framework for climate also has the potential to impact emission caps in the EU Emissions Trading System (EU ETS), which imposes emission caps on approximately 12,000 utilities and manufacturing companies in the region. October 23, 2012, <http://www.businessweek.com/news/2012-10-23/european-union-to-propose-2030-climate-framework-by-2014>.

“A Multiobjective Optimization Approach for CCS Infrastructure Considering Cost and Environmental Impact.”

The following is the Abstract of this article: “In this study, [the authors] address the design of a carbon capture and storage infrastructure with economic and environmental concerns. Given a set of available technologies to capture, [store], and transport CO₂, the problem consists of determining the optimal planning of the [carbon capture and storage]

infrastructure capable of satisfying a predefined CO₂ reduction target. The planning task is formulated as a multiobjective mixed-integer linear programming (moMILP) problem, which simultaneously accounts for the minimization of cost and environmental impact. The environmental impact is measured through all contributions made by operation and installation of the [carbon capture and storage] infrastructure. The emissions considered in the environmental impact analysis are quantified according to the principles of Life Cycle Assessment (LCA), specifically the Eco-indicator 99 method. The multiobjective optimization problem was solved by using the ϵ -constraint method. The capability of the proposed modeling framework is illustrated and applied to a real case study based on Korea, for which valuable insights are obtained.” **Jae-Uk Lee, Jee-Hoon Han, and In-Beum Lee**, *Ind. Eng. Chem. Res.*, Available online October 10, 2012, doi:10.1021/ie3009583, <http://pubs.acs.org/doi/abs/10.1021/ie3009583>. (Subscription required.)

GEOLOGY

“Reactivity of Mount Simon Sandstone and the Eau Claire Shale Under CO₂ Storage Conditions.”

The following is the Abstract of this article: “The Mount Simon sandstone and Eau Claire shale formations are target storage and [caprock] formations for the Illinois Basin–Decatur Geologic Carbon Sequestration Project. [The authors] reacted rock samples with brine and supercritical CO₂ at 51°C and 19.5 MPa to access the reactivity of these formations at storage conditions and to address the applicability of using published kinetic and thermodynamic constants to predict geochemical alteration that may occur during storage by quantifying parameter uncertainty against experimental data. Incongruent dissolution of iron-rich clays and formation of secondary clays and amorphous silica will dominate geochemical alterations at this CO₂ storage site in CO₂-rich brines. The surrogate iron-rich clay in the model required significant adjustments to its thermodynamic constants and inclusion of incongruent reaction terms to capture the change in solution composition under acid CO₂ conditions. This result emphasizes the need for experiments that constrain the conceptual geochemical model, calibrate mean parameter values, and quantify parameter uncertainty in reactive-transport simulations that will be used to estimate long-term CO₂ trapping mechanisms and changes in porosity and permeability.” **Susan A. Carroll, Walt W. McNab, Zurong Dai, and Sharon C. Torres**, *Environ. Sci. Technol.*, Available online August 8, 2012, doi:10.1021/es301269k, <http://pubs.acs.org/doi/abs/10.1021/es301269k>. (Subscription required.)

“CO₂-brine-caprock interaction: Reactivity experiments on Eau Claire shale and a review of relevant literature.”

The following is the Abstract of this article: “Long term containment of stored CO₂ in deep geological reservoirs will depend on the performance of the caprock to prevent the buoyant CO₂ from escaping to shallow drinking water [formations] or the ground surface. Here [the authors] report new laboratory experiments on CO₂-brine-caprock interactions and a review of the relevant literature. The Eau Claire Formation is the caprock overlying the Mount Simon sandstone formation, one of the target geological CO₂ storage reservoirs in the Midwest USA region. Batch experiments of Eau Claire shale dissolution in brine were conducted

GEOLOGY (CONTINUED)

at 200°C and 300 bars to test the extent of fluid-rock reactions. Scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis indicate minor dissolution of K-feldspar and anhydrite, and precipitation of pore-filling and pore-bridging illite and/or smectite, and siderite in the vicinity of pyrite. [The authors] also reviewed relevant reactivity experiments, modeling work, and field observations in the literature in an attempt to help define the framework for future studies on the geochemical systems of the caprock overlain on geological CO₂ storage formations. Reactivity of the caprock is generally shown to be low and limited to the vicinity of the CO₂-caprock interface, and is related to the original caprock mineralogical and petrophysical properties. Stable isotope studies indicate that CO₂ exists in both free phase and dissolved phase within the caprock. Carbonate and feldspar dissolution is reported in most studies, along with clay and secondary carbonate precipitation. Currently, research is mainly focused on the micro-fracture scale geochemistry of the shaly caprock. More attention is required on the potential pore scale reactions that may become significant given the long time scale associated with geological carbon storage.” **Faye Liu, Peng Lu, Craig Griffith, Sheila W. Hedges, Yee Soong, Helge Hellevang, and Chen Zhu**, *International Journal of Greenhouse Gas Control*, Available in March 2012 edition, doi:10.1016/j.ijggc.2012.01.012, <http://www.sciencedirect.com/science/article/pii/S1750583612000266>. (Subscription may be required.)

“Coupled alkali feldspar dissolution and secondary mineral precipitation in batch systems – 2: New experiments with supercritical CO₂ and implications for carbon [storage].”

The following is the Abstract of this article: “In order to evaluate the extent of CO₂-water-rock interactions in geological formations for [carbon storage], three batch experiments were conducted on alkali feldspars-CO₂-brine interactions at 150–200°C and 300 bars. The elevated temperatures were necessary to accelerate the reactions to facilitate attainable laboratory measurements. Temporal evolution of fluid chemistry was monitored by major element analysis of in situ fluid samples. SEM, TEM and XRD analysis of reaction products showed extensive dissolution features (etch pits, channels, kinks and steps) on feldspars and precipitation of secondary minerals (boehmite, kaolinite, muscovite and paragonite) on feldspar surfaces. Therefore, these experiments have generated both solution chemistry and secondary mineral identity. The experimental results show that partial equilibrium was not attained between secondary minerals and aqueous solutions for the feldspar hydrolysis batch systems. Evidence came from both solution chemistry (supersaturation of the secondary minerals during the entire experimental duration) and metastable co-existence of secondary minerals. The slow precipitation of secondary minerals results in a negative feedback in the dissolution-precipitation loop, reducing the overall feldspar dissolution rates by orders of magnitude. Furthermore, the experimental data indicate the form of rate laws greatly influence the steady state rates under which feldspar dissolution took place. Negligence of both the mitigating effects of secondary mineral precipitation and the sigmoidal shape of rate-Δ*G**r* relationship can overestimate the extent of feldspar dissolution during CO₂ storage. Finally, the literature on feldspar dissolution in CO₂-charged systems has been reviewed. The data available are insufficient and new experiments are urgently needed to establish a database on feldspar

dissolution mechanism, rates and rate laws, as well as secondary mineral information at CO₂ storage conditions.” **Peng Lu, Qi Fu, William E. Seyfried Jr. Sheila W. Hedges, Yee Soong, Kyle Jones, and Chen Zhu**, *Applied Geochemistry*, Available online May 18, 2012, doi:10.1016/j.apgeochem.2012.04.005, <http://www.sciencedirect.com/science/article/pii/S0883292712001023>. (Subscription may be required.)

TECHNOLOGY

“A SAFT equation of state for the quaternary H₂S-CO₂-H₂O-NaCl system.”

The following is the Abstract of this article: “Phase equilibria and thermodynamic properties of the quaternary H₂S-CO₂-H₂O-NaCl system were studied using a statistical associating fluid theory (SAFT)-based equation of state (EOS) at temperatures from 0 to 200°C (373.15–473.15 K), pressures up to 600 bar (60 MPa) and concentrations of NaCl up to 6 mol/kgH₂O. The understanding of the physical-chemical properties of this system is critical for predicting the consequences of co-injection of CO₂ and H₂S into geological formations (geological carbon [storage]) as an option for mitigating the global warming trend. [EOS] parameters were generated from regression of available and reliable experimental data and incorporation of existing parameters for some subsystems. Densities were predicted and compared with available experimental results. Using the EOS developed in this study, [the authors] predicted equilibrium compositions in both liquid and vapor phases, fugacity coefficients of components, the equilibrium pressures at a given composition of the H₂O-rich phase in electrolyte solutions with NaCl varying from 0 to 4 mol/kgH₂O, and the aqueous solution densities. These predicted values are tabulated and available as supplementary data in the electronic version online. These predictions provide information and guidance for future experiments regarding the thermodynamic properties and phase behaviors in the H₂S-CO₂-H₂O-NaCl system.” **Xiaoyan Ji and Chen Zhu**, *Geochimica et Cosmochimica Acta*, Available online August 15, 2012, doi:10.1016/j.gca.2012.05.023, <http://www.sciencedirect.com/science/article/pii/S0016703712003109>. (Subscription may be required.)

“Process-based approach to CO₂ [release] detection by vadose zone gas monitoring at geologic CO₂ storage sites.”

The following is the Abstract of this article: “A critical issue for geologic carbon [storage] is the ability to detect CO₂ in the vadose zone. Here [the authors] present a new process-based approach to identify CO₂ that has [released] from deep geologic storage reservoirs into the shallow subsurface. Whereas current CO₂ concentration-based methods require years of background measurements to quantify variability of natural vadose zone CO₂, this new approach examines chemical relationships between vadose zone N₂, O₂, CO₂, and CH₄ to promptly distinguish a [release] signal from natural vadose zone CO₂. The method uses sequential inspection of the following gas concentration relationships: 1) O₂ versus CO₂ to distinguish in-situ vadose zone background processes (biologic respiration, methane oxidation, and CO₂ dissolution) from exogenous deep [release] input, 2) CO₂ versus N₂ to further distinguish dissolution of CO₂ from exogenous deep [release] input, and 3) CO₂

TECHNOLOGY (CONTINUED)

versus N₂/O₂ to assess the degree of respiration, CH₄ oxidation and atmospheric mixing/dilution occurring in the system. The approach was developed at a natural CO₂-rich control site and successfully applied at an engineered site where deep gases migrated into the vadose zone. The ability to identify gas [release] into the vadose zone without the need for background measurements could decrease uncertainty in [release] detection and expedite implementation of future geologic CO₂ storage projects.” **K.D. Romanak, P.C. Bennett, Changbing Yang, and Susan D. Hovorka**, *Geophysical Research Letters*, Published on August 15, 2012, doi:10.1029/2012GL052426, <http://www.agu.org/pubs/crossref/2012/2012GL052426.shtml>. (Subscription may be required.)

“Workflow using sparse vintage data for building a first geological and reservoir model for CO₂ geological storage in deep saline [formation]. A case study in the St. Lawrence Platform, Canada.”

The following is the Abstract of this article: “Among all geological CO₂ storage possibilities, deep saline [formations] are of great interest due to their worldwide repartition and their important storage volume. [The authors] present a workflow using available vintage data with poor 2D seismic coverage for building a first geological and reservoir model for CO₂ geological storage in the deep saline [formations] of the St. Lawrence Platform in the Bécancour area (Québec, Canada). In order to optimize the sparse available geoinformation using a geostatistical method, [the authors] kriged the tops of the geological formations recorded at 11 wells using surfaces modeled from seismic horizons picked on 99.4 line-km of 2-D seismic reflection data. Modeled geological horizons show a good compromise between the geometric structure expressed by the variograms and the interpreted variations evaluated from seismic horizons. Using available well logs, distribution of porosity and permeability are computed for generating multiple realizations of the petrophysical properties of the targeted aquifer by sequential Gaussian simulations. The scarcity of available petrophysical data in the targeted aquifer generates high variability between the different realizations. Due to this uncertainty, the population of the 3-D geological model with petrophysical properties that are required for further geostatistical simulations of CO₂ injection do not allow to achieve reliable results. The methodology presented in this paper shows the possibilities and limits of using vintage data, and provides evidence that geophysical data acquired in a 3-D fashion are important to fully characterize a reservoir for CO₂ geological storage.” **Maxime Claprood, Erwan Gloaguen, Bernard Giroux, Elena Konstantinovskaya, Michel Malo, and Mathieu J. Duchesne**, *Greenhouse Gases: Science and Technology*, Available online June 27, 2012, doi:10.1002/ghg.1292, <http://onlinelibrary.wiley.com/doi/10.1002/ghg.1292/abstract>. (Subscription may be required.)

“Simulations of long-column flow experiments related to geologic carbon [storage]: effects of outer wall boundary condition on upward flow and formation of liquid CO₂.”

The following is the Abstract of this article: “Improving understanding of CO₂ migration, phase change, and trapping processes motivates the development of large-scale laboratory experiments to bridge the gap between bench-scale experiments and field-scale studies. Critical to the

design of such experiments are defensible configurations that mimic relevant subsurface flow scenarios. [The authors] use numerical simulation with TOUGH2/ECO2M and ECO2N to design flow and transport experiments aimed at understanding upward flows including the transition of CO₂ from supercritical to liquid and gaseous forms. These experiments are designed for a large-scale facility such as the proposed laboratory for underground CO₂ investigations (LUCI). LUCI would consist of one or more long-column pressure vessels (LCPVs) several hundred meters in length filled with porous materials. An LCPV with an insulated outer wall corresponds to the column being at the center of a large upwelling plume. If the outer wall of the LCPV is assigned fixed temperature boundary conditions corresponding to the geothermal gradient, the LCPV represents a narrow upwelling through a fault or well. Numerical simulations of upward flow in the columns reveal complex temporal variations of temperature and saturation, including the appearance of liquid CO₂ due to expansion cooling. The results are sensitive to outer thermal boundary conditions. Understanding of the simulations is aided by time-series animations of saturation-depth profiles and trajectories through P-T (pressure-temperature) space with superimposed phase saturations. The strong dependence of flow on hydrologic properties and the lack of knowledge of three-phase relative permeability and hysteresis underlines the need for large-scale flow experiments to understand multiphase [release] behavior.” **Curtis M. Oldenburg, Christine Doughty, Catherine A. Peters, and Patrick F. Dobson**, *Greenhouse Gases: Science and Technology*, Available online August 1, 2012, doi:10.1002/ghg.1294, <http://onlinelibrary.wiley.com/doi/10.1002/ghg.1294/abstract>. (Subscription may be required.)



TERRESTRIAL

“An assessment of forest landowner interest in selling forest carbon credits in the Lake States, USA.”

The following is the Abstract of this article: “The [Nation’s] family forest lands can be an important contributor to carbon [storage] efforts. Yet very little is known about how family forest landowners view programs that enable them to sell carbon credits generated from the growth of their forest and the compensation that would be required to encourage a meaningful level of participation. To address this information gap, [the authors] conducted a study to identify and quantify family forest landowner interest in participating in a voluntary carbon market trading program in the Lake States, USA. A mail survey was administered to 2,200 randomly selected family forest owners in Michigan, Wisconsin, and Minnesota. The questionnaire assessed landowner interest in participating in a hypothetical carbon credit trading program and sought information on landowner objectives and practices, perspectives on carbon credit programs and forest land characteristics. A total of 850 usable responses were received. A logistic regression model was developed to examine the factors affecting participation in a forest carbon offset project by family forest owners and estimate landowner participation probability. Results show that carbon program characteristics alongside landowner and parcel characteristics are associated with the decision to participate in a carbon credit program.

TERRESTRIAL (CONTINUED)

Specifically, carbon credit payment amount, contract towards climate change, absentee status, land tenure and total acres owned were found to be significant determinants. [The authors'] findings indicate that carbon [storage] management may align with the ownership goals of many family forest owners in the Lake States." **Kristell A. Miller, Stephanie A. Snyder, and Michael A. Kilgore**, *Forest Policy and Economics*, Available online October 23, 2012, doi:10.1016/j.forpol.2012.09.009, <http://www.sciencedirect.com/science/article/pii/S1389934112002201>. (Subscription may be required.)

TRADING

Reuters, "South Korea Doubles 2013 Emissions Reduction Target," and *BusinessGreen*, "South Korea Doubles Emissions Target for 2013."

Ahead of the launch of a new cap-and-trade scheme in 2015, the South Korean Ministry of Knowledge Economy announced that local industrial and power sectors will be required to reduce GHG emissions by three percent in 2013, compared to the 1.4 percent reduction target for 2012. The fourth largest economy in Asia, South Korea aims to cut 17.2 million metric tons of CO₂ equivalent (CO₂e) of next year's expected emissions, compared to the 8 million metric tons of CO₂ reduction of this year's levels. The doubling of the emissions target is designed to boost competitiveness and help South Korean businesses prepare for the introduction of the national emissions trading scheme, which was approved by lawmakers in May and will start in January 2015. Emitters that fail to meet their reduction targets next year will face fines that will be leveled in 2014. According to the South Korean government, it is expected that industrial and power entities will account for approximately 97 percent of the country's total emissions

in 2013, which is expected to be around 589.8 million metric tons of CO₂ equivalent. October 15, 2012, <http://www.reuters.com/article/2012/10/15/us-korea-emissions-idUSBRE89E03Z20121015>, and October 15, 2012, <http://m.businessgreen.com/bg/news/2216985/south-korea-doubles-emissions-target-for-2013>.

"Relating R&D and investment policies to [carbon capture and storage] market diffusion through two-factor learning."

The following is the Abstract of this article: "[Carbon capture and storage] has the potential to play a major role in the stabilization of anthropogenic [GHGs]. To develop the capture technology from its current demonstration phase towards commercial maturity, significant funding is directed to [carbon capture and storage], such as the EU's €4.5 bn NER300 fund. However, [little is known] about how this funding relates to market diffusion of [carbon capture and storage]. This paper addresses that question. [The authors] initially review past learning effects from both capacity installations and R&D efforts for a similar technology using the concept of two-factor learning. [The authors] apply the obtained learning-by-doing and learning-by-searching rates to [carbon capture and storage] in the electricity market model"J gevqt, which simulates 19 European countries hourly until 2040, to understand the impact of learning and associated policies on [carbon capture and storage] market diffusion. [The authors] evaluate the effectiveness of policies addressing learning-by-doing and learning-by-searching by relating the policy budget to the realized [carbon capture and storage] capacity and find that, at lower policy cost, both methods are about equally effective. At higher spending levels, policies promoting learning-by-doing are more effective. Overall, policy effectiveness increases in low CO₂ price scenarios, but the CO₂ price still remains the key prerequisite for the economic competitiveness, even with major policy support." **Richard Lohwasser and Reinhard Madlener**, *Energy Policy*, Available online October 31, 2012, doi.org/10.1016/j.enpol.2012.09.061, <http://www.sciencedirect.com/science/article/pii/S0301421512008439>. (Subscription may be required.)

RECENT PUBLICATIONS

"Initial Risk Analysis and Decision Making Framework."

The following is the Introduction of this document: "Commercialization of new carbon capture simulation initiative (CCSI) technology will include two key elements of risk management, namely, technical risk (will process and plant performance be effective, safe, and reliable) and enterprise risk (can project losses and costs be controlled within the constraints of market demand to maintain profitability and investor confidence). Both of these elements of risk are incorporated into the risk analysis subtask. Thus far, this subtask has developed a prototype demonstration tool that quantifies risk based on the expected profitability of expenditures when retrofitting carbon capture technology on a stylized 650 MW pulverized coal electric power generator. The prototype is based on the selection of specific technical and financial factors believed to be important determinants of the expected profitability of carbon capture, subject to uncertainty. The uncertainty surrounding the technical performance and financial variables selected thus far is propagated in a model that calculates the expected profitability of investments in carbon capture and measures risk in terms of variability in expected net returns from these investments. Given the preliminary nature of the results of this prototype, additional work is required to expand the scope of the model to include additional risk factors, additional information on extant and proposed risk factors, the results of a qualitative risk factor elicitation process, and feedback from utilities and other interested parties involved in the carbon capture project. Additional information on proposed distributions of these risk factors will be integrated into a commercial implementation framework for the purpose of a comparative technology investment analysis." The document is available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20932.pdf.

RECENT PUBLICATIONS (CONTINUED)

“Geologic Evaluation of the Tucson Basin for Carbon Dioxide [Storage] Potential.”

The following is from the Introduction of this document: “DOE, including its [NETL] and West Coast Regional Carbon Sequestration Partnership (WESTCARB), have established national programs to evaluate the technical feasibility of long-term subsurface geologic storage of CO₂ produced by industrial activity. The WESTCARB is a consortium of seven western U.S. [states] and one Canadian Province that is one of seven regional North American partnerships established to evaluate technical aspects of high-volume CO₂ capture and [storage]. Collaborative WESTCARB research programs have included more than 90 public agencies, private companies, and non-profit organizations. The Arizona Geological Survey (AZGS) began work in 2010 on ‘WESTCARB Phase III – Arizona Geological Characterization.’ As part of ‘WESTCARB Phase III,’ the AZGS is evaluating the potential for CO₂ [storage] in geologic formations that are below a level of 800 meters (m) (2,625 feet [ft]) depth below land surface (bls). This evaluation is directed at porous and permeable geologic formations with impermeable sealing strata in Cenozoic sedimentary basins in the Basin and Range Province, and Paleozoic sedimentary formations of the Colorado Plateau. An initial screening of Cenozoic sedimentary basins with significant depth and volume below the 800 m (2,625 ft) bls level resulted in 10 candidate basins from a total of 88 basins. This report represents ongoing WESTCARB assessment of CO₂ storage potential in the Tucson basin, one of 10 Cenozoic basins in Arizona identified during the preliminary evaluation, and is part of Tasks 2 and 3 of Arizona WESTCARB Phase III. Task 2 consists primarily of characterizing basin structure, stratigraphy, lithology, and the nature of seals or a [caprock]. This task also includes determining the storage capacity of permeable sediments below 800 m (2,625 ft) depth. Task 3 is to determine if, and at what depth, saline groundwater approaches 10,000 milligrams per liter (mg/L) of total dissolved solids (TDS), characterized in a separate salinity study. This concentration represents the threshold above which water is considered non-potable and unsuitable as drinking water. Based on the extent of permeable strata underlying impermeable strata, saturated with saline groundwater above 10,000 mg/L, the CO₂ storage volume below 800 m (2,625 ft) can be revised from earlier estimates.” The entire document is available at: http://repository.azgs.az.gov/uri_gin/azgs/dlio/1479.

“Coal – Energy for Sustainable Development.”

The following is a summary of this document: “Coal is an essential resource for meeting the challenges facing the modern world. It plays a major role in delivering electricity across the globe, is fundamental in the creation of steel and concrete, and provides energy for transport. [The World Coal Association (WCA)] has published ‘Coal – Energy for Sustainable Development,’ which highlights the vital role coal has in delivering energy to the 1.3 billion people who lack access to it as well as coal’s role in building sustainable communities. This section looks at the challenges of providing greater access to energy worldwide, the role played by coal and how access to energy is essential to sustainable development.” The full report is available at: <http://www.worldcoal.org/resources/wca-publications/>.

“World Energy Outlook 2012.”

The following is a summary of this publication: “[WEO-2012] presents authoritative projections of energy trends through to 2035 and insights into what they mean for energy security, environmental sustainability and economic development. Oil, coal, natural gas, renewables and nuclear power are all covered, together with an update on climate change issues. Global energy demand, production, trade, investment and [CO₂] emissions are broken down by region or country, by fuel and by sector.” The full version is available for purchase at: <http://www.iea.org/W/bookshop/add.aspx?id=433%20>.

“CO₂ Emissions from Fuel Combustion.”

The following is a summary of this document: “In recognition of fundamental changes in the way governments approach energy-related environmental issues, the [International Energy Agency (IEA)] has prepared this publication on CO₂ emissions from fuel combustion. This annual publication was first published in 1997 and has become an essential tool for analysts and policy makers. The data in this book are designed to assist in understanding the evolution of the emissions of CO₂ from 1971 to 2010 for more than 140 countries and regions by sector and by fuel. Emissions were calculated using IEA energy databases and the default methods and emission factors from the Revised 1996 [Intergovernmental Panel on Climate Change (IPCC)] Guidelines for National Greenhouse Gas Inventories.” The complete International Energy Agency (IEA) document is available at: <http://www.iea.org/w/bookshop/add.aspx?id=618>.

LEGISLATIVE ACTIVITY

“Public concepts of [carbon capture and storage]: Understanding of the Dutch general public and its reflection in the media.”

The following is the Abstract of this article: “This study aims to increase understanding of the public view on [carbon capture and storage] and

energy innovations in the Netherlands. The study is based on the premise that to understand the public’s concerns and to predict their future opinion, it is necessary to know how people arrive at their evaluations about [carbon capture and storage]. The study described in this paper aimed to enhance insight into currently held beliefs and awareness among the general public about [carbon capture and storage] and CO₂ as well as to investigate the role of the media as a vehicle for knowledge transfer. To meet the first aim, [the authors] interviewed 15 lay people

LEGISLATIVE ACTIVITY (CONTINUED)

to identify commonly held beliefs. Next, [the authors] investigated the prevalence of these beliefs by administering a questionnaire among 401 respondents. To meet the second aim, [the authors] analyzed the 430 articles mentioning [carbon capture and storage] in all major Dutch newspapers from mid-2009 to mid-2010 and investigated respondents' media use and exposure to recent media events about [carbon capture and storage]. The survey revealed several beliefs that were shared by a large group of respondents, some of which were factually incorrect. The media analysis did not yield evidence that national newspapers reinforce or create particular misperceptions such as found in the survey.” **Marjolein de Best-Waldhober, Suzanne Brunsting, and Mia Paukovic**, *International Journal of Greenhouse Gas Control*, Available online November 2012, doi. org/10.1016/j.ijggc.2012.08.016, <http://www.sciencedirect.com/science/article/pii/S1750583612002125>. (Subscription may be required.)

“Argument map for carbon capture and storage.”

The following is the Abstract of this article: “[Carbon capture and storage] can contribute to the deep CO₂ cuts which are necessary to achieve climate change targets. There is, however, a strong public debate whether [carbon capture and storage] should be implemented. In this article [the authors] give an overview of the arguments for and against based on the opinion of Dutch stakeholders. [Carbon capture and storage] is an umbrella term for a wide range of different configurations of separate technologies. Some arguments are applicable in general for all [carbon capture and storage] chains; some are only valid for a particular configuration. In this paper [the authors] will discuss these arguments in the context of the background of different [carbon capture and storage] configurations. The argument that [carbon capture and storage] costs a lot of extra energy, for instance, is valid for the power sector, not for gas treatment. A good understanding of the [carbon capture and storage] debate and the arguments used may help with developing a better energy policy and may give direction to future research and technology development.”

Sander van Egmond and Marko P. Hekkert, *International Journal of Greenhouse Gas Control*, Available online November 2012, doi. org/10.1016/j.ijggc.2012.08.010, <http://www.sciencedirect.com/science/article/pii/S1750583612001958>. (Subscription may be required.)



EVENTS

December 4-5, 2012, **1st International Conference on Global Environmental Changes**, *Government College University, Faisalabad, Pakistan*. This event will bring together researchers, scientists, and policy makers to discuss consequences and mitigation strategies of potential global environmental changes. Topics of interest include, but are not limited to: renewable energy resources; energy policy, planning, and management; potential climate change indicators; and mitigation strategies and adaptation. The conference brochure is available at: <http://gcuf.edu.pk/data/Env%20Conference%20Brochure.pdf>.

December 12, 2012, **Carbon Capture and Storage: The Safety Issues**, *Broadway House, London, UK*. Organized by the Fire and Blast Information Group, this one-day technical meeting includes sessions focused on topics such as management of the carbon capture and storage CO₂ stream; fracture control and the design of dense-phase CO₂ pipelines; CO₂ model validation data collection; and CO₂ corrosion experiments. For registration and abstract information, visit: <http://www.fabig.com/events>.

December 12-14, 2012, **International Conference on Sustainable Development and Governance**, *Ettimadai Campus, Coimbatore, Tamil Nadu, India*. The International Conference on Sustainable Development and Governance: Building Commerce and Communities, is a platform for leaders and academics to consider solutions for the water, energy, and management issues facing communities and industry in India. Included in the agenda is a session focused on carbon trading issues. The entire conference program is available at: <http://amritasustainabledevelopmentconference.org/>.

February 7-9, 2013, **International Conference on Energy Resources and Technologies for Sustainable Development**, *Howrah (near Kolkata), West Bengal, India*. The theme of the conference is the utilization of energy resources through alternative energy technologies for cleaner environment and sustainable development. Topics to be discussed include, but are not limited to: energy resources; clean coal technology and integrated gasification combined cycle (IGCC); combustion system modeling and analysis; and energy policy, planning, and economics. To learn more, visit the conference website at: <http://www.icertsd.com/>.



EVENTS (CONTINUED)

February 28, 2013, **Westminster Energy Environment and Transport Forum**, *Central London, UK*. This forum will cover the options for taking carbon capture and storage technology forward as part of the wider work that is being undertaken to secure future energy supplies and to reduce carbon emissions. Planned sessions include examining the progress and next steps in technology development, deployment costs, the barriers to successful commercialization, and the wider impact and deployment of the technology. To download the latest agenda, visit: <http://www.westminsterforumprojects.co.uk/forums/event.php?eid=487>.

March 7-9, 2013, **2013 NELA National Conference: Delivering a Low Carbon Future**, *The Sebel Albert Park, Melbourne, Victoria, Australia*. This National Environmental Law Association (NELA) conference brings together different aspects of clean energy law, such as environment and climate change lawyers and those involved in environment protection, resources and energy regulation and planning, carbon and biodiversity credits, and emissions trading. Topics to be discussed include the role of state governments in planning a low-carbon future. To download the full program, visit the conference website at: <http://nelaconference.com.au/>.

May 13-16, 2013, **12th Annual Conference on Carbon Capture, Utilization & Sequestration**, *David L. Lawrence Convention Center, Pittsburgh, Pennsylvania, USA*. This conference will provide a forum for the exchange of experience among U.S. and international scientific and engineering communities working on such technology and systems; facilitate the necessary dialogue between technology developers/purveyors, industry, and the public on the development and deployment of viable technologies; and 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/>.

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