NETL the ENERGY lab
Office of Fossil Energy

Carbon Sequestration Newsletter

A Call for Papers
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JANUARY 2012

WHAT'S INSIDE?

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

***FutureGen Alliance News Release*, "FutureGen 2.0 Geologic Characterization Well Successfully and Safely Completed."**

Drilling of the characterization well at the FutureGen 2.0 carbon dioxide (CO_2) storage site in Morgan County, Illinois, was successfully completed, according to the FutureGen Alliance. Reaching a final depth of 4,812 feet, geologists examined the 460-foot thick Eau Claire formation that will form the caprock overlaying a 500-foot thick portion of the Mt. Simon sandstone that forms the potential CO_2 storage reservoir. Further geologic testing will be conducted on data collected from the well to confirm that the geology is suitable for CO_2 storage. Once the drill rig is removed from the well site and a smaller service rig is installed over the well head, hydrologic testing will be conducted in which saline water will be removed from the Mt. Simon sandstone and then reinjected to monitor the formation's response. When the hydrologic testing is complete, the well will be used as a monitoring well for use in future phases of the project. The FutureGen Alliance is a non-profit membership organization created to further the development and demonstration of near-zero emissions coal technology. For more information on FutureGen 2.0, visit: http://www.futuregenalliance.org/. December 20, 2011, http://www.futuregenalliance.org/wp-content/uploads/2011/12/FutureGen_2_0_Geologic_Characterization_Well_Successfully_and_Safely.pdf.

***Fossil Energy Techline*, "CO_2 Injection Begins in Illinois."**

The Midwest Geological Sequestration Consortium (MGSC), one of seven U.S. Department of Energy (DOE) Regional Carbon Sequestration Partnerships (RCSPs), has begun injecting CO_2 for their large-scale CO_2 injection test in Decatur, Illinois. The CO_2 is being captured from the Archer Daniels Midland (ADM) Ethanol Production Facility in Decatur, Illinois. A processing plant built for this project removes water from the CO_2 stream and then compresses the dry CO_2 to a supercritical phase. The compressed CO_2 then travels through a one mile-long pipeline to the wellhead where it is injected into the Mt. Simon Sandstone at a depth of approximately 7,000 feet. November 21, 2011, http://www.netl.doe.gov/publications/press/2011/111121_co2_injection.html.

SEQUESTRATION IN THE NEWS

***B&W News Release*, "B&W Awarded $2.8 Million in DOE Funding for Carbon Capture Research."**

DOE has awarded the Babcock & Wilcox Power Generation Group, Inc. (B&W PGG) $2.8 million in funding to study chemical formulations to improve the performance of its Regenerable Solvent Absorption Technology™ (RSAT) process solvent used to capture CO_2 from coal-fired power plants. B&W will contribute $700,000 toward research and development (R&D) for the project, which will be managed by the National Energy Technology Laboratory (NETL). Work will be conducted at

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Sequestration in the News (Continued)

the B&W Research Center in Barberton, Ohio, where multiple technologies have been developed and tested to capture CO_2 emissions from coal-fired power plants. December 19, 2011, http://phx.corporate-ir.net/phoenix.zhtml?c=236851&p=irol-newsArticle_print&ID=1640860&highlight=.

***The Standard*, "Report Backs Nirranda South Carbon Storage Project,"** and ***Carbon Capture Journal*, "Otway Project Findings Support Geological CO_2 Storage."**

The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) Otway Project at Nirranda South in southwest Victoria, Australia, has verified the potential for geologic CO_2 storage, according to a paper published in the journal "Proceedings of the National Academy of Sciences of the USA." The project, which began in April 2008 and is now in its second stage (running until 2015), studies CO_2 storage in a nearby depleted natural gas reservoir two kilometers underground. According to the journal paper, titled, "Safe storage and effective monitoring of CO_2 in depleted gas fields," the project confirmed that depleted gas fields could store significant amounts of CO_2, and that large-scale geologic storage could be monitored. The Australian Federal Government, the Victorian State Government, and CO2CRC members support this project. To read the journal paper, click: http://www.pnas.org/content/early/2011/12/16/1107255108.full.pdf+html. December 14, 2011, http://www.standard.net.au/news/local/news/general/report-backs-nirranda-south-carbon-storage-project/2391952.aspx and December 18, 2011, http://www.carboncapturejournal.com/displaynews.php?NewsID=883.

***Engineering News*, "Norway to Commission $1 [Billion] Carbon Capture and Storage Project in 2012."**

According to the Norwegian State-owned oil and gas company Gassnova, the Technology Centre Mongstad (TCM) project in Norway will be commissioned in the second quarter of 2012. Currently under construction and approximately 85 percent complete, the $1 billion TCM project will further develop carbon capture and storage (CCS) technologies by testing, verifying, and demonstrating technology suitable for CO_2 capture facilities. For more information on TCM, the world's largest facility for testing CO_2 capture technologies, visit: http://www.tcmda.com/en/. December 1, 2011, http://www.engineeringnews.co.za/article/norway-to-commission-1bn-carbon-capture-and-storage-project-in-2012-2011-12-01.

ANNOUNCEMENTS

Symposium on CO_2 Geosequestration.

A one- to two-day symposium on CO_2 geosequestration is being planned for the 34th International Geological Congress (IGC) meeting, held in Brisbane, Australia, on August 5-10, 2012. The symposium will include several sessions, covering topics such as: storage site exploration, evaluation, and selection; storage capacity; case studies and new projects; and CO_2 risk analysis and mitigation. Abstracts are being accepted through February 17, 2012. For more information, visit: http://www.34igc.org/.

Big Sky Annual Meeting.

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

IEAGHG 2012 Summer School.

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

Call for Scientific Research Proposals.

Carbon Management Canada (CMC) is now accepting proposals for its third round of research funding, emphasizing research with potential major impacts on GHG emissions from the fossil fuel industry and large stationary emitters. CMC expects to allocate approximately $10 million for this call for proposals, with a deadline of February 15, 2012. For more information, go to: http://www.cmc-nce.ca/news/2011/11/15/call-for-scientific-research-proposals/.

Call for Papers.

Abstracts are now being accepted for the 11th International Conference on Greenhouse Gas Control Technologies (GHGT-11), to be held November 18-22, 2012, at the Kyoto International Conference Center in Kyoto, Japan. The objective of GHGT-11 is to bring together stakeholders in the CCS field to discuss new insights, experiences, developments, and research in GHG emission reduction. Both oral and poster presentations will be accepted on the technical and social aspects of CCS; the deadline is February 10, 2012. For more information, as well as a list of technical themes, visit: http://www.ghgt.info/docs/docs/GHGT-11/GHGT_11_CFP_FINAL_web.pdf.

SCIENCE

***Discovery News*, "Rattlesnakes Can't Keep Up With Climate Change."**

According to researchers, potential climate change could force rattlesnakes to adapt as much as 1,000 times more quickly than in the past in order to find new, tolerable habitats. The study, published in the journal "PLoS One," created maps of the ranges of 11 rattlesnake species at 4,000-year intervals, going back 320,000 years. Researchers then analyzed each era's climate conditions, studying how temperature and precipitation affected the snakes' suitable ranges. In the past, rattlesnakes moved to new habitats when facing unsuitable changes in climate to which they could not physically adapt. However, using accepted climate projections from the Intergovernmental Panel on Climate Change (IPCC) to see how potential climate change would affect them through the year 2100, researchers found that rattlesnakes would have to move from 100 to 1,000 times more quickly than they have over the last 300 millennia to survive and reach acceptable habitats. December 14, 2011, http://news.discovery.com/animals/rattlesnake-climate-change-111214.html.

***Tehran Times*, "Pair of NASA Studies Reaffirm Impact of Global Warming."**

NASA officials have released a pair of studies showing that potential climate change over the next century may lead to a transformation for Earth's plants and animals. In the first report, titled, "Paleoclimate Record Points Toward Potential Rapid Climate Changes," researchers from NASA's Goddard Institute for Space Studies analyzed the Earth's paleoclimate history and suggested the possibility of changes, such as sea level rise and the change of ecological habitats, if potential climate change is not avoided. In the second study, titled, "NASA – Climate Change May Bring Big Ecosystem Changes," researchers from NASA's Jet Propulsion Laboratory and the California Institute of Technology examined the effect potential climate change could have on Earth's plant life over the next three centuries, such as reducing biodiversity and

Science (Continued)

affecting Earth's element cycles. The NASA report, "NASA – Climate Change May Bring Big Ecosystem Changes," is available at: http://www.nasa.gov/topics/earth/features/climate20111214.html. The NASA report, "Paleoclimate Record Points Toward Potential Rapid Climate Changes," is available at: http://www.nasa.gov/topics/earth/features/rapid-change-feature.html. December 20, 2011, http://www.tehrantimes.com/science/93704-pair-of-nasa-studies-reaffirm-impact-of-global-warming.

Policy

***PRWeb*, "World Bank's New Greenhouse Gas Accounting Methodology Approved by SCS."**

Scientific Certification Systems (SCS), a global leader in providing third-party environmental and sustainability certification, auditing, testing, and standards, has approved the World Bank's new GHG accounting methodology under the Verified Carbon Standard (VCS). Based on the Western Kenya Smallholder Agriculture Carbon Finance project, which focuses on helping farmers adopt practices that increase carbon in soil and biomass on agricultural lands, the new methodology will allow project developers to estimate GHG reductions of sustainable land management practices (SALM). January 6, 2012, http://www.prweb.com/releases/2012/1/prweb9082681.htm.

"Effectiveness of setting cumulative carbon dioxide emissions reduction targets."

The following is the Abstract of this article: "In current policies, targets for GHG and more specifically CO_2 emissions are set on the basis of annual emissions. However, warming effects associated with global average temperature rise depend on accumulation of GHG in the atmosphere. Due to the quantity and longevity of CO_2 in the atmosphere there is increasing awareness that taking into account cumulative CO_2 emissions in defining targets for restraining the growth of CO_2 emissions would be particularly effective. The notion of effectiveness is linked to measuring the degree of achievement of the objectives. Considering CO_2 emissions targets set over a few decades, the path of emissions reduction contains relevant information that cannot be captured by a classical measure like the distance to the target. The main contribution of this paper is the definition of an original measure of [CO_2] reduction effectiveness, which allows comparison of specified CO_2 reduction paths expressed in deterministic or probabilistic ways. Appropriate metrics are used to illustrate the proposed measure which in particular captures the importance of early action. The χ_0 measure is applied to simple what-if scenarios for the EU27 electricity and heat sector to 2050, evaluating the impact of each scenario with respect to a reference case." **Gianfranco Chicco and Paule M. Stephenson**, *Energy*, Available online December 17, 2011, doi:10.1016/j.energy.2011.11.024, http://www.sciencedirect.com/science/article/pii/S0360544211007420. (Subscription may be required.)

Geology

"The Impact of Geologic Variability on Capacity and Cost Estimated for Storing CO_2 in Deep-Saline Aquifers."

The following is the Abstract of this article: "While numerous studies find that deep-saline sandstone aquifers in the United States could store many decades worth of the [Nation's] current annual CO_2 emissions, the likely cost of this storage (i.e. the cost of storage only and not capture and transport costs) has been harder to constrain. [The authors] use publically available data of key reservoir properties to produce geo-referenced rasters of estimated storage capacity and cost for regions within 15 deep-saline sandstone aquifers in the United States. The rasters reveal the reservoir quality of these aquifers to be so variable that the cost estimates for storage span three orders of magnitude and average > \$100/tonne CO_2. However, when the cost and corresponding capacity estimates in the rasters are assembled into a marginal abatement cost curve (MACC), [the authors] find that ~ 75 [percent] of the estimated storage capacity could be available for < \$2/tonne. Furthermore, ~ 80 [percent] of the total estimated storage capacity in the rasters is concentrated within just two of the aquifers – the Frio Formation along the Texas Gulf Coast, and the Mt. Simon Formation in the Michigan Basin, which together make up only ~ 20 [percent] of the areas analyzed. While [the authors'] assessment is not comprehensive, the results suggest there should be an abundance of low-cost storage for CO_2 in deep-saline aquifers, but a majority of this storage is likely to be concentrated within specific regions of a smaller number of these aquifers." **Jordan K. Eccles, Lincoln Pratson, Richard G. Newell, and Robert B. Jackson**, *Energy Economics*, Available online December 14, 2011, doi:10.1016/j.eneco.2011.11.015, http://www.sciencedirect.com/science/article/pii/S0140988311002891. (Subscription may be required.)

"Predicting CO_2-water interfacial tension under pressure and temperature conditions of geologic CO_2 storage."

The following is the Abstract of this article: "Storage in subsurface geologic formations, principally saline aquifers, is currently under development as a major approach to counter anthropogenic CO_2 emissions. To ensure the stability and long-term viability of geologic carbon storage, injected CO_2 must be kept in place by an overlying cap rock of very low permeability. Capillary forces in the cap rock act to prevent upward migration and escape of the stored supercritical fluid, with interfacial tension (IFT) between the aqueous brine phase and the CO_2 phase being the primary control. However, published experimental CO_2-water IFT data vary widely, mainly because of inadequate experimental protocols or inappropriate use of bulk-fluid properties in computing IFT from experimental observations. Only two published data sets were found to meet all criteria of merit for an accurate measurement of IFT over the entire range of pressure (5-45 MPa) and temperature (298-383 K) pertinent to geologic carbon storage. In such circumstances, molecular simulations can enhance the utility of limited data when used to validate assumptions made in their interpretation, resolve discrepancies among data, and fill gaps where data are lacking. Simulations may also be used to provide insight into the relationship between IFT and fundamental properties, such as the strength of the CO_2-H_2O interaction. Through molecular dynamics simulations, [the authors] compared the quality of three CO_2 models and two H_2O models (SPC/E and TIP4P2005) in predicting IFT under the

Geology (Continued)

pressure and temperature conditions relevant to geologic CO_2 [storage]. Interfacial tension at fixed temperature simulated via molecular dynamics decreased strongly with increasing pressure below the critical CO_2 pressure of 7 MPa, then leveled off, in agreement with experiment, whereas increasing temperature from 300 to 383 K at fixed pressure had little effect on IFT, which is also consistent with experimental data. [The authors'] results demonstrated that the strength of the short-range portion of the CO_2-H_2O interaction exerts a major influence on IFT. The CO_2 model that best represented the attractive part of this interaction for randomly-oriented water molecules also best captures the experimental pressure dependence of IFT when combined with either water model. When combined with the SPC/E water model, this CO_2 model underestimated IFT by ~10 mN/m, which approximately equals the amount by which the SPC/E water model underestimates the surface tension of pure water. When combined with the TIP4P2005 water model, this model accurately captured the pressure dependence of the CO_2-H_2O IFT at 383 K over the entire pressure range examined. These pressure variations will have the dominant effect on IFT – especially at pressures lower than the CO_2 critical pressure (~7 MPa) – and, therefore, on the CO_2 storage capacity and sealing integrity of a subsurface reservoir." **Laura C. Nielsen, Ian C. Bourg, and Garrison Sposito**, *Geochimica et Cosmochimica Acta*, Available online December 19, 2011, doi:10.1016/j.gca.2011.12.018, http://www.sciencedirect.com/science/article/pii/S0016703711007393. (Subscription may be required.)

"Pore Size Effects on the Sorption of Supercritical CO_2 in Mesoporous CPG-10 Silica."

The following is the Abstract of this article: "Excess sorption isotherms of supercritical [CO_2] in mesoporous CPG-10 silica glasses with nominal pore sizes of 7.5 and 35 nm were measured gravimetrically at 35 and 50°C and pressures of 0–200 bar. Formation of broad maxima in the excess sorption was observed at fluid densities below the bulk critical density. Positive values of excess sorption were measured at bulk densities below 0.7 g/cm3, i.e., the interfacial fluid is denser than the bulk fluid at low pressures. Zero and negative values were obtained at higher densities, i.e., the adsorbed fluid becomes equal to and eventually less dense than the corresponding bulk fluid. Pronounced confinement effects on sorption behavior have been found and further analyzed by normalizing the excess sorption to the adsorbent surface area and pore volume, yielding new insight into supercritical fluid adsorption in this range of pore sizes and P, T conditions. If normalized to the specific surface area, the excess sorption is higher for the 35 nm pore size material, but the pore volume normalized excess sorption is higher for the 7.5 nm pore size material. With increasing pore width, the excess sorption peak position shifts to higher pressure. Both CPG-10 materials exhibit regions of constant mean pore fluid density as a function of bulk CO_2 density at 35°C but not at 50°C. This region is located between the excess sorption peak maximum and the adsorption/depletion transition point. Applied to the situation of CO_2 [storage] in dry sandstone formations, the results of this study indicate that carbon storage capacity is enhanced by sorption effects, particularly at low temperature and in narrow pores with high surface to volume ratios." **Gernot Rother, Elizabeth G. Krukowski, Dirk Wallacher, Nico Grimm, Robert J. Bodnar, and David R. Cole**, *J. Phys. Chem. C*, Available online December 27, 2011, doi:10.1021/jp209341q, http://pubs.acs.org/doi/abs/10.1021/jp209341q. (Subscription may be required.)

Technology

"Carbon dioxide capture with membranes at an IGCC power plant."

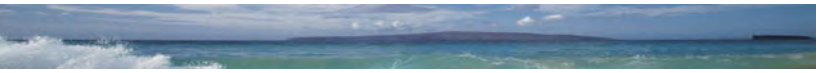
The following is the Abstract of this article: "Integrated Gasification Combined Cycle (IGCC) power plants are being developed as an economical method of producing electricity from coal while simultaneously capturing CO_2 for [storage]. In these plants, conventional cold absorption processes are considered the baseline technology to separate CO_2 from gasified coal syngas. Separation and [storage] of the CO_2 by these methods increases the levelized cost of the electricity (LCOE) produced by approximately 30 [percent]. This paper describes the use of hydrogen-selective and CO_2-selective membranes used in various process designs to perform the same separation. The best design, using recently developed membranes, has 40 [percent] of the capital cost and uses 50 [percent] of the energy of cold absorption. The resulting increase in the LCOE to separate and [store] the CO_2 is then approximately 15 [percent]. If higher permeance, and especially more selective, membranes can be developed, the cost of the technology described will be reduced even further." **Tim C. Merkel, Meijuan Zhou, and Richard W. Baker**, *Journal of Membrane Science*, Available online November 12, 2011, doi:10.1016/j.memsci.2011.11.012, http://www.sciencedirect.com/science/article/pii/S0376738811008283. (Subscription may be required.)

"Influence of droplet mutual interaction on carbon dioxide capture process in sprays."

The following is the Abstract of this article: "Sprays are an important tool for [CO_2] capture through absorption. To figure out CO_2 capture processes in sprays, the gas absorbed by a single droplet under droplet mutual interaction is investigated. In the study, the number density of droplet is in the range of 103–106 cm^{-3}. By conceiving a bubble as the influence distance of the droplet–droplet interaction, the predictions indicate that the mutual interaction plays an important role on the absorption process and uptake amount of CO_2 when the number density is as high as 106 cm^{-3} with droplet radius of 30 μm. Specifically, the absorption period and CO_2 uptake amount of a droplet are reduced by [seven percent] and 10 [percent], respectively, so that the absorption rate is decreased compared to the droplet without interaction. Though the droplet mutual interaction abates the CO_2 uptake amount of a single droplet, a higher number density is conducive to the total uptake amount of CO_2 from the gas phase to the liquid phase. With the number density of 106 cm^{-3} and increasing the droplet radius from 10 to 50 μm, CO_2 capture from the gas phase to the liquid phase is intensified from 0.35 [percent] to 47.8 [percent], even though the droplet–droplet interaction lessens the CO_2 uptake amount of a single droplet by a factor of 48 [percent]. In conclusion, a dense spray with larger droplet radii enhances the droplet–droplet interaction and thereby reduces CO_2 capture capacity of single droplets; but more solute can be removed from the gas phase." **Wei-Hsin Chen, Yu-Lin Hou, and Chen-I Hung**, *Applied Energy*,

Technology (Continued)

Available online November 29, 2011, doi:10.1016/j.apenergy.2011.10.035, http://www.sciencedirect.com/science/article/pii/S0306261911006891. (Subscription may be required.)



Terrestrial

"Sustainable dynamics of size-structured forest under climate change."

The following is the Abstract of this article: "The paper investigates the impact of global climate change on the sustainable growth of forest, namely, on its aggregated characteristics such as the number of trees, the basal area, and the amount of carbon [stored] in the stand. The forest dynamics is described by a nonlinear size-structured population model. The existence of a steady state regime is proven and explicit formulas for the aggregated characteristics are obtained. A numeric simulation on realistic data illustrates and extends the obtained analytic results." **Natali Hritonenko, Yuri Yatsenko, Renan-Ulrich Goetz, and Angels Xabadia**, *Applied Mathematics Letters*, Available online December 21, 2011, doi:10.1016/j.aml.2011.12.020, http://www.sciencedirect.com/science/article/pii/S089396591100615X. (Subscription may be required.)

"Changes in soil carbon sequestration, fraction and soil fertility in response to sugarcane residue retention are site-specific."

The following is the Abstract of this article: "Sugarcane crop residues contain substantial quantities of C and plant nutrients, but there have been relatively few studies of how sugarcane residues enrich the soil and contribute to C [storage], and most studies have been undertaken at only one or a few sites. The purpose of this study was to address these knowledge gaps by determining the magnitude and time scale of changes in soil concentrations of total C, C fractions and plant nutrients following retention of sugarcane residues. C fractions were determined by two different methods. [The authors] sampled soils from five experiments, in contrasting environments, where sugarcane residues had been either retained or removed for between [one] and 17 years. Changes in the concentration of both soil C and plant nutrients were highly site-specific and not in proportion to the period that residues were retained: for example, soil C (0–250 mm) decreased by 0.9 g kg^{-1} and 0.5 g kg^{-1} at sites where residues had been retained for [one] and 17 years, respectively, but increased by 2.0 g kg^{-1} at a site with residues retained for [six] years. Soil C composition, defined by the $KMnO_4$ oxidation and particulate organic C-ultraviolet photo-oxidation fractionation (POC-UV) schemes, appeared to be a more sensitive indicator of changes in residue management, indicating that increases in readily-oxidizable C and particulate organic C, respectively, after [one] year of retaining instead of burning residues. The two methods provided different information that was complementary in understanding changes in soil C. The $KMnO_4$ method identified downward movement of C fractions in the profile to 250 mm, while the labile fractions measured by the POC-UV scheme appeared to be more sensitive to early changes in residue management (after [one] year). While recent studies have found that several concentrations of $KMnO_4$ reduced all C fractions by a similar magnitude and thus concentrated on the fraction oxidized by the 333 mM concentration of $KMnO_4$, [the authors] found that use of both this and the 33 mM concentration enabled a greater understanding of changes in C pools due to residue management." **P.J. Thorburn, E.A. Meier, K. Collins, F.A. Robertson**, *Soil and Tillage Research*, Available online December 22, 2011, doi:10.1016/j.still.2011.11.009, http://www.sciencedirect.com/science/article/pii/S016719871100208X. (Subscription may be required.)

Trading

***Western Climate Initiative*, "Final Offset Protocol Review and Recommendation Process Available."**

The Western Climate Initiative (WCI) released a standard process to review offset protocols and recommend them for adoption into their partner jurisdictions' rules and regulations to help ensure an adequate supply of high-quality offsets. The WCI Design Recommendations (2008) advocate establishing an offset system to support the WCI cap-and-trade program. The Design for the WCI Regional Program (2010) recommends essential criteria for credible offsets, and that the standards and processes for approving offset projects should be developed in advance of the start of the cap-and-trade program, and in an open and transparent manner. The final process provides a step-by-step description of how existing offset protocols will be reviewed by WCI Partner jurisdictions in regard to how they meet WCI offset criteria. According to WCI, consistent, transparent processes are expected to lower project development costs and support learning and sharing of experience among WCI Partner jurisdictions and offset protocol developers. To download the Final Offset Protocol Review and Recommendation Process, go to: http://www.westernclimateinitiative.org/document-archives/Offsets-Committee-Documents/Offset-Protocol-Review-and-Recommendation-Process/. December 19, 2011, http://www.westernclimateinitiative.org/news-and-updates/140-final-offset-protocol-review-and-recommendation-process-available.

"Carbon sequestration and permit trading on the competitive fringe."

The following is the Abstract of this article: "This paper makes two contributions to the carbon-[storage] policy literature. First and foremost, [the authors] develop a theoretical framework in which [storage] and permit-trading markets are analyzed jointly in the context of a competitive fringe model. [The authors'] framework formalizes the linkage between regulatory policy changes (as they manifest themselves in the permit market) and subsequent equilibrium allocations in the [storage] market. Second, [the authors] perform a numerical analysis demonstrating the role market structure, or market power, might play in the determination of the equilibrium [storage] allocation and carbon price. Both [the authors'] analytical and numerical results demonstrate the importance of incorporating into empirical supply-side models demand-side information that is reflective of an underlying market structure." **Arthur J. Caplan**, *Economic Modeling*, Available online September 28, 2011, doi:10.1016/j.econmod.2011.08.018, http://www.sciencedirect.com/science/article/pii/S0264999311002100. (Subscription may be required.)

Recent Publications

"CO_2 Storage Atlas: Norwegian North Sea."

The following is from the Introduction of this document: "Production of power and other use of fossil energy is the largest source of [GHG] emissions globally. Capture and storage of CO_2 in geological formations emerges as an important potential measure to reduce global emissions. The Norwegian government places great emphasis on CCS as a measure to reduce CO_2 emissions. The government has set ambitious goals for achieving CO_2 capture at gas fired power plants and for establishing a chain for transport and injection of CO_2. In its Special Report on Carbon Dioxide Capture and Storage (2005), the United Nations IPCC concludes that capture and storage of CO_2 may account for as much as one half of emission reductions in this century. However, major challenges must be solved before this potential can be [realized]. The IPCC report points out that there is as yet no experience from capture of CO_2 from large coal and gas power plants. Norway has extensive experience in storage of CO_2 in geological structures. Since 1996, approximately one million tonnes of CO_2 per year have been separated from gas production on the Sleipner Vest field in the North Sea for storage in Utsira, a geological formation 1,000 meters below the seabed. In connection with treatment of the well stream from the Snøhvit field and the liquefied natural gas (LNG) production on Melkøya, there is capacity for separation and storage of 700,000 tonnes of CO_2 in a reservoir 2,600 meters below the seabed. There is significant technical potential for storing CO_2 in geological formations around the world. Producing oil and gas fields, abandoned oil and gas fields and other formations such as saline aquifers are all candidates for such storage. Storage in reservoirs that are no longer in operation is a good solution in terms of geology because these structures are likely to be impermeable after having held oil and gas for millions of years. Other formations are also considered to be secure storage alternatives for CO_2. Environmentally sound storage of CO_2 is a precondition for a successful CCS chain. Consequently, the mapping, qualification and verification of storage sites is indispensable for CCS as a climate change mitigation measure. Geological formations offshore Norway are expected to be well-suited for storing large quantities of CO_2. It is important to have the best possible understanding of what can be the CO_2 storage potential. These factors necessitate an enhanced effort within the mapping and investigation of CO_2 storage sites. The production of this CO_2 storage atlas is at the very centre of this effort, and the atlas will be a key component in the development of aquifers at the Norwegian Continental Shelf as storage sites for CO_2. Various Norwegian research institutions and commercial enterprises have extensive experience and competence within CO_2 storage." To view the complete CO_2 Storage Atlas, visit: http://www.npd.no/Global/Norsk/3-Publikasjoner/Rapporter/PDF/CO2-ATLAS-lav.pdf.

"Mountaineer Commercial Scale Carbon Capture and Storage (CCS) Project CO_2 Storage Report."

The following is from the Executive Summary of this document: "American Electric Power (AEP) has been actively involved in the development of CCS technology over the past eight years. AEP's early work with CCS began in 2003 in the Ohio River Valley CO_2 Storage Project. Additionally, AEP's Mountaineer power plant in New Haven, West Virginia hosted two CCS projects which include the Product Validation Facility (PVF) and the Mountaineer Commercial Scale Project (MT CCS II), facility. The PVF project was a 20 [megawatt (MW)] equivalent ammonia-based post combustion CO_2 capture and [storage] facility and the CSP is a planned scale-up of the same technologies for a 235 MW equivalent coal fired unit. There is substantial overlap with respect to the storage aspect between these two projects, however this report is primarily focused on the storage aspects of MT CCS II. Some of the broad findings and technical details captured from the previous projects are being shared in this report but further details are out of the scope of this project and cannot be shared. The MT CCS II project has been divided into four phases, Phase I – Front-end Engineering and Design, Phase II – Detailed Design, Phase III – Construction, and Phase IV – Operations; the MT CCS II project has recently completed Phase I. As a part of Phase I of MT CCS II, a geologic characterization well was drilled at Borrow Area which is approximately [two] miles southwest from the Mountaineer plant. Also, two 2D seismic lines were purchased, processed and analyzed. The characterization well at the Borrow Area and the two additional 2D seismic lines were essential in the characterization of the local geology. Prior to completing the Borrow Area characterization well, a geologic model for MT CCS II was generated based on the geologic knowledge gained from the PVF project and data from five deep wells of the PVF project (two injection wells and three deep monitoring wells). This geologic model was used as an input for a reservoir simulation model and multiple simulations were generated for a CO_2 injection rate of 1.5-million metric tonnes/year (the target capture rate of MT CCS II). The target reservoir for injection is the lower copper ridge formation at a depth of approximately 8,100 ft. The simulation results provided an estimate of CO_2 footprint, the extent of the pressure perturbation field, the expected injection pressures, and the CO_2 saturation in the reservoir (along with other parameters). Based on these reservoir simulations, it was decided that two injection wells (two sites with one well at each location with an approximately [seven] miles distance between the two sites) will be adequate to safely inject 1.5 million metric tonnes of CO_2 each year for a period of five years." The entire AEP CO_2 Storage Report is available at: http://www.globalccsinstitute.com/sites/default/files/publications/27436/mt-ccs-ii-co2-storage-report-final_0.pdf.

"Canadian and Albertan perceptions of carbon capture and storage."

The following is from the Introduction of this document: "Project Pioneer represents a major step toward advancing the reduction of a key GHG emission – [CO_2]. TransAlta and its project partners believe that maintaining the long-term viability of fossil-fired generation is a global necessity. Through economic CCS [the authors] can keep coal and natural gas as fuel options while addressing climate change concerns. Much of the world, including Canada, is fortunate to have huge, reliable reserves of low-cost coal – more coal than oil, in fact. Within the global electricity generation mix, coal is vital and often

Recent Publications (Continued)

the only practical fuel for some regions. With billions of dollars of energy infrastructure already built (and billions more to come) CCS may be the only way to minimize the long-term impact these facilities will have on the environment over the course of their lifespan. Project Pioneer will demonstrate a post-combustion, retrofit [CCS] process that can be attached to existing energy infrastructure. A solution to the CO_2 emissions challenge exists through CCS technology. CCS is a safe, tested and effective technology for reducing the amount of CO_2 entering the atmosphere. A number of projects have already demonstrated that with proper site selection, design and management, CO_2 can be successfully stored for many years… In partnership with Shell Canada, TransAlta commissioned a polling firm in the summer of 2010, to conduct research amongst Canadians and Albertans regarding their perceptions of CCS. Both corporate entities, with two separate CCS projects (Shell's Quest, and TransAlta's Pioneer), felt that with the shortage of established data on the subject of public perceptions on CCS, this initial research would serve to create baselines of perceptions not only at the local level, where the coal-fired plant Keephills 3 and the future carbon capture facility (CCF) of Pioneer would be located, but also to gauge the broader public acceptance for CCS, and to better understand where people would have questions regarding the technology, so that [the authors] could work to address those. What people would tell [the authors] through public polling, would form one of a number of pillars that would help determine a public engagement strategy, so [the authors] could ensure [they] were addressing the right issues that people had questions about. This initial polling activity in 2010 was designed to establish both an Alberta and a Canada baseline for the purposes of Project Pioneer." The full TransAlta Project Pioneer report is available at: http://www.globalccsinstitute.com/sites/default/files/publications/27611/public-perceptions-report-2010-polling-results.pdf.

"Policy Recommendations for Selection & Development of Offshore Geologic Carbon Sequestration Projects Within Texas State Waters."

The following is the Abstract of this document: "This report evaluates the potential environmental impact of geologic carbon [storage] projects in the state waters of Texas and makes recommendations for decisions that can be followed during the site selection phase to alleviate risk and mitigate potential harm. This report also makes related recommendations for consideration during the project development and operations phase related to site-specific monitoring, verification, accounting and reports, and response planning." The full Environmental Defense Fund (EDF) report is available at: http://blogs.edf.org/energyexchange/files/2011/12/EDF-Policy-Recommendations-Offshore-CCS-Dec-2011.pdf.

Legislative Activity

***University College London Carbon Capture Legal Programme*, "CCS Gains CDM Eligibility at COP17."**

An executive board with the Kyoto Protocol has adopted draft modalities and procedures for CCS, allowing CCS projects to be eligible under the Clean Development Mechanism (CDM). Any outstanding issues associated with including CCS in the CDM will be addressed by the Subsidiary Body for Scientific and Technological Advice (SBSTA). The CDM allows emission reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one metric ton of CO_2. These CERs can be traded and sold and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. The final draft of the modalities and procedures adopted by the CMP is available at the Global CCS Institute website at: http://www.globalccsinstitute.com/sites/default/files/campaign/25936/files/111209-sbsta-recommendation-ccs-cdm.pdf. December 9, 2011, http://www.ucl.ac.uk/cclp/ccsnews.php?rn=1312.

Events

February 5-7, 2012, **3rd International Conference on Climate Change and Sustainable Management of Natural Resources**, *Gwalior, Madhya Pradesh, India*. This conference will examine the evidences and causes of potential climate change; its impacts on humans and ecosystems; technological, social, ethical, and political responses; and strategies for adaptation. To learn more, go to: http://www.itmuniversity.ac.in/TIMS/ABOUT-INTERNATIONAL-CONFERENCE.php.

Events (Continued)

February 7, 2012, **Carbon Capture and Storage: Demonstration Programs and the Pathway to 2050**, *Central London, UK*. This seminar will assess the requirements for CCS deployment in the UK. Discussions will consider the technical challenges and feasibility of post-combustion CCS, as well as front-end engineering and design (FEED) study findings and the barriers that will need to be overcome in order to make the technology commercially viable in the UK. To download an agenda, click: http://www.westminsterforumprojects.co.uk/forums/event.php?eid=323.

February 7-9, 2012, **Carbon Management Technology Conference**, *Caribe Royale Hotel & Convention Center, Orlando, Florida, USA*. This inaugural conference draws professionals from all engineering disciplines to share their expertise on the reduction of GHG emissions and adaptation to changing climate. The conference will focus on engineering perspectives regarding key issues, including technologies, strategies, policies, and management systems. More information is located at: http://www.spe.org/events/cmtc/2012/index.php.

February 27-28, 2012, **Platts' 6th Annual European Carbon Capture and Storage**, *London Hilton Tower Bridge Hotel, London, UK*. Providing attendees an overview of European CCS and its development, this conference also covers the latest policy developments and deployment challenges, such as finance, public awareness, and storage liability. In addition, projects from around the world will be showcased in their various stages. For a detailed program, visit the conference website at: http://www.platts.com/ConferenceDetail/2012/pc265/index.

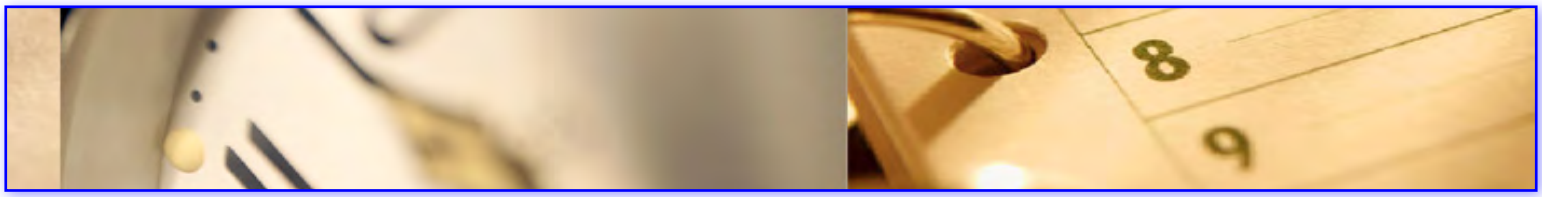
March 12-14, 2012, **Optimising Enhanced Oil Recovery**, *Venue to be Determined, Abu Dhabi, United Arab Emirates*. While the focus of this conference is on maximizing oil production in the Middle East by discussing enhanced oil recovery (EOR) strategies used worldwide, it commences with a one-day session dedicated to the development, technology, investment, and strategy of making CCS a reality. Topics covered include deployment of CCS facilities in the Middle East, CO_2 capture and EOR case studies, and CO_2 transportation strategies. For more information, go to: http://v11.vuturevx.com/exchange-sites/Whitmore%20Group/59/events-pdfs-eu/eor2-mktg-agenda.pdf.

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

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

July 23-25, 2012, **Carbon Capture and Storage: Science, Technology, and Policy**, *MIT, Cambridge, Massachusetts, USA*. This energy short course covers the science, technology, and policy aspects of CCS, focusing on the role of CCS in the climate change mitigation portfolio; the technical approaches to CO_2 capture; the science behind geologic storage, site selection, and risk evaluation; and the role of policy in establishing a market and business opportunities for CCS. For more information, visit the course website at: http://web.mit.edu/professional/short-programs/courses/carbon_capture_storage.html.

November 18-22, 2012, **International Conference on Greenhouse Gas Technologies 11 (GHGT-11)**, *Kyoto International Conference Center, Japan*. This will be the second visit to Kyoto by the GHGT conference series, with more than 1,600 delegates expected to attend. A formal agenda has not yet been developed; however, planning for GHGT-11 is underway. A call for papers has been issued and both oral and poster presentations will be accepted with a deadline of February 10, 2012. Visit: http://www.ghgt.info/index.php/Content-GHGT11/ghgt-11-overview.html for more details.



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