



Carbon Sequestration Newsletter



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JANUARY 2011



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number of important challenges must be addressed in order for widespread commercial deployment to be achieved. In addition, the report notes that globally significant national investments are occurring to advance the deployment of CCS technologies. There are 32 active or completed CSLF-recognized projects that demonstrate worldwide collaboration on CCS and contribute to the CCS knowledge base. The CSLF is a 25-member, ministerial-level international climate change initiative focused on developing and deploying cost-effective CCS technologies worldwide. (See **Recent Publications** section for a portion of the Introduction and a link to **CSLF's 2010 Technology Roadmap**.) To learn more about the 32 projects that demonstrate worldwide CCS collaboration, click: <http://www.cslforum.org/projects/>. December 2, 2010, http://www.cslforum.org/pressroom/publications/CSLF_Roadmap_Press_Release2.pdf.

SEQUESTRATION IN THE NEWS

ExxonMobil News Release, "ExxonMobil Expands World's Largest Carbon Capture Plant in Wyoming."

ExxonMobil completed an \$86 million expansion of the world's largest carbon dioxide (CO₂) capture plant, in LaBarge, Wyoming, including the installation of compressors to capture 50 percent more CO₂ for potential use in enhanced oil recovery (EOR) and other industrial uses. The expansion provides the plant with the capacity to capture approximately 365 million cubic feet of CO₂ per day from the natural gas streams produced from fields in Wyoming. According to ExxonMobil, the captured CO₂ is sold to companies for EOR. December 10, 2010, http://www.businesswire.com/portal/site/exxonmobil/index.jsp?ndmViewId=news_view&ndmConfigId=1001106&newsId=20101210005689&newsLang=en.

Reuters, "China's Shenhua Says CTL Plant to Begin Storing Carbon in '11."

A pilot CCS facility built by China's Shenhua Group at their coal-to-liquid (CTL) plant in Inner Mongolia will begin injecting CO₂ in underground storage facilities in early 2011, according to the firm. The CTL plant is the first of its kind to go into operation in China, which has two small pilot CCS plants in Beijing and Shanghai. Shenhua plans to produce 3 million tonnes of oil products from coal in 2015, up from 500,000 tonnes in 2010; in addition, the company plans to produce 11 million tonnes of oil products



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

Carbon Sequestration Leadership Forum Press Release, "Advancement of Carbon Capture and Storage Contingent on Addressing Key Issues."

According to a report released by the Carbon Sequestration Leadership Forum (CSLF), significant international progress on advancing carbon capture and storage (CCS) has been made in the past year. The report, titled, "CSLF's 2010 Technology Roadmap," also states that a

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SEQUESTRATION IN THE NEWS (CONTINUED)

and 18.3 billion cubic meters of gas from coal by 2020. November 29, 2010, <http://www.reuters.com/article/idUSTRE6AT0L320101130>.

CSIRO Media Release, "CO₂ Capture from Coal Power Begins in [Queensland]."

Tarong Power Station has begun capturing CO₂ using post-combustion capture technology, becoming the first power station in Queensland to demonstrate such technology. The \$5 million post-combustion capture demonstration project, a partnership between CSIRO and Tarong Energy Corporation Limited, uses a liquid solvent to capture CO₂ from flue gases, which experts believe has the potential to reduce CO₂ emissions from coal-fired power stations by more than 80 percent. The pilot plant, designed to capture approximately 1,000 tonnes of CO₂ per year, will evaluate the effectiveness of CO₂ capture using amine-based solvents and inform the development of efficient and economical post-combustion capture technology at commercial scale. The project received funding from the Australian Government as part of the Asia-Pacific Partnership on Clean Development and Climate program, which includes two other post-combustion capture pilot plants operating in Victoria and China. December 2, 2010, <http://www.csiro.au/news/CO2-capture-from-coal-power-begins-in-Qld.html>.

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ANNOUNCEMENTS

NETL Releases Accomplishments Document.

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has released a new document, titled, "Carbon Sequestration Program FY2008-2009 Accomplishments," which highlights the accomplishments of the Carbon Sequestration Program during the 2008 and 2009 fiscal years (FY). 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_AR2008-2009.pdf.

Third Carbon Sequestration Atlas Estimates Up to 5,700 Years of CO₂ Storage Potential in U.S. and Portions of Canada.

DOE released the "Carbon Sequestration Atlas of the United States and Canada – Third Edition (Atlas III)," which documents 1,800 billion to more than 20,000 billion metric tons of CO₂ storage resource potential in saline formations, oil and gas reservoirs, and unmineable coal areas in the United States and portions of Canada. This suggests a potential 500 to 5,700 years of CO₂ storage resources in assessed geologic formations. In addition, Atlas III provides updates on Regional Carbon Sequestration Partnership (RCSP) activities, DOE's Carbon Sequestration Program, international CCS collaborations, worldwide CCS projects, CCS regulatory issues, and CO₂ stationary source emissions. To view an interactive version, go to: <http://www.natcarb.org>; a print version is available at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIII/.

Call for Papers for 10th Annual CCS Conference.

The 10th Annual CCS Conference, held at the David L. Lawrence Convention Center in Pittsburgh, Pennsylvania, on May 2-5, 2011, is accepting papers/posters for peer review. Topics include: RCSP large-scale field testing, U.S.-Canadian CCS collaboration, and American Recovery and Reinvestment Act of 2009 (Recovery Act) investments. Abstracts are due February 18, 2011; full papers are due April 18, 2011. For more information, including a complete list of topics, visit: <http://www.carbonsq.com/callforpapersccs2011.pdf>.

DOE Technology Receives Prestigious Award.

A DOE project demonstrating DryFinishing™ technology, a more affordable way to control emissions while improving fuel quality by simultaneously drying and refining coal, has been named the 2010 Coal-Fired Project of the Year by Power Engineering magazine. The award honors technologies that uncover breakthrough solutions in coal-fired, gas-fired, nuclear, and renewable sustainable energy categories. For more information, visit: http://www.fossil.energy.gov/news/techlines/2010/10059-DOE_Funded_Technology_Wins_Award.html.

Canada and British Columbia Sign Agreement on Greenhouse Gas (GHG) Data Collection.

With the support of the Canadian Council of Ministers of the Environment (CCME), Canada and British Columbia announced they will coordinate their GHG emission reporting under a national single window system. The Federal, provincial, and territorial governments will ensure that all jurisdictions are able to measure, track, and report progress on GHG reduction. To view the Environment Canada news release, click: <http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=615F3B21-033F-4BD3-9A14-74098416EA04>.

SCIENCE

Associated Press, "Feds: Wolverines Need Protection But Have to Wait."

According to wildlife officials, the wolverine population is worthy of being classified as threatened or endangered due to potential climate change. The wolverine population has grown to an estimated 250 to 300 since being nearly wiped out in the West during the early 20th century. However, warmer winter temperatures are reducing the snow pack in the West, which wolverines need to reproduce. According to the Fish and Wildlife Service (FWS), wolverines likely exist as a network of semi-isolated populations that require gene flow between groups to prevent extinction. The reduced snow pack means the cover suitable for wolverines is shrinking, resulting in growing distances between the populations, making it more difficult

for the species to exchange genes as a result. Environmental models project the wolverine's habitat will shrink by approximately 25 percent by 2045, and by nearly 66 percent by 2099. As a result, the species will be added to a list of species awaiting Federal protection; the length of time a species remains on the list depends on funds available and the status of species ahead of them on the list. December 13, 2010, http://www.google.com/hostednews/ap/article/ALeqM5i6vCjeIHR61NSPm_O_r0R8o8fp8kQ?docId=cd03eb6b7da94ad69de10fad648340c0.

UPI, "Bamboo Urged as Climate-Change Tool."

According to the International Network for Bamboo and Rattan (INBAR), bamboo could be considered as a way to mitigate GHG emissions because it can absorb CO₂, needs little water, grows quickly, and can withstand storms. There are more than 1,000

SCIENCE (CONTINUED)

species of bamboo in the world, all of which have yet to be studied or utilized for mitigation. According to INBAR, 2.5 acres of bamboo in China can capture 30 tons more of CO₂ over a 10-year span than the same area of fir trees in China. December 8, 2010, http://www.upi.com/Science_News/2010/12/08/Bamboo-urged-as-climate-change-tool/UPI-35271291855205/.

POLICY

Carbon Capture Journal, “UK Committee Releases Fourth Carbon Budget.”

The UK Committee on Climate Change released a report on the fourth carbon budget covering the period of 2023 to 2027; the UK Government will propose draft legislation for the fourth budget in Spring 2011. Key recommendations and findings of the report include: a 2030 target to reduce emissions by 60 percent relative to 1990 levels (46 percent relative to 2009 levels); a global offer budget of 1,800 MtCO₂e; the second and third budgets should be adjusted to reflect the intended budget for the non-traded sector, giving an economy-wide reduction of 37 percent in 2020 relative to 1990; and new policies will be required, including reform of the electricity market. December 7, 2010, <http://www.carboncapturejournal.com/displaynews.php?NewsID=701>.

“U.S. Department of Energy’s Regional Carbon Sequestration Partnership Initiative: Update on Validation and Development Phases.”

The following is the abstract of this article: “DOE is the lead [Federal] agency for the development and deployment of carbon sequestration technologies. The RCSPs are the mechanism DOE utilizes to prove the technology and to develop human capital, stakeholder networks, information for regulatory policy, best practices documents and training to work toward the commercialization of CCS. The RCSPs are tasked with determining the most suitable technologies, regulations, and infrastructure for carbon capture, transport, and storage in their respective geographic areas of responsibility. The seven partnerships include more than 400 state agencies, universities, national laboratories, private companies, and environmental organizations, spanning 43 states and four Canadian provinces. The Regional Partnerships Initiative is being implemented in three phases: Characterization, Validation, and Development. The initial Characterization Phase began in 2003 and was completed in 2005 and focused on characterization of CO₂ storage potential within each region. It was followed by the Validation Phase, which began in 2005 and is nearing completion in 2011. The focus of the Validation Phase has been on small-scale field tests throughout the seven partnerships in various formation types such as saline, oil-bearing, and coal seams. The Validation Phase has characterized suitable CO₂ storage reservoirs and identified the need for comprehensive legal and regulatory frameworks to enable commercial-scale CCS deployment. Finally, the Development Phase will consist of a series of large-scale, one-million-ton, injection tests

throughout the United States and Canada. The objective of these large-scale tests is to identify the regulatory path or challenges in permitting CCS projects, to demonstrate the technology can inject CO₂ safely, and to verify its permanence in geologic formations in preparation for the commercialization of geologic storage.” **Traci Rodosta, John Litynski, Sean Plasynski, Lee Spangler, Robert Finley, Edward Steadman, David Ball, Gerald Hill, Brian McPherson, Elizabeth Burton, and Derek Vikara.** Presented at the 10th International Conference on Greenhouse Gas Control Technologies (GHGT-10), held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, <https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPol%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00625%2Epdf>.

“Preparing to ramp up large-scale CCS demonstrations: An engineering-economic assessment of CO₂ pipeline transportation in China.”

The following is the Abstract of this article: “An integrated CCS system requires safe and cost-efficient solutions for transportation of the CO₂ from the capturing facility to the location of storage. While growing efforts in China are underway to understand CO₂ capture and storage, comparatively less attention has been paid to CO₂ transportation issues. Also, to the best of [the authors’] knowledge, there are no publicly available China-specific cost models for CO₂ pipeline transportation that have been published in peer-reviewed journals. This paper has been developed to determine a first-order estimate of China’s cost of onshore CO₂ pipeline transportation. An engineering-economic model based on China-specific data, codes, and standards to the greatest extent possible has been developed for this purpose. Based on the model, five illustrative case studies on pipelines for transporting captured CO₂ from typical Integrated Gasification Combined Cycle (IGCC) and Ultra-supercritical (USC) generating units of 250 megawatt (MW), 400 MW, 660 MW, 1000 MW, and 2× 1000 MW are carried out. The results show the capital costs of constructing a 100-kilometers (km) pipeline are between \$18 million and \$102 million, depending on the amount of CO₂ transported. Corresponding figures for the levelized costs are \$1.84–\$3.06 per tonne of CO₂. Sensitivity analyses are also performed examining the effect of pipeline length and soil temperature on pipeline diameter, as well as flow rate and capital cost on levelized cost. The pipeline length is found to impact the diameter significantly, whereas soil temperature demonstrates insensitivity to pipeline diameter. Both flow rate and capital cost have significant effects on levelized cost. Comparison to other existing models based on either North American or European data implies a major cost difference between developed countries and China: China’s cost of onshore CO₂ pipeline transportation is very likely much lower than those estimated in the developed countries. For a 0.02 MtCO₂/d case, for example, the levelized cost of CO₂ transportation in China is about two-thirds that of the developed countries.” **Hengwei Liu and Kelly Sims Gallagher,** *International Journal of Greenhouse Gas Control*, Available online December 10, 2010, doi:10.1016/j.ijggc.2010.11.005, <http://www.sciencedirect.com/science/article/B83WP-51NN68D-2/2/bd075bd090d8c4bdee093bc0c34b85cb>. (Subscription may be required.)

GEOLOGY

“U.S. Department of Energy’s Site Screening, Site Selection, and Initial Characterization for Storage of CO₂ in Deep Geological Formations.”

The following is the abstract of this article: “DOE is the lead Federal agency for the development and deployment of carbon sequestration technologies. As part of its mission to facilitate technology transfer and develop guidelines from lessons learned, DOE is developing a series of best practices manuals (BPMs) for CCS. The “Site Screening, Site Selection, and Initial Characterization for Storage of CO₂ in Deep Geological Formations” BPM is a compilation of best practices and includes flowchart diagrams illustrating the general decision making process for Site Screening, Site Selection, and Initial Characterization. The BPM integrates the knowledge gained from various programmatic efforts, with particular emphasis on the Characterization Phase through pilot-scale CO₂ injection testing of the Validation Phase of the RCSP Initiative. Key geologic and surface elements that suitable candidate storage sites should possess are identified, along with example Site Screening, Site Selection, and Initial Characterization protocols for large-scale geologic storage projects located across diverse geologic and regional settings. This manual has been written as a working document, establishing a framework and methodology for proper site selection for CO₂ geologic storage. This will be useful for future CO₂ emitters, transporters, and storage providers. It will also be of use in informing local, regional, state, and national governmental agencies of best practices in proper sequestration site selection. Furthermore, it will educate the inquisitive general public on options and processes for geologic CO₂ storage. In addition to providing best practices, the manual presents a geologic storage resource and capacity classification system. The system provides a ‘standard’ to communicate storage and capacity estimates, uncertainty and project development risk, data guidelines and analyses for adequate site characterization, and guidelines for reporting estimates within the classification based on each project’s status.” **Traci Rodosta, John Litynski, Sean Plasynski, Scott Hickman, Scott Frailey, and Larry Myer.** Presented at the 10th International Conference on Greenhouse Gas Control Technologies (GHGT-10), held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, <https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPol%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00586%2Epdf>.

“The pressure impact of CO₂ storage on neighboring sites.”

The following is the Abstract of this article: “[The authors] present a saline [formation] showcase model from the North German Basin, predicting the regional pressure impact of a small industrial scale CO₂ storage operation on its surroundings. The static model is based on real geology while the injection program is fictitious. [The authors] simulated a rate controlled injection of 2.5 Million tons CO₂ per year through a single vertical well into the structural top of a dome shaped anticline, over a period of 10 years. The target is a 20 m thick sandstone layer intercalated in low permeability claystone sequences. [The authors] used ECLIPSE300 with its CO₂ storage module and MUFTE-UG to predict

pressure at the top of the target sandstone layer in 1, 5, 10, and roughly 31 km distance to the injection point. The farthest point represents the structural top of a neighboring anticlinal dome, another favorable potential storage site. [The authors] varied the model’s boundary conditions, permeability, permeability anisotropy, rock compressibility, and injection temperature. A total of nine model scenarios were run, five with MUFTE-UG and another four with ECLIPSE. Comparison of reference scenarios showed that the results of both simulators match well. In the open boundary model, pressure increase is lowest and dissipates back to the pre-injection state within 30 years after injection shutdown. In the fully closed models, pressure peaks are high, equilibrating to a remnant, model-wide overpressure several decades after the end of injection. In the distance, this equilibrated, model-wide overpressure is the actual maximum pressure. In the model scenarios which are laterally half open, half closed, pressure relief is seriously retarded in comparison to the fully open model. In all cases, the pressure maximum arrives at the neighboring structure (31 km distance) years after the actual injection shutdown. Rock compressibility impacts both the peak pressure and the speed of the pressure build-up and relief. High permeabilities are more important in the immediate injection area than for the regional footprint. In all of [the] fully closed (i.e. the most pressurized) models, the remnant regional overpressure amounted to about 9 bars. If 10 bars are taken as the maximum tolerable overpressure, then the volumetric storage capacity of the target structure itself is not affected. However, injection into the target structure does affect the storage capacity of the neighboring site. While a purely volumetric approach yields a cumulative storage capacity of roughly 175 Mt for both structures, a tolerable regional overpressure of 10 bars lowers the joint storage capacity to about 32 Mt CO₂. Exactly what regional pressures are tolerable for a given [formation], however, needs to be determined on a site specific base.” **Frauke Schäfer, Lena Walter, Holger Class, Christian Müller,** Presented at the 10th International Conference on Greenhouse Gas Control Technologies (GHGT-10), held September 19-23, 2010, at RAI in Amsterdam, The Netherlands, <https://www4.eventsinteractive.com/iea/viewpdf.esp?id=270025&file=%5C%5CDCFILE01%5CEP11%24%5CEventwin%5CPol%5Coffice27%5Cdocs%5Cpdf%5Cghgt10Final00642%2Epdf>.

TECHNOLOGY

“The gas membrane sensor (GMS): A new method for gas measurements in deep boreholes applied at the CO₂SINK site.”

The following is the abstract of this article: “A newly developed geochemical monitoring tool for the real time and in situ determination of CO₂ and other gases in the underground and in boreholes was successfully applied for the first time at the CO₂SINK test site in Ketzin, Germany. The method uses a phase separating membrane to separate gases dissolved in borehole fluids, water and brines. Ar is used as a carrier gas to conduct the collected gases through capillaries to the surface, where the gas phase is analyzed in real-time with a portable mass spectrometer for all permanent gases. In the observation wells of the CO₂SINK storage site, the dissolved CO₂ concentrations in the borehole fluid were quantified using permeation rates determined in the laboratory for the applied membrane type. Increasing reservoir

TECHNOLOGY (CONTINUED)

gas concentrations of He, H₂, CH₄ and N₂ as well as the arrival of the injected Kr tracer gas and of N₂, used for technical operations, at the monitoring wells were observed. The breakthrough of the CO₂ front into both observation wells, at a distance of 50 m and 112 m was recorded after the injection of about 500 and 11,000 tons CO₂, respectively.”

Martin Zimmer, Joerg Erzinger, Christian Kujawa, and CO₂-SINK Group, *International Journal of Greenhouse Gas Control*, Available online December 14, 2010, doi:10.1016/j.ijggc.2010.11.007, <http://www.sciencedirect.com/science/article/B83WP-51PGM1R-1/2/1afb483710a8217d1910adec05bbfa2>. (Subscription may be required.)

“Carbon Dioxide Sequestration through Novel Use of Ion Exchange Fibers (IX-Fibers).”

The following is the Abstract of this article: “Electrical power generation and metal removal processes are practiced globally and share two common attributes that make them ideal candidates to be incorporated in a novel [CO₂] sequestration scheme using ion exchange fibers (IX-fibers). First, the softening of boiler feed water used in power generation and the removal of metals from finishing wastewaters often employs the use of ion exchange for the purpose of selective separation. Second, both processes represent significant point source CO₂ emissions. This investigation demonstrated that by using IX-fibers it is possible to sequester a portion of the CO₂ produced in these practices as carbonate alkalinity during the regeneration step of both the water softening and trace heavy metal removal processes. Weak acid IX-fibers were used for hardness removal while hybrid cation exchange fibers (HCIX-F) loaded with hydrated Zr(IV) oxide (HZO) were used to remove toxic heavy metals such as zinc, cadmium, and copper. IX-fibers offer the unique capability to use and consume CO₂ during the efficient regeneration of IX-fibers, whereas commercial ion exchange resins are not amenable to regeneration with CO₂. A much shorter intraparticle diffusion path length in cylindrical IX-fibers as compared to resin beads is the underlying reason for a highly efficient regeneration of the fibers. In addition to sequestering CO₂, no hazardous or aggressive chemicals/brine solutions are present in the regenerant wastes as compared with traditional ion exchange processes.” **S. Padungthong, J.E. Greenleaf, and A.K. Sengupta**, *Chemical Engineering Research and Design*, Available December 5, 2010, doi:10.1016/j.cherd.2010.11.012, <http://www.sciencedirect.com/science/article/B8JGF-51MJYSG-1/2/438a5cee3f4e65ebe611dff727730a87>. (Subscription may be required.)

“Reactive transport modeling of effects of convective mixing on long-term CO₂ geological storage in deep saline formations.”

The following is the Abstract of this article: “The existing form of the injected CO₂ gas is very important to the feasibility and security of CO₂ storage projects in specific geological formations. The residual gas, solubility and mineral trapping mechanisms are safer forms for CO₂ geological storage than the gas trapping. Dissolution of the injected CO₂ accumulated beneath a low-permeability caprock causes an increase in the water density, resulting in a ‘convective mixing’ phenomenon. In this paper, a series of reactive transport simulations were performed to investigate the

dissolution–diffusion–convection process of CO₂ in the formation water, coupled with geochemical reactions between the gas, and formation water and rocks in a two-dimensional model based on the mineralogical composition in Songliao Basin of China. According to the changes in gaseous and aqueous CO₂, [the authors] divided the simulation process into four stages: (1) dissolution-dominated period; (2) diffusion-dominated period; (3) early convection-dominated period; and (4) late convection-dominated period. Sensitivity modeling indicated brine salinity, initial CO₂ gas saturation accumulated beneath the caprock, geochemical reactions, mineralogical compositions, vertical and horizontal permeabilities, and height and width of the model used in this study have an influence on the onset and/or evolution of the convection process.” **Wei Zhang, Yilian Li, and Anne Nyatichi Omambia**, *International Journal of Greenhouse Gas Control*, Available online November 24, 2010, doi:10.1016/j.ijggc.2010.10.007, <http://www.sciencedirect.com/science/article/B83WP-51J7KB3-1/2/34bdd75d8a8dbc7c2e0f7288da279ffa>. (Subscription may be required.)



TERRESTRIAL

“Soil carbon storage and stratification under different tillage systems in a semi-arid region.”

The following is the abstract of this article: “Changes in the agricultural management can potentially increase the accumulation rate of soil organic carbon (SOC), thereby sequestering CO₂ from the atmosphere. In a long-term experiment [the authors] examined the effects of various tillage intensities: no-tillage (NT), minimum tillage with chisel plow (MT), and conventional tillage with mouldboard plow (CT), on the topsoil profile distribution (0-30 cm) of SOC, on a semi-arid loamy soil from Central Spain. The crop sequence established was cheap pea (*Cicer arietinum* L.) cv. Inmaculada/barley (*Hordeum vulgare* L.) cv. Volley. Soil organic carbon in the various tillage treatments was expressed on a content bases and the equivalent soil mass approach. Measurements made at the end of 17 years showed that in the 0-30 cm depth, stocks of SOC had increased under NT compared with MT and CT. Most dramatic changes occurred within the 0-5 cm layer where plots under NT had 5.8 and 7.6 Mg ha⁻¹ more SOC than under MT or CT respectively. No-tillage plots, however, exhibited strong vertical gradients of SOC with concentrations decreasing from 0-5 to 20-30 cm. Stratification ratios of SOC in 1992 showed no significant differences between tillage systems. On the contrary, from 1993 onwards all stratification ratios were significantly higher in NT than in the other two tillage systems. In addition, since 2003 stratification ratios of SOC obtained under NT were systematically >2 and more than 2-fold those obtained under MT and CT. Stratification ratios >2 are uncommon under degraded conditions and could suggest that NT management system may have the most benefits to soil quality in semi arid regions with low native soil organic matter.” **C. López-Fando and M.T. Pardo**, *Soil and Tillage Research*, Available online December 4, 2010, doi:10.1016/j.still.2010.10.011, http://www.sciencedirect.com/science/article/B6TC6-51MCG1B_1/2/f3e17f4f8a30d8154966efc83b56b1d7. (Subscription may be required.)

TRADING

Carbon Market Update, December 31, 2010

CCX-CFI 2010 (\$/tCO ₂)	EU ETS-EUA DEC 2010
\$0.05 (Vintage 2009)	(\$/tCO ₂) \$14.24

(Converted from € to US\$)

RGGI News Release, “RGGI Auction Yields \$48.2 Million for Investment in Energy Savings and Clean Energy.”

The 10 Northeast and Mid-Atlantic states participating in the Regional Greenhouse Gas Initiative (RGGI) released the results of their 10th regional auction of CO₂ allowances, held December 1, 2010. The auction saw 57 percent (24,755,000) of the current control period CO₂ allowances (2009-2011) offered sold at a clearing price of \$1.86 per allowance, yielding a total of \$46,044,300; 55 percent (1,172,000) of allowances offered for a future control period (2012-2014) were sold at the same clearing price, yielding a total of \$2,179,920. For the current control period, 38 entities submitted winning bids ranging from \$1.86 to \$10.02; for the future control period, four bidders submitted winning bids ranging from \$1.86 to \$2.01. Proceeds from the 10 RGGI auctions now total more than \$777.5 million, of which more than 80 percent is being reinvested by states in strategic energy programs. The next RGGI auction is scheduled for March 9, 2011. December 3, 2010, http://www.rggi.org/docs/Auction_10_Release_Report.pdf.

“How carbon pricing changes the relative competitiveness of low-carbon baseload generating technologies.”

The following is the Abstract of this article: “There is wide public debate about which electricity generating technologies will best be suited to reduce [GHG] emissions. Sometimes this debate ignores real-world practicalities and leads to over-optimistic conclusions. Here [the authors] define and apply a set of fit-for-service criteria to identify technologies capable of supplying baseload electricity and reducing GHGs by amounts and within the timescale set by the Intergovernmental Panel on Climate Change (IPCC). Only five current technologies meet these criteria: coal (both pulverized fuel and integrated gasification combined cycle) with CCS; combined cycle gas turbine with CCS; Generation III nuclear fission; and solar thermal backed by heat storage and gas turbines. To compare costs and performance, [the authors] undertook a meta-review of authoritative peer-reviewed studies of levelized cost of electricity (LCOE) and life-cycle GHG emissions for these technologies. Future baseload electricity technology selection will be influenced by the total cost of technology substitution, including carbon pricing, which is synergistically related to both LCOE and emissions. Nuclear energy is the cheapest option and best able to meet the IPCC timetable for GHG abatement. Solar thermal is the most expensive, while CCS will require rapid major advances in technology to meet that timetable.” **Martin Nicholson, Tom Biegler, and Barry W. Brook**, *Energy*, Available online November 18, 2010, doi:10.1016/j.energy.2010.10.039, <http://www.sciencedirect.com/science/article/B6V2S-51H0085-6/2/68f10707d6938ad8d447a023c8efe7ca>. (Subscription may be required.)

RECENT PUBLICATIONS

“Carbon Sequestration Program FY2008-2009 Accomplishments.”

The following is from the document: “The mission of DOE’s NETL-managed Carbon Sequestration Program is to create a public benefit by discovering and developing methods to economically separate and permanently store GHG emissions from the combustion of fossil fuels. The technologies developed through the program will be used to maintain fossil fuel power plants as viable, clean sources of electric power. This goal will be accomplished by reducing the cost of these technologies and conducting demonstrations based on sound science to ensure that commercial applications can reliably and safely capture, transport, store, and monitor CO₂ injected into geologic formations... The Carbon Sequestration 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 R&D activities and social demands. In the remainder of the document, significant accomplishments are reported for each aspect of the Carbon Sequestration Program. These accomplishments are identified for the last three FYs (2007-2009) and organized in reverse chronological order by Carbon Sequestration Program element (Core R&D, Infrastructure, and Global Collaborations). A section containing Carbon Sequestration Program Recovery Act-related Accomplishments follows.” The complete document is available on NETL’s Carbon Sequestration Reference Shelf at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/CS_AR2008-2009.pdf.



RECENT PUBLICATIONS (CONTINUED)

“CSLF’s 2010 Technology Roadmap.”

The following is from the Introduction of this document: “CCS can play a critical role in tackling global climate change. In order for it to be an effective part of the solution, CCS must be demonstrated as soon as possible with wide deployment before the target date of CCS commercialization by 2020. A prerequisite to this achievement is the establishment of the technical foundation for affordable capture, transport, and safe and effective long-term geologic storage of CO₂ as quickly as possible. This Technology Roadmap (TRM) has identified the current status of CCS technologies around the world; the increasing level of activity in the industry; the major technology needs and gaps; and the key milestones for a wide development of improved cost-effective technologies for the separation, capture, transport, and long-term storage of CO₂. Implementation of national and international pilot and demonstration projects is seen as a critical component in the development of lower-cost, improved capture technologies and safe long-term storage. The demonstration projects have to be built in parallel with R&D efforts in order to close the technological gaps as cost effectively as possible. The CSLF will continue to catalyze the deployment of CCS technologies by actively working with member countries, governments, industry, and all sectors of the international research community on the strategic priorities outlined in this TRM. The CSLF will also continue to work with existing and new support organizations, such as the Global Carbon Capture and Storage Institute, in order to efficiently utilize scarce world resources and effort and to ensure that key technology gaps are addressed and closed.” The complete technology roadmap is available at: http://www.cslforum.org/publications/documents/CSLF_Technology_Roadmap_2010.pdf.

“A Cleaner Future for Power Stations.”

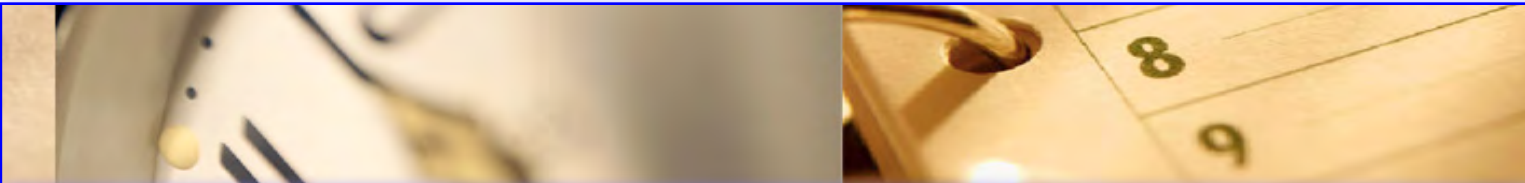
The following is from the Introduction of this document: “On [July 23, 2010] the [Australian] Government released the Cleaner Future for Power Stations election commitment which includes the establishment of new emissions standards and reporting requirements for power stations, and in particular that all new coal-fired power stations will be required to meet best practice emissions standards and be built CCS-Ready. Specifically, the [Australian] Government announced: (1) *Best practice emissions standards for new coal-fired power stations*: [a] all new coal-fired power stations will be required to meet an emission standard set with reference to best practice coal-fired generation technology; [b] the standard for best practice will be determined in consultation with stakeholders; [c] the starting point for consultation will be below the level (0.86 tCO₂-e/MWh) at which transitional assistance was proposed under the Carbon Pollution Reduction Scheme (CPRS); and [d] the standards are to commence in 2011. (2) *CCS-Ready standards*: [a] approval will only be granted to new coal-fired generators which meet the emissions standard and are capable of retrofitting CCS technologies; [b] all new coal-fired generators will be required to retrofit CCS technologies within an appropriate time after they become commercially available; and [c] the standard for CCS-Ready, tailored for Australian conditions, will be determined by the Government in consultation with stakeholders. The National CCS Council (formerly the National Low Emissions Coal Council) will play a key role in assisting with the work on the CCS-Ready standard. (3) *Expansion of Energy Efficiency Opportunities (EEO) program to cover all existing generators, including coal-fired power stations*. (4.) *Publication of National Energy and Greenhouse Reporting (NGER) data*: [a] The Government will publish annual facility-level greenhouse gas emissions and electricity production data by electricity generation facility. The Government has established an Interdepartmental Task Group (ITG) to develop these measures, in consultation with energy market institutions, State and Territory Governments, industry, and environmental stakeholders. This discussion paper is intended to facilitate initial consultation with stakeholders on the *Cleaner Future for Power Stations* measures. It outlines the Government’s commitment in relation to each of these elements, discusses the context of these measures, and proposes a way forward to defining and implementing measures. It also raises a series of important questions, for which stakeholder feedback is sought.” The entire document is available at: [http://www.ret.gov.au/energy/Documents/sustainability%20and%20climate%20change/MO%20Final%20InterDepartmental%20Discussion%20Paper%20Cleaner%20Future%20Power%20Station%2026%20November%202010%20EMBARGO%20til%2030%20November%20\(2\).pdf](http://www.ret.gov.au/energy/Documents/sustainability%20and%20climate%20change/MO%20Final%20InterDepartmental%20Discussion%20Paper%20Cleaner%20Future%20Power%20Station%2026%20November%202010%20EMBARGO%20til%2030%20November%20(2).pdf).

LEGISLATIVE ACTIVITY

Wall Street Journal, “California Adopts Cap and Trade,” and Reuters, “California Approves Cap and Trade.”

The California Air Resources Board (CARB) voted on December 16, 2010, to cap the state’s major industries’ GHG emissions and establish the first large-scale cap-and-trade program in the United States. The cap-and-trade plan would require 600 industrial plants in the state to cap their GHG emissions in 2012, and reduce those levels over the next eight years. Companies that are unable to cut their emissions by

the required amount would be able to obtain emission allowances from the state, or buy them from other emitters with excess allowances. In addition, companies could also comply with required emissions cuts by purchasing carbon offsets associated with emission-reduction projects, such as forests that are managed to contain CO₂. Under the first few years of the proposed cap-and-trade rules, most allowances would be given away; in later years, the majority of the allowances would be sold in auctions with a floor price of \$10 per metric ton of CO₂ on sold allowances. December 17, 2010, <http://online.wsj.com/article/SB10001424052748703395204576024650186378260.html>, and December 17, 2010, <http://www.reuters.com/article/idUS382911868420101217>.



EVENTS

January 24-25, 2011, **Coal Markets: The Outlook for Coal and Coal-Fired Power**, *Hyatt Regency, Miami, Florida*. This conference will look at the current state of the coal industry, focusing on topics such as the regulatory landscape and new clean coal technologies. Included are sessions on carbon legislation, CCS, and CO₂ cap-and-trade schemes. To download a brochure, visit the conference website at: <http://www.euci.com/conferences/0111-coal-markets/>.

January 25-26, 2011, **Carbon Markets and Climate Finance Africa**, *Hilton Sandton, Johannesburg, South Africa*. This conference provides attendees with a forum to develop and discuss carbon market institutional capacity and increase the pace of project investment and development. Included is a session on the Clean Development Mechanism (CDM). To download the full agenda, visit the conference website at: <http://www2.greenpowerconferences.co.uk/EF/?sSubSystem=Prospectus&sEventCode=CM1101ZA&sSessionID=4ac1fcafd0aca881be3564fe03b6479-1692677>.

January 31-February 1, 2011, **Carbon Capture and Storage Conference**, *Calgary Telus Convention Centre, Calgary, Alberta, Canada*. Attendees of this conference will have the opportunity to discuss the global perspective of meeting GHG targets, overcoming geologic storage challenges, CCS business model commercialization, and public acceptance. For more information, visit the conference website at: <http://www.canadianinstitute.com/CCS.htm>.

February 17-18, 2011, **5th Annual European Carbon Capture and Storage**, *Grange St. Paul's Hotel, London, United Kingdom*. Sponsored by Platts, this conference provides an overview of the European CCS industry and its development. Topics to be discussed include the latest in policy developments; deployment challenges, such as finance, public awareness, and storage liability; and project case studies. For the full agenda, visit: <http://www.platts.com/ConferenceDetail/2011/pc165/index>.

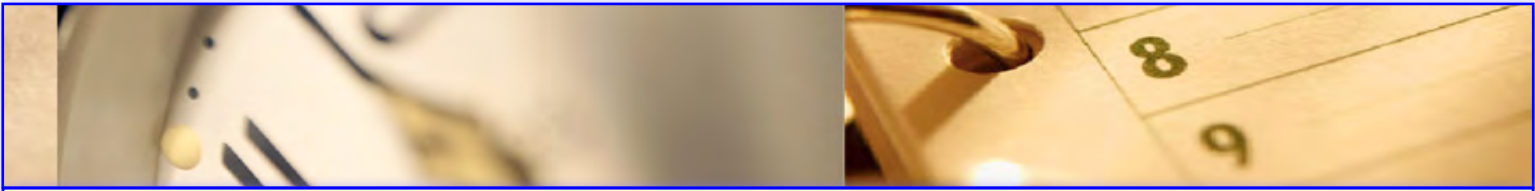
February 21-24, 2011, **Coal Power Generation 2011**, *Mandarin Orchard, Singapore*. This two-day event focuses on the building of coal-fired power plants in Asia. Among the topics to be discussed are the commercial competitiveness of CCS, costs and risks of CCS, and how CCS can make coal power generation more socially acceptable. For more information, visit the conference website at: <http://www.coalpowergeneration.com/>.

February 23-24, 2011, **Carbon Management for Oil and Gas**, *Prince Hotel and Residence, Kuala Lumpur, Malaysia*. This summit brings together carbon experts to share their experiences in implementing successful CCS and EOR technologies. Effective methods of CO₂ transportation will be examined, as will geologic storage options in Southeast Asia. Other key topics to be covered include the economics, legal issues, and public perceptions of CCS. For more information, visit: <http://www.summit-carbonmanagement.com/Event.aspx?id=394956>.

March 1-3, 2011, **Carbon Market Insights 2011**, *Amsterdam RAI, Amsterdam, The Netherlands*. This conference will focus on international negotiations and domestic legislation in the carbon market. The program will also focus on the trading and market dynamics of carbon as an emerging commodity. To view the conference website, which includes a downloadable program, click: <http://www.pointcarbon.com/events/conferences/cmi2011/>.

April 4-8, 2011, **Greenhouse 2011**, *Cairns Convention Centre, Queensland, Australia*. Attendees of this conference will be presented with the latest information in climate change science from scientists and industry representatives. The program also covers topics such as climate modeling, climate change projections, and policy and economics. For a detailed program, visit the conference website at: <http://www.greenhouse2011.com/page.aspx>.

April 12-14, 2011, **Energy Efficiency Global Forum**, *SQUARE Brussels Meeting Centre, Brussels, Belgium*. This three-day conference brings together members of the worldwide energy efficiency community to discuss the clean-energy economy. In its fourth year, the Energy Efficiency Global Forum (EE Global) also includes technology sessions focused on global energy policy, technology, and delivery. For more information, go to: <http://eeglobalforum.org/index.html>.



EVENTS (CONTINUED)

April 13-15, 2011, **3rd Annual China Clean Coal Summit 2011**, *Qingdao, Shandong, China*. In addition to providing updates in China's clean coal technology, coal-to-liquids (CTLs), CCS, and future integrated gasification combined cycle (IGCC) technology, this summit will offer case studies, future project information, site tours, and an international forum. For more information, click: <http://chinacleancoalsummit.com/index.asp>.

July 11-14, 2011, **Global Conference on Global Warming 2011**, *Calouste Gulbenkian Congress Center, Lisbon, Portugal*. This international conference discusses potential solutions to climate change issues and provides a forum for the exchange of the latest developments and technical information. One of the specialized sessions will be on CO₂ storage and utilization. To view a complete list of conference-related topics, click: http://www.gcgw.org/gcgw11/documents/poster_GCGW11.pdf.

FOR SUBSCRIPTION DETAILS...

Please visit <http://listserv.netl.doe.gov/mailman/listinfo/sequestration>, enter your email address, and create a password. This will enable you to receive a pdf version of the Carbon Sequestration Newsletter at no cost.

To view an archive with past issues of the newsletter, see: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/subscribe.html.

To learn more about DOE's Carbon Sequestration Program, please contact Sean Plasynski at sean.plasynski@netl.doe.gov, or Dawn Deel at dawn.deel@netl.doe.gov.