Office of Fossil Energy

Carbon Sequestration Newsletter

December 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

***Fossil Energy Techline*, "DOE Approves Field Test for Promising Carbon Capture Technology."**

The U.S. Department of Energy (DOE) has approved a promising post-combustion membrane technology to advance to a larger-scale field test. The technology, with $18.75 million in funding from the American Recovery and Reinvestment Act of 2009 (ARRA), successfully demonstrated the separation and capture of 90 percent of the carbon dioxide (CO_2) from a pulverized coal plant. In the ARRA-funded project, Membrane Technology and Research Inc. (MTR) and its partners tested the Polaris™ membrane system, which uses a CO_2-selective polymeric membrane material and module to capture CO_2 from a plant's flue gas. Since the Polaris™ membranes are 10 times more permeable to CO_2 than conventional materials and use a slipstream of combustion air as a sweep gas, the system has potential for reduced energy requirements, reasonable capture costs, and greater efficiencies for post-combustion capture – all of which are factors for retrofitting existing coal-based plants. MTR will next begin fabricating a 1-megawatt (MW) system capable of meeting DOE's program goals of capturing more than 90 percent of CO_2 from flue gas with a less than 35 percent increase in cost of electricity. The 1-MW system, capable of meeting DOE goals for a 20-ton/day slipstream of coal-fired flue gas, will be tested at DOE's National Carbon Capture Center (NCCC) in Wilsonville, Alabama, beginning in 2013. The data generated in a six-month field test will be used by MTR to develop a preliminary 20-MW full-scale commercial design in cooperation with their partners. November 20, 2012, http://www.fossil.energy.gov/news/techlines/2012/12057-DOE_Approves_Carbon_Capture_Field_.html.

Sequestration in the News

***ULTimateCO2 Press Release*, "Step Forward for CCS as New [~$5.2M] European Project Aids Understanding the Long-Term Fate of CO_2 Storage."**

ULTimateCO2, a new four-year, [~$5.2M] European project, will advance understanding of the long-term fate of CO_2 when captured and stored in geologic formations as part of the carbon capture and storage (CCS) process. Detailed lab, field, and modeling studies of the main physical and chemical processes involved will be covered by the project, as will their long-term impacts, including: trapping mechanisms of CO_2 in geological formations; fluid-rock interactions and the effect on the integrity of caprocks; and release due to the lack of integrity of operating or abandoned wells. In addition, the project will develop recommendations for operators and regulators of CO_2 storage sites to improve their long-term performance. The project's outcomes will be disseminated to a broad audience to improve public understanding. November 18, 2012, http://www.ultimateco2.eu/documents/UltimateCO2_press_release_final_version.pdf.

National Energy
Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

13131 Dairy Ashford Road, Suite 225
Sugar Land, TX 77478

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South, Suite 201
Fairbanks, AK 99709

Traci Rodosta
304-285-1345
traci.rodosta@netl.doe.gov

Dawn M. Deel
304-285-4133
dawn.deel@netl.doe.gov

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681

Sequestration in the News (Continued)

***Carbon Management Canada*, "CMC Announces Eight New Research Projects."**

Carbon Management Canada (CMC) has awarded a total of $3.75 million to eight new research projects. The projects include, but are not limited to: developing greenhouse gas (GHG) sensors using nanotechnology; improving ways of assessing caprock integrity for CO_2 storage; discovering ways to reduce CO_2 emissions in cement production; examining and testing methods to securely store CO_2 in mine tailing through formation of carbonate materials; and investigating ways carbon-pricing policies could drive innovation and the development of low-carbon economies. With the addition of these awards, CMC has committed a total of $22 million to 44 research projects at Canadian universities, with additional contributions and partners from more than 100 companies, stakeholder organizations, and universities from other countries. November 29, 2012, http://www.carbonmanagement.ca/cmc-announces-eight-new-research-projects/.

***Cranfield University Press Release*, "Cranfield [University] Opens New Clean Energy Research [Center]."**

On behalf of the U.K. Department of Energy and Climate Change (DECC), Cranfield University opened its new $3.2 million high-tech energy laboratory. Housing a range of near industrial-scale equipment for the research and development (R&D) of clean and renewable energy technologies, the laboratory supports research into carbon capture and transport systems, clean fossil fuel technologies, bioenergy, and energy-from-waste. The facilities are used for process development; studies into materials performance; and the reliability of systems and components, such as the integrity of heat exchangers, gas turbine blades, and CO_2 pipelines. November 27, 2012, http://www.cranfield.ac.uk/news/pressreleases/2012/page59122.html.

ANNOUNCEMENTS

CSLF Recognizes Three DOE CCUS Projects.

The Carbon Sequestration Leadership Forum (CSLF) recognized three DOE projects as important advancements toward commercialization and large-scale deployment of carbon capture, utilization, and storage (CCUS) technologies. The three DOE projects are (1) the Illinois Basin Decatur Project, a large-scale CCUS demonstration project being conducted by the Midwest Geological Sequestration Consortium (MGSC); (2) Air Products & Chemicals, Inc., an ARRA-funded, large-scale industrial CCUS project; and (3) the Illinois Industrial Carbon Capture and Storage Project, another ARRA-funded, large-scale industrial CCUS project. More information is available at: http://www.fossil.energy.gov/news/techlines/2012/12051-CSLF_Praises_DOE_Carbon_Storage_Pr.html.

MGSC Completes First Year of CO_2 Injection Operations.

The Illinois Basin-Decatur Project has completed the first year of injecting CO_2 from an industrial plant at a large-scale test site in Illinois. The project uses CO_2 from an industrial source and injects it into the Mount Simon Sandstone saline formation approximately 7,000 feet below the surface. Injection operations began November 17, 2011, with an average injection rate of 1,000 metric tons (1,100 tons) per day; after approximately one year, a total of 317,000 metric tons (350,000 tons) of CO_2 have been injected – about one-third of the planned 1 million metric ton (1.1 million ton) injection volume. To learn more, visit: http://www.fossil.energy.gov/news/techlines/2012/12056-Carbon_Storage_Partner_Completes_F.html.

Geologic CO_2 Storage Standard Developed.

CSA Group and the International Performance Assessment Center for Geologic Storage of Carbon Dioxide (IPAC-CO_2) have announced the CSA Z741 Geologic Storage of Carbon Dioxide Standard, the world's first bi-national CCS standard for geologic CO_2 storage for Canada and the United States. The standard establishes requirements and recommendations for the safe, long-term geological storage of CO_2 in a way that minimizes risks to the environment and human health. To view the standard, go to: http://ipac-co2.com/uploads/File/PDFs/CSA%20IPAC-CO2%20CCS%20Standard%202012%20Final%20News%20Release%20v1%20copy.pdf.

CO_2 Capture Membranes Developed in DOE-Funded Project.

Researchers from Ohio State University have developed a new hybrid membrane that combines the separation performance of inorganic membranes with the cost-effectiveness of polymer membranes. Further information can be viewed at: http://www.fossil.energy.gov/news/techlines/2012/12053-OSU_Develops_Novel_Composite_Membr.html.

RGGI Releases Q3 2012 Secondary Market Report.

According to the Regional Greenhouse Gas Initiative's (RGGI) "Report on the Secondary Market for RGGI CO_2 Allowances: Third Quarter 2012," 92 percent of RGGI's CO_2 allowances are held by compliance entities and their affiliates. The report found that RGGI CO_2 allowance prices were stable in the third quarter of 2012, ranging from $1.93 to $1.95, which is consistent with the Auction 17 clearing price of $1.93. The complete report is available at: http://www.rggi.org/docs/Market/MM_Secondary_Market_Report_2012_Q3.pdf.

New Home for CCS Legal Resources Website.

The UCL Carbon Capture Legal Program, which has developed and hosted a legal resources website designed to provide accessible and objection information on CCS law developments and policy, will now be managed by the Global Carbon Capture and Storage Institute (GCCSI). The material is now available at: http://www.globalccsinstitute.com/networks/cclp.

SCIENCE

***The Canadian Press*, "Pine Beetles Contributing to Climate Change, Study Says."**

According to research conducted by scientists from the University of Toronto, the widespread population of mountain pine beetles could be contributing to potential climate change. Published in the journal "Nature Geoscience," the research shows that the warming climate has allowed the beetle to spread into forests that had previously been too cold for their survival; specifically, the data showed that the tree-killing bugs have spread over approximately 20 percent of the total area of British Columbia over the last decade. To gauge its effect on the regional climate, researchers studied the results of turning approximately 60,000 square miles of green forest into grey, leafless stands of dead trees. By using temperature data from satellites, they concluded that, on average, beetle-ravaged forests were one degree warmer than healthy forests during summer months. November 25, 2012, http://www.ctvnews.ca/sci-tech/pine-beetles-contributing-to-climate-change-study-says-1.1053055.

Science (Continued)

***Sheffield University News Release*, "Innovative Project Set to Use Cosmic Rays Detectors to Map Out Carbon Storage Volumes."**

Geoscientists, particle physicists, and engineers are collaborating on a bid to develop a novel techniqueusing cosmic rays for monitoring CO_2 storage sites. The researchers will work together to examine the potential of using subatomic particles from cosmic rays (known as muons) that cascade from the upper atmosphere and penetrate rock deep underground; the developed devices will be tested at Boulby mine, on the edge of the North Yorkshire moors. The detection of cosmic ray muons can measure the ongoing CO_2 levels in any potential carbon store by mapping the density profile of the material above the detectors. Current monitoring technology typically involves the collection of seismic data, enabling snapshots of CO_2 storage levels to be taken over time; muon tomography offers the chance to develop a continuous, passive monitoring system for deep subsurface storage sites. Alongside matched funding from industry, DECC is providing funding for the monitoring project. November 21, 2012, http://www.sheffield.ac.uk/news/nr/particle-physics-carbon-dioxide-lee-thompson-muons-cosmic-rays-1.226552.

Policy

"Assessing socio-technical mindsets: Public deliberations on carbon capture and storage in the context of energy sources and climate change."

The following is the Abstract of this article: "The adaptation and transition to new configurations of energy systems brought on by challenges of climate change, energy security, and sustainability have encouraged more integrative approaches that bring together the social and technical dimensions of technology. The perspectives of energy systems and climate change play an important role in the development and implementation of emer ging energy technologies and attendant policies on [GHG] reduction.This research examines citizens' views on climate change and a number of energy systems, with a specific focus on the use of CCS as a technology to address [GHG] emissions. An all-day workshop with 82 local participants was held in the city of Calgary in Alberta, Canada to explore the views of climate change, energy and CCS. Participants were provided the opportunity to ask experts questions and discuss in small groups their views of climate change policy and energy systems. Results demonstrate that participants' assessments of energy systems are influenced by social–political–institutional–economic contexts such as trust in industry and government, perception of parties benefiting from the technology, and tradeoffs between energy systems. [The authors] discuss [their] findings in the context of understanding social learning processes as part of socio-technical systems change." **Edna F. Einsiedel, Amanda D. Boyd, Jennifer Medlock, and Peta Ashworth**, *Energy Policy*, Available online November 21, 2012, doi:10.1016/j.enpol.2012.10.042, http://www.sciencedirect.com/science/article/pii/S0301421512009238. (Subscription may be required.)

Geology

"Enhanced biomimetic CO_2 [storage] and $CaCO_3$ crystallization using complex encapsulated metal organic framework."

The following is the Abstract of this article: "A new biomimetic complex (Co-BBP) that mimics the active site of carbonic anhydrase (CA) was prepared by the coordination of cobalt (II) with 2, 6-bis(2-benzimidazolyl) and was encapsulated into a metal organic framework (Co-BBP@Tb-MOF). Carbon dioxide [storage] was carried out via an *in vitro* mineralization approach using these biomimetic catalysts. The biomimetic catalysts were expected to enhance CO_2 hydration and calcium carbonate ($CaCO_3$) crystallization based on the same mechanism as that of CA." **Prakash C. Sahoo, Young Nam Jang, Seung Woo Lee**, *Journal of Crystal Growth*, Available online November 30, 2012, doi:10.1016/j.jcrysgro.2012.11.043, http://www.sciencedirect.com/science/article/pii/S0022024812008408?v=s5. (Subscription may be required.)

"Permeability Reduction Produced by Grain Reorganization and Accumulation of Exsolved CO_2 during Geologic Carbon [Storage]: A New CO_2 Trapping Mechanism."

The following is the Abstract of this article: "Carbon [storage] experiments were conducted on uncemented sediment and lithified rock from the Eau Claire Formation, which consisted primarily of K-feldspar and quartz. Cores were heated to accentuate reactivity between fluid and mineral grains and to force CO_2 exsolution. Measured permeability of one sediment core ultimately reduced by 4 orders of magnitude as it was incrementally heated from 21 to 150°C. Water-rock interaction produced some alteration, yielding sub-μm clay precipitation on K-feldspar grains in the core's upstream end. Experimental results also revealed abundant newly formed pore space in regions of the core, and in some cases pores that were several times larger than the average grain size of the sediment. These large pores likely formed from elevated localized pressure caused by rapid CO_2 exsolution within the core and/or an accumulating CO_2 phase capable of pushing out surrounding sediment. [Carbon dioxide] filled the pores and blocked flow pathways. Comparison with a similar experiment using a solid arkose core indicates that CO_2 accumulation and grain reorganization mainly contributed to permeability reduction during the heated sediment core experiment. This suggests that CO_2 injection into sediments may store more CO_2 and cause additional permeability reduction than is possible in lithified rock due to grain reorganization." **Andrew J. Luhmann; Xiang-Zhao Kong; Benjamin M. Tutolo; Kang Ding; Martin O. Saar; and William E. Seyfried, Jr.**, *Environ. Sci. Technol.*, Available online November 10, 2012, doi:10.1021/es3031209, http://pubs.acs.org/doi/abs/10.1021/es3031209. (Subscription required.)

"Impacts of Geochemical Reactions on Geologic Carbon [Storage]."

The following is the Abstract of this article: "In the face of increasing energy demands, geologic CO_2 [storage] (GCS) is a promising option to mitigate the adverse effects of climate change. To ensure the environmental sustainability of this option, the rates and mechanisms of key geochemical reactions and their impacts on GCS performance, the multiphase reactive transport of CO_2, and the management of environmental risks [must be understood]. Strong interdisciplinary collaborations are required to

Geology (Continued)

minimize environmental impacts and optimize the performance of GCS operations." **Young-Shin Jun, Daniel E. Giammar, and Charles J. Werth**, *Environ. Sci. Technol.*, Available online November 6, 2012, doi:10.1021/es3027133, http://pubs.acs.org/doi/abs/10.1021/es3027133. (Subscription required.)

Technology

"[Storage] of Flue Gas CO_2 by Direct Gas-solid Carbonation of Air Pollution Control System Residues."

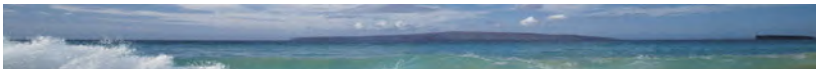
The following is the Abstract of this article: "Direct gas-solid carbonation reactions of residues from an air pollution control system (APCr) were conducted using different combinations of simulated flue gas to study the impact on CO_2 [storage]. X-ray diffraction analysis of APCr determined the existence of CaClOH, whose maximum theoretical CO_2 [storage] potential of 58.13 g CO_2/kg APCr was calculated by the reference intensity ratio method. The reaction mechanism obeyed a model of a fast kinetics-controlled process followed by a slow product layer diffusion-controlled process. Temperature is the key factor in direct gas-solid carbonation and had a notable influence on both the carbonation conversion and the CO_2 [storage] rate. The optimal CO_2 [storage] temperature of 395°C was conveniently obtained for APCr using a continuous heating experiment. [Carbon dioxide] content in the flue gas had a definite influence on the CO_2 [storage] rate of the kinetics-controlled process, but almost no influence on the final carbonation conversion. Typical concentrations of [sulfur dioxide (SO_2)] in the flue gas could not only accelerate the carbonation reaction rate of the product layer diffusion-controlled process, but also improve the final carbonation conversion. Maximum carbonation conversions of between 68.6 [percent] and 77.1 [percent] were achieved in a typical flue gas. Features of rapid CO_2 [storage] rate, strong impurities resistance, and high capture conversion for direct gas-solid carbonation were proved in this study, which presents a theoretical foundation for the applied use of this encouraging technology on [CCS]." **Sicong Tian and Jianguo Jiang**, *Environ. Sci. Technol.*, Available online November 26, 2012, doi:10.1021/es303713a, http://pubs.acs.org/doi/abs/10.1021/es303713a. (Subscription required.)

"Detecting Supercritical CO_2 in Brine at Sequestration Pressure with an Optical Fiber Sensor."

The following is the Abstract of this article: "Monitoring of [stored] carbon is essential to establishing the environmental safety and the efficacy of geological carbon [storage]. [Storage] in saline [formations] requires the detection of supercritical CO_2 and CO_2-saturated brine as distinct from the native reservoir brine. Here [the authors] demonstrate an all-optical approach to detect both supercritical CO_2, and saturated brine under [storage] conditions. The method employs a long-period grating written on an optical fiber with a resonance wavelength that is sensitive to local refractive index within a pressure- and temperature-controlled apparatus at 40°C and 1,400 [pounds per square inch (psi)] (9.65 MPa). The supercritical CO_2 and brine are clearly distinguished by a wavelength shift of 1.149 nm (refractive index difference of 0.2371). The CO_2 saturated brine is also detectable relative to brine, with a resonance wavelength shift of 0.192 nm (refractive index difference of 0.0396). Importantly, these findings indicate the potential for distributed, all-optical monitoring of CO_2 [storage] in saline [formations]." **Bo Bao, Luis Melo, Benjamin Davies, Hossein Fadaei, David Sinton, and Peter Wild**, *Environ. Sci. Technol.*, Available online November 15, 2012, doi:10.1021/es303596a, http://pubs.acs.org/doi/abs/10.1021/es303596a. (Subscription required.)

"Practical and Economic Aspects of the Ex-Situ Process: Implications for CO_2 [Storage]."

The following is the Abstract of this article: "The risk of CO_2 [release] and the very slow rate of CO_2 dissolution in brine present major technical challenges for secure implementation of CO_2 [storage] at large scale in saline [formations]. To tackle these issues, a new technology based on Ex-Situ Dissolution Approach (ESDA) was developed recently aiming at dissolving CO_2 in brine phase prior to injection into the [formation] to eliminate or minimize the risk of [release] and accelerate CO_2 dissolution rate in brine. The ESDA is based on the mass transfer from CO_2 droplets into brine in co-current pipeline flow. This paper presents mass transfer modeling associated with the ESDA process concerning the evolution of the droplet size and the pressure change along the pipeline. In addition, a technical and economic feasibility of the ESDA in comparison with the standard CCS technologies is presented. Various aspects such as CO_2 displacement, geochemical reactions, CO_2 [release], pressure build-up, well spacing and dissolution efficiency for the ESDA are also discussed. This study enables the evaluation of the ESDA process for CO_2 [storage] through a systematic way." **Sohrab Zendehboudi, Alireza Bahadori, Ali Lohi, Ali Elkamel, and Ioannis Chatzis**, *Energy Fuels*, Available online November 13, 2012, doi:10.1021/ef301278c, http://pubs.acs.org/doi/abs/10.1021/ef301278c. (Subscription required.)



Terrestrial

"Effect of Freeze-Thaw on the Mineralization of Organic Carbon, and Organic Nitrogen in Wetland Soil."

The following is the Abstract of this article: "The mineralization of organic carbon and organic nitrogen in soil is one of the key processes in the carbon and nitrogen cycles in wetland soil. In general it is believed that the mineralization of organic carbon and organic nitrogen in soil mainly depends on the moisture and temperature. Conditions of soil moisture affect the soil respiration rate by restricting the penetration of oxygen and the types of mic roorganisms, but temperature affects the mineralization rates of organic carbon and organic nitrogen in soil by affecting microbial activity. Because of the interaction between temperature and moisture, the real mineralization rate in a soil often depends on both moisture and temperature conditions at the same time." **Xiaofei Yu**, *Material Cycling of Wetland Soils Driven by Freeze-Thaw Effects*, Available online January 1, 2013, doi:10.1007/978-3-642-34465-7_7, http://link.springer.com/chapter/10.1007/978-3-642-34465-7_7. (Subscription required.)

TERRESTRIAL (CONTINUED)

"Biochar Fertilizer for Soil Amendment and Carbon [Storage]."

The following is the Abstract of this article: "Use of biochar fertilizer is potentially an attractive approach for soil amendment and carbon [storage] possibly at giga tons of carbon (GtC) scale. Cation exchange capacity (CEC) is an important parameter in retaining inorganic nutrients, such as K^+ and NH_4^+ in soil. This experimental study showed that the CEC value of biochar is related to the biomass pyrolysis temperature. Biochar materials made from the pelletized peanut hulls at pyrolysis temperature of about [400°C] yield the best CEC value. As the pyrolysis temperature increases over [400°C], the CEC value decreases. The biochar produced from the [400°C] pyrolysis possesses certain binding affinity for ammonium bicarbonate (NH_4HCO_3) probably because of the presence of more biochar surface functional groups. Addition of ammonium bicarbonate to biochar can help neutralize the pH of biochar material potentially beneficial for certain agricultural soil applications in relation to soil amendment and carbon [storage]." **James Weifu Lee, Bob Hawkins, Xiaonian Li, and Danny M. Day**, *Advanced Biofuels and Bioproducts*, Available online January 1, 2013, doi:10.1007/978-1-4614-3348-4_6, http://link.springer.com/chapter/10.1007/978-1-4614-3348-4_6. (Subscription required.)

TRADING

***Los Angeles Times*, "California's First Carbon-Credit Auction Raises $290 Million."**

The California Air Resources Board announced that the state's first auction of GHG emission credits generated nearly $290 million. All 23.1 million allowances available for 2013 sold for $10.09 each (the minimum was $10), generating $233.3 million; of the nearly 40 million credits available for 2015, the state sold approximately 14 percent, generating an additional $55.8 million. Some of the money generated will be used for energy efficiency and other projects. The result of the Global Warming Solutions Act (AB 32; passed in 2006), the cap-and-trade program aims to reduce California's production of GHGs, including CO_2, to 1990 levels (approximately 17 percent lower than current amounts) by 2020. More than 350 industrial businesses in California participated in the auction, representing approximately 600 facilities throughout the state, including utilities, food processors, and oil refineries; the program will cover distributors of natural gas and other fuels beginning in 2015. Under the program, emitters initially get 90 percent of their needed credits free; if they plan to emit GHGs above allotted levels, they are required to buy more emission credits, which start at a minimum price of $10 for the right to emit 1 metric ton of GHGs. November 20, 2012, http://www.latimes.com/business/la-fi-pollution-credits-20121120,0,1417750.story.

***RGGI News Release*, "RGGI Auction Sells 19.7 Million CO_2 Allowances at $1.93."**

The nine RGGI-participating states announced the results of their CO_2 allowances auction held on December 5, 2012. The results indicate 19,774,000 CO_2 allowances were sold at the 18th auction, generating $38.1 million for reinvestment by the RGGI states. Bids for the CO_2 allowances ranged from $1.93 to $5.14 per allowance, with a clearing price of $1.93; the allowances sold represent 53 percent of the 37,563,083 allowances offered for sale. The auction proceeds will be used to fund a variety of consumer benefit initiatives, including investments in energy efficiency, clean and renewable energy, direct bill assistance, and GHG abatement and climate change adaptation. The next RGGI auction (19th) is scheduled for March 13, 2013. December 7, 2012, http://www.rggi.org/docs/Auctions/18/PR120712_Auction18.pdf.

"RFID-enabled carbon offsetting and trading."

The following is the Abstract of this article: "This paper presents a novel approach to carbon credit trading with pervasive computing technologies, particularly RFID (or barcode) technology. It introduces RFID tags as certificates for the rights to claim carbon credits in carbon offsetting and trading. It enables buyers, including end-consumers, that buy products with carbon credits to hold and claim these credits unlike existing carbon offsetting schemes. It also supports the simple intuitive trading of carbon credits by trading RFID tags coupled to the credits. The approach was constructed and evaluated with real customers and real carbon credits in a real supply chain. It can also be used to encourage industries and homes to reduce [GHG] emissions." **Ichiro Satoh**, *Pervasive and Mobile Computing*, Available online October 15, 2012, doi: 10.1016/j.pmcj.2012.09.003, http://www.sciencedirect.com/science/article/pii/S1574119212001149. (Subscription may be required.)

"Carbon price forecasting with a novel hybrid ARIMA and least squares support vector machines methodology."

The following is the Abstract of this article: "In general, due to inherently high complexity, carbon prices simultaneously contain linear and nonlinear patterns. Although the traditional autoregressive integrated moving average (ARIMA) model has been one of the most popular linear models in time series forecasting, the ARIMA model cannot capture nonlinear patterns. The least squares support vector machine (LSSVM), a novel neural network technique, has been successfully applied in solving nonlinear regression estimation problems. Therefore, [the authors] propose a novel hybrid methodology that exploits the unique strength of the ARIMA and LSSVM models in forecasting carbon prices. Additionally, particle swarm optimization (PSO) is used to find the optimal parameters of LSSVM in order to improve the prediction accuracy. For verification and testing, two main future carbon prices under the [European Union Emissions Trading Scheme (EU ETS)] were used to examine the forecasting ability of the proposed hybrid methodology. The empirical results obtained demonstrate the appeal of the proposed hybrid methodology for carbon price forecasting." **Bangzhu Zhu and Yiming Wei**, *Omega*, Available June 2013, doi.org/10.1016/j.omega.2012.06.005, http://www.sciencedirect.com/science/article/pii/S0305048312001004. (Subscription may be required.)

Recent Publications

"Carbon Capture and Storage: [Mobilizing] private sector finance for CCS in the UK."

The following is from the Introduction of this document: "This report presents the findings of a joint project by the Energy Technologies Institute and the Ecofin Research Foundation to examine the conditions for [mobilizing] private sector financing of [CCS] in the UK. It is based on structured interviews with capital providers, project developers and other key stakeholders. The UK has adopted ambitious targets to reduce [GHG] emissions by 80 [percent] by 2050. Achieving these targets will be hugely challenging in engineering and economic terms. Many future energy system scenarios envisage a key role for CCS in enabling the UK to deliver its emissions targets at an affordable cost. CCS is the process of capturing and securely storing [CO_2] instead of emitting it into the atmosphere." To download the full report, go to: http://eti.co.uk/downloads/literature/Ecofin_CCS_Report.pdf.

"Perspectives on Carbon Capture and Storage."

The following is from the Introduction of this document: "Climate change is a pressing environmental problem that threatens human health, security and prosperity. The world's scientists have concluded that 'warming of the climatesystem is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.' Anthropogenic emissions of [GHGs] are responsible for the bulk of these trends… Climate change is not only an environmental problem, but also a public health, national security and prosperity problem… In order for global average temperatures to remain within bounds that may avoid the dangerous impacts of climate change, global CO_2 emissions would need to peak within the next decade, and decrease at the very least by 50-85 [percent] compared to year 2000 levels by mid-century. The more [the needed reductions are delayed], the higher the degree of warming that the planet is locked into. The continued increase of [GHGs] as a result of human activities poses a structural challenge to global energy systems and economies. Fortunately, a number of technologies are available to mitigate emissions, although not as yet deployed at the scale necessary. These include increasing efficiency and reducing demand in all energy-consuming sectors, switching to renewable and lower carbon energy sources, increasing carbon uptake in forests and soils, and [CCS]." This ENGO Network on CCS document is available at: http://www.engonetwork.org/engo_perspectives_on_ccs_digital_version.pdf.

"Carbon Capture and Storage Regulatory Review for Trinidad and Tobago."

The following is from the Introduction of this document: "The Inter-American Development Bank (IDB) has provided a grant to Trinidad and Tobago to assist with the consideration of the impact of climate change into national policies and institutions. The grant program is titled 'Mainstreaming of Climate Change into National Development and Capacity Building for Participation in Carbon Markets' (the Program). As part of the Program, the Government is undertaking a study to examine the feasibility of a CCS project in Trinidad and Tobago. Through this study, it is hoped that the Government and other stakeholders will better understand the potential role CCS could play in Trinidad and Tobago. The Global CCS Institute is supportive of the initiative and is pleased to contribute to the Program through the 'Carbon Capture and Storage Regulatory Review for Trinidad and Tobago' (the Review). The Review considers the existing legal and regulatory framework as it pertains to CCS in Trinidad and Tobago. The major sources of CO_2 emissions in Trinidad and Tobago are the energy and manufacturing sectors. The 'National Climate Change Policy 2011' indicates that the CO_2 emission levels for Trinidad and Tobago for 2008 was 28.37 [metric tons] of CO_2 per capita, the highest in the region. Given that the country is the leading producer of oil and gas in the Caribbean as well as being the largest producer of methanol and the largest trader of ammonia this figure is not surprising." To read the complete review, please visit: http://cdn.globalccsinstitute.com/sites/default/files/publications/54126/ccs-regulatory-review-trinidad-tobago.pdf.

"Climate change, impacts and vulnerability in Europe 2012."

The following is from the Executive Summary of this document: "The United Nations Framework Convention on Climate Change (UNFCCC) has agreed to limit the increase in global mean temperature since pre industrial times to less than 2°C, in order to prevent the most severe impacts of climate change. Current global actions to reduce [GHG] emissions ('mitigation') are insufficient to constrain the temperature increase to 2°C, and global warming could be well above 2°C by 2100. Even if the 2°C limit is kept, substantial impacts on society, human health and ecosystems are projected to occur. Adaptation to and mitigation of climate change are therefore both needed. The European Commission has initiated various actions to integrate and mainstream adaptation into EU sectoral policies following the publication of the White Paper on adaptation to climate change in 2009. Furthermore, many countries in Europe have already adopted national adaptation strategies and some have followed up with specific action plans. The European Commission plans publishing its European Adaptation Strategy in 2013, which will include further proposals for adaptation actions across the EU. This report aims at providing a strong knowledge base for the development and implementation of adaptation strategies and actions at both national and EU levels. The indicators presented here are also accessible via the [European Environment Agency (EEA)] indicator management system and the European Climate Adaptation Platform (Climate-ADAPT). Early in 2013 the EEA will publish a dedicated report on adaptation,

Recent Publications (Continued)

which will assess actions to adapt to climate change at European, national and sub-national levels." The complete report is available for download at: http://bookshop.europa.eu/en/climate-change-impacts-and-vulnerability-in-europe-2012-pbTHAL12012/;pgid=y8dIS7GUWMdSR0EAlMEUUsWb0000UZ7LPTrH;sid=UuYkAgarTUkkC1YTga-6pWSOH4U6cAF4VDU=?CatalogCategoryID=h2YKABstrXcAAAEjXJEY4e5L. (Purchase may be required.)

Legislative Activity

***GHG Monitor News*, "California State Senator Reintroduces CCS Legislation."**

California Senator Michael Rubio reintroduced legislation aimed at clarifying subsurface pore space ownership and filling regulatory gaps for the permitting of CCS projects in California. The bill states that subsurface pore space ownership in California belongs to the surface landowner; reasserts a previous provision from AB 32 that requires the state Air Resources Board to adopt final protocols for CCS projects by 2016; ensures that CCS and enhanced oil recovery (EOR) projects aimed at storing CO_2 are considered eligible emissions reduction technologies under AB 32; and clarifies the authority of the California Department of Conservation's Division of Oil, Gas and Geothermal Resources and the State Fire Marshal to regulate CO_2 injection for EOR and intrastate pipelines, respectively. SB 34 is available for viewing at: http://www.leginfo.ca.gov/pub/13-14/bill/sen/sb_0001-0050/sb_34_bill_20121203_introduced.pdf. The bill contains several points from the earlier policy recommendations of the California CCS Review Panel. This group was commissioned by several state agencies to focus on the challenges the CCS industry faces in California. The earlier policy recommendations are available at: http://climatechange.ca.gov/carbon_capture_review_panel/documents/2011-01-14_CSS_Panel_Recommendations.pdf. December 7, 2012, http://ghgnews.com/index.cfm/california-state-senator-reintroduces-ccs-legislation/.

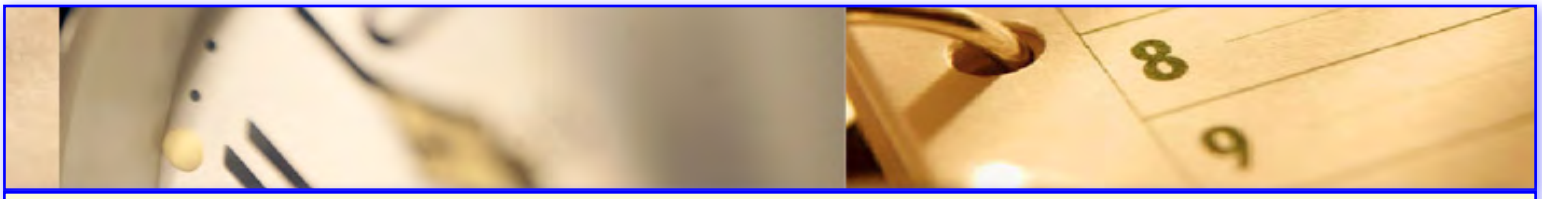
***United Kingdom Department of Energy & Climate Change Press Release*, "An Energy Bill to Power Low-Carbon Economic Growth, Protect Consumers, and Keep the Lights On."**

A bill to promote low-carbon economic growth in the United Kingdom was introduced to Parliament on November 29, 2012. The bill aims to reform the design of the electricity market to promote construction of low-carbon energy infrastructure and low-carbon manufacturing supply chains. In particular, the bill provides support for technologies like CCS by allowing the government tonegotiate rates with power plants installed with CCS and other low-carbon technologies. The operators would then sell the electricity to consumers and the government would pay the difference between the market price and negotiated rates. This structure would alleviate some of the operational costs that affect technologies like CCS and their long-term development. November 29, 2012, http://www.decc.gov.uk/en/content/cms/news/pn12_151/pn12_151.aspx.

Events

January 23-24, 2013, **National Seminar on "Climate Change and Sustainable Development: Issues and Challenges,"** *Sri Aurobindo Seminar Hall, Faculty of Arts, Sayajiganj, Vadodara*. Some of the main objectives of this seminar are to address potential climate change-related social and economic issues and challenges in selected sectors of the economy, understand economic behavior under risk and uncertainty in the context of potential climate change, and assess the adaption and/or mitigation needs in the face of a potentially changing climate. For more information, visit: http://www.msubaroda.ac.in/arts/upload/NATIONAL_SEMINAR_Climate_Change_and_Sust_Devt_Jan_2013.pdf.

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



Events (Continued)

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

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

March 20-21, 2013, **RECS Market Meeting 2013**, *Hotel Melia Berlin, Berlin, Germany*. The third edition of this annual event offers insight into the renewable energy market in Europe. Included in the program is a pre-conference workshop explaining the workings of the electricity tracking and certificate system in the renewable energy market. The meeting itself includes a panel discussion and will cover topics such as new policy and national developments, corporate social responsibility, and the voluntary market. For the complete program, visit the conference website at: http://www.recsmarket.eu/Home.aspx.

May 13-16, 2013, **12th Annual Conference on Carbon Capture, Utilization & Sequestration**, *David L. Lawrence Convention Center, Pittsburgh, Pennsylvania, USA*. This conference will provide a forum for the exchange of experience among U.S. and international scientific and engineering communities working on such technology and systems; facilitate the necessary dialogue between technology developers/purveyors, industry, and the public on the development and deployment of viable technologies; and share experience on developing the necessary capacity within the public and private sector to move the technology base forward. More information is available at: http://www.carbonsq.com/.

May 27-30, 2013, **Impacts World 2013**, *Potsdam, Germany*. This conference aims to develop a new vision for potential climate impact research by laying the foundations for regular, community-driven synthesis of potential climate change impact analyses. As a discussion-based conference, scientists and decision makers from local and international levels will be brought together to initiate a coordinated climate impact research agenda. To learn more, click: http://www.climate-impacts-2013.org/index.php?article_id=1.

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To learn more about DOE's Carbon Storage Program, please contact Traci Rodosta at traci.rodosta@netl.doe.gov, or Dawn Deel at dawn.deel@netl.doe.gov.