Carbon Storage Newsletter

SEPTEMBER 2014

WHAT'S INSIDE?

HIGHLIGHTS

"NETL Collaborations Advance Carbon Management Strategies."

The Carbon Capture Simulation Initiative (CCSI) and the National Risk Assessment Partnership (NRAP) are using predictive computational modeling to help the U.S. Department of Energy (DOE) meet its goal of having carbon capture and storage (CCS) technologies ready for demonstration in the 2020 to 2025 timeframe. This goal requires the development of new approaches to reduce the 20 to 30 years typically required for commercial deployment of new technology concepts. Led by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL), the two collaborative efforts use computational modeling, which involves developing mathematical equations and computer code to simulate the real-life behavior of engineered and natural systems. The use of these models allows for more efficient, timely, and cost-effective technology development and deployment. For more information, visit DOE's national lab webpage. From *NETL News Release* on August 27, 2014.

"Projects Selected for Safe and Permanent Geologic Storage of Carbon Dioxide."

DOE selected 13 projects to develop technologies and methodologies for geologic carbon dioxide (CO_2) storage. The projects will develop technologies, methodologies, and characterization tools to improve the ability to predict geologic storage capacity, understand geomechanical processes, and enhance geologic storage safety. The total value of the projects is approximately $17.6 million over three years, with $13.8 million of DOE funding and $3.8 million of non-Federal cost sharing. The projects will be managed by NETL and were awarded in two areas of interest: "Geomechanical Research" and "Fractured Reservoir and Seal Behavior." Project details are available via the link. CCS research is focused on developing technologies to capture industrially generated CO_2 and safely and permanently store it in underground geologic formations in order to reduce the amount of CO_2 being released into the atmosphere. From *NETL News Release* on August 6, 2014

"Construction Begins on DOE-Sponsored Carbon Capture Project at Kentucky Power Plant."

Construction started on a DOE-funded carbon capture pilot project at Kentucky Utilities' E.W. Brown Generating Station near Harrodsburg, Kentucky, USA. The unit will test, at slipstream scale, a novel system conceived by the University of Kentucky Center for Applied Energy Research (UKCAER) to capture CO_2 from the flue gas of an operating coal-fired power plant. The 2-megawatt thermal system will be the first megawatt-scale carbon capture pilot unit in the Commonwealth of Kentucky and will be managed by NETL for DOE's Carbon Capture Program. For more information about the UKCAER project, visit NETL's project webpage. From *NETL News Release* on July 21, 2014.

"World's Largest Post-Combustion Carbon Capture Project Begins in Construction."

In partnership with NRG Energy Inc. and JX Nippon, DOE announced the beginning of construction on the Petra Nova Project, the first commercial-scale, post-combustion carbon capture retrofit project in the United States. Once completed, the project is expected to capture approximately 1.4 million metric tons of CO_2 per year from an existing coal-fired power plant in Texas, USA; the captured CO_2

HIGHLIGHTS (CONTINUED)

will then be used for enhanced oil recovery (EOR) at a depleted oil field approximately 80 miles away. The 240-megawatt project is expected to capture 90 percent of the CO_2 using a process previously deployed in a DOE-sponsored, three-year, pilot-scale test in Alabama in which more than 150,000 metric tons of CO_2 were successfully captured annually from a coal-fired power plant. From *NETL News Release* on July 16, 2014.

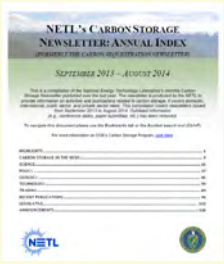
ANNOUNCEMENTS

DOE Project Captures and Stores more than One Million Metric Tons of CO_2.

DOE, in partnership with Air Products and Chemicals, Inc., announced that more than 1 million metric tons of CO_2 have been captured at a hydrogen production facility in Port Arthur, Texas, USA. The project captures more than 90 percent of the CO_2 from the product stream of two commercial-scale steam methane reformers using vacuum swing adsorption. In addition to geologic storage, the captured CO_2 will be used for EOR at the depleted West Hastings Field in southeast Texas.

Carbon Storage Newsletter Annual Index 2014 Available.

This document is a compilation of NETL's Carbon Storage Newsletter published over the September 2013 to August 2014 timeframe. Outdated information (e.g., conference dates, paper submittals, etc.) has been removed.



Call for Papers: 2015 CCUS Conference: Abstracts Now Being Accepted.

The Call for Papers for the 14th Annual Conference on Carbon Capture, Utilization, and Storage has been released, and abstracts are being accepted through January 23, 2015. The theme of this year's conference, scheduled for April 28 through May 1, 2015, in Pittsburgh, Pennsylvania, USA, is "Advancing CO_2 Emission Reduction Systems to Achieve Global Reduction Goals, Meet Electricity Needs, and Utilize Domestic Resources."

BSCSP Kevin Dome Carbon Storage Project Blog Available.

The Big Sky Carbon Sequestration Project (BSCSP) has created a "News from the Kevin Dome" blog on the BSCSP website as an effort to regularly update the public about work being done on the Kevin Dome Carbon Storage Project. BSCSP expects to post updates on a weekly basis and as developments occur in the field.

Save the Date: MGSC Conference.

The Midwest Geological Sequestration Consortium (MGSC) will hold their annual conference at the I Hotel and Conference Center in Champaign, Illinois, USA, on November 6, 2014. More details will be available in the future.

12th International Conference on Greenhouse Gas Control Technologies.

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

RGGI Q2 2014 Secondary Market Report.

According to their recently released report, Potomac Economics, the independent market monitor for the Regional Greenhouse Gas Initiative (RGGI), continues to find no evidence of anti-competitive conduct in the RGGI CO_2 allowance secondary market.

CarbonKids Book Can Help Children Understand CCS.

A group of Western Australian primary school students released a book that will help children better understand greenhouse gases (GHGs) and the process of CCS. Titled "A Day in the Life of a Carbon Atom – Starring: Adom," the publication was released at the 2014 National Carbon Capture and Storage Conference in Sydney, Australia, and is part of a $200,000 Australian Government sponsorship.

Carbon Storage in the News

"Wells In Northern Montana Mark Big Step For MSU Carbon Sequestration Research."

Researchers from the Montana State University (MSU)-led BSCSP drilled a pair of wells in Toole County, Montana, USA, to test the underlying sedimentary formation's ability to store CO_2. The Kevin Dome Large-Scale Carbon Storage Project is an eight-year project being run through BSCSP. Kevin Dome has contained naturally occurring CO_2 for 50 million years in the Middle Duperow formation, a deep, porous rock layer, which occurs below the Potlatch Anhydrite formation, a dense layer of rock that acts as a cap. The plan is to extract 1 million metric tons of CO_2 stored in Kevin Dome, bring it approximately 4,000 feet through the first of the two completed wells, transport it six miles via pipeline, and inject it into the down-dip flank of the Middle Duperow formation where CO_2 does not occur. The second well, which was drilled to a depth of nearly 5,000 feet, will be used to monitor the CO_2 and subsurface geochemistry near a yet-to-be-drilled injection well. BSCSP, of DOE's Regional Carbon Sequestration Partnerships (RCSPs), is seeking to develop novel approaches for carbon storage in Montana, Wyoming, Idaho, South Dakota, eastern Washington, and Oregon. From *Fairfield Sun Time* on August 18, 2014.

"Peterhead Power Station Opens Doors for CCS Tours."

United Kingdom (UK)-based utility SSE conducted tours at Peterhead power station in order to inform the public about the station and future proposals for a CCS project at Peterhead. Four tour groups, consisting of nearly 100 local people, participated. SSE is supporting Shell, who is developing a full-scale gas CCS project where up to 10 million metric tons of CO_2 emissions could be captured and transported via pipeline offshore to Shell's existing Goldeneye reservoir for long-term storage. The Peterhead project is one of two CCS demonstration projects selected by the UK Government to enter a Front-End Engineering Design (FEED) study as part of their CCS commercialization competition. From *PennEnergy* on August 13, 2014.

"Shell Fits Final Module on Alberta Oil Sands' First Carbon Capture Project."

Shell Canada fit the final module for the Quest CCS project in Alberta, Canada. The project is now 70 percent complete and expected to start up in 2015. Once complete, the project will capture more than 1 million metric tons of CO_2 per year from Shell's Scotford upgrader north of Edmonton, Alberta, and inject the CO_2 for storage. The upgrader converts mined bitumen from Shell's Athabasca oil sands project into refinery-ready crude; 35 percent of direct emissions will be captured from the Scotford facility. The project received funding from the Alberta and Canadian Federal government to help mitigate GHG emissions from oil sands. From *Reuters* on August 27, 2014.

Science

"N.J. Announces Climate Change Mapping Website."

Scientists from Rutgers University announced the launch of NJADAPT.org, a climate change mapping website that allows New Jersey community planners to see how infrastructure, population, and the environment are affected by storm surges, coastal flooding, and sea level rise. In addition to interactive maps, the website also contains a self-assessment tool for towns and cities, and plans are in place to add inland flooding and local temperature maps. Interactive map users are able to see evacuation routes, emergency medical services, schools, and other energy facilities on maps, then add layers to see how areas could be affected by potential climate change. From *NewsWorks* on August 14, 2014.

"Climate Change Reflected in Altered Missouri River Flow, Report Says."

According to a recently released U.S. Geological Survey (USGS) report, the Missouri River's stream flow has experienced change over the last 50 years, leading to water shortages in Montana and Wyoming and flooding in the Dakotas. Beginning in the Rocky Mountains of western Montana, the Missouri River flows east and south for more than 2,300 miles before entering the Mississippi River north of St. Louis, Missouri. According to the USGS report, potential climate shifts may be causing changes in the Missouri River Basin. Scientists note that higher stream flow in the Dakotas occurred even as water use increased; in addition, it was also noted that lower stream flow in some areas could also be related in part to groundwater pumping. From *Los Angeles Times* on August 17, 2014.

Policy

"U.S. EPA Approves Carbon Sequestration Permits in Central Illinois."

The U.S. Environmental Protection Agency (EPA) approved four identical permits allowing the FutureGen Industrial Alliance Inc. to inject CO_2 in Illinois. FutureGen plans to capture the CO_2 from a retrofitted coal-fired power plant in Meredosia, Illinois, and then transport it for injection in the proposed wells in Morgan County, Illinois. The FutureGen project goal is to capture and inject 1.1 million metric tons of CO_2 per year for 20 years. EPA completed a technical review of the permits, which were the Nation's first Class VI underground injection permits for carbon storage, before approving them. Before injecting CO_2, the integrity of the wells must be demonstrated. More information is available on the EPA website. From *U.S. EPA News Release* on September 2, 2014.

"Chile Set to Pass Latin America's Second Carbon Tax."

Chile is set to become the second country in Latin America to approve a carbon tax. If approved, Chile will start charging $5 per metric ton of CO_2 in 2017; Mexico, the other Latin American country to price carbon emissions, charges approximately $2 less per metric ton of CO_2. Chile has voluntarily committed to reduce its GHG emissions 20 percent by 2020 based on 2007 levels. The carbon tax is part of a broader package of tax reforms that included other environmental taxes intended to reduce GHG emissions and address potential climate change. From *Responding to Climate Change* on September 3, 2014.

Policy (Continued)

"Public perception of carbon capture and storage (CCS): A review."

The following is the Abstract of this article: "CCS is regarded as an important bridging technology to a sustainable energy production. Whether it will be deployed on a large scale depends on both technological advances and social processes. Public perception of CCS can be crucial, and research interest in this topic has been growing. This review analyzes the public perception research thus far (42 articles were identified). Laypeople's concerns and spontaneous reactions to the technology have been thoroughly analyzed, and the results form a good basis for risk communication about CCS. What deserves more research is the role of the context (particularly the social context) in which CCS would be deployed. More case studies are also needed to gain a clearer picture of what matters for CCS acceptance at the project level, as opposed to societal acceptability of CCS." **Selma L'Orange Seigo, Simone Dohle, and Michael Siegrist**, *Renewable and Sustainable Energy Reviews*. (Subscription may be required.)

"An overview of current status of carbon dioxide capture and storage technologies."

The following is the Abstract of this article: "Global warming and climate change concerns have triggered global efforts to reduce the concentration of atmospheric CO_2. CCS is considered a crucial strategy for meeting CO_2 emission reduction targets. In this paper, various aspects of CCS are reviewed and discussed including the state of the art technologies for CO_2 capture, separation, transport, storage, [release], monitoring, and life cycle analysis. The selection of specific CO_2 capture technology heavily depends on the type of CO_2 generating plant and fuel used. Among those CO_2 separation processes, absorption is the most mature and commonly adopted due to its higher efficiency and lower cost. Pipeline is considered to be the most viable solution for large volume of CO_2 transport. Among those geological formations for CO_2 storage, [EOR] is mature and has been practiced for many years but its economical viability for anthropogenic sources needs to be demonstrated. There are growing interests in CO_2 storage in saline [formations] due to their enormous potential storage capacity and several projects are in the pipeline for demonstration of its viability. There are multiple hurdles to CCS deployment including the absence of a clear business case for CCS investment and the absence of robust economic incentives to support the additional high capital and operating costs of the whole CCS process." **Dennis Y.C. Leunga, Giorgio Caramannab, and M. Mercedes Maroto-Valerb**, *Renewable and Sustainable Energy Reviews*. (Subscription may be required.)

Geology

"Modeling and measurement of CO_2 solubility in salty aqueous solutions and application in the Erdos Basin."

The following is the Abstract of this article: "Geological carbon storage (GCS) is recognized as an effective method for mitigating the greenhouse effect. Deep saline [formations] hold the highest potential capacity for CO_2 storage. [Carbon dioxide] solubility in salty aqueous solutions under geological [storage] conditions plays a key role in GCS. However, most CO_2 solubility studies focus mainly on single-salt solutions ([sodium chloride (NaCl) and calcium chloride ($CaCl_2$)]), and extrapolation of these studies to aqueous solutions with mixed ions is unavailable. To fill the research gap, based on the collection of CO_2 solubility data, a semi-empirical thermodynamic model is proposed in this paper to calculate CO_2 solubility in aqueous solutions containing K^+, Na^+, Ca^{2+} and Mg^{2+} in the temperature and pressure ranges from 313 K to 378 K and from 50 bar to 220 bar. To describe the CO_2–liquid phase equilibrium, the Peng–Robinson equation of state (PR EoS) and the Setschenov equation are applied. The former has been modified to improve its performance in the studied T–P range, and the latter shows excellent accuracy with only three optimized parameters. Before modeling was done, experimental studies were conducted. Brine sampling from five reservoirs potentially chosen for CO_2 [storage] in the Erdos Basin was carried out using a monitoring well in the support of the Shenhua Group CCS site project. The chemical composition of the samples was determined, and experiments measuring CO_2 solubility were carried out in synthetic brine with 64 valid data points reported. An analytical method with a simplified sampling technique was chosen. In the range studied, the average absolute deviation of CO_2 solubility between the model and experimental results was 2.01 [percent], and the maximum absolute deviation in this study was less than 4.79 [percent]. The proposed model and experimental data therefore possess broad adaptability to GCS with satisfactory accuracy." **Lu Wang, Zhaoli Shen, Lisha Hu, and Qingchun Yu**, *Fluid Phase Equilibria*. (Subscription may be required.)

"Simulating Geologic Co-sequestration of Carbon Dioxide and Hydrogen Sulfide in a Basalt Formation."

The following is the Abstract of this article: "Co-[stored] CO_2 with [hydrogen sulfide (H_2S)] impurities could affect geologic storage, causing changes in pH and oxidation state that affect mineral dissolution and precipitation reactions and the mobility of metals present in the reservoir rocks. [The authors] have developed a variable component, non-isothermal simulator, STOMP-COMP (Water, Multiple Components, Salt and Energy), which simulates multiphase flow gas mixtures in deep saline reservoirs, and the resulting reactions with reservoir minerals. [The authors] use this simulator to model the co-injection of CO_2 and H_2S into brecciated basalt flow top. A 1000 metric ton injection of these supercritical fluids, with 99 [percent] CO_2 and 1 [percent] H_2S, is [stored] rapidly by solubility and mineral trapping. [Carbon dioxide] is trapped mainly as calcite within a few decades and H_2S is trapped as pyrite within several years." **Bacon DH, R Ramanathan, HT Schaef, and BP McGrail**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

Technology

"Passive injection: A strategy for mitigating reservoir pressurization, induced seismicity and brine migration in geologic CO_2 storage."

Technology (Continued)

The following is the Abstract of this article: "Many technical, regulatory and public perception challenges remain to be addressed before large-scale deployment of CO_2 geologic storage becomes a reality. Two major risks associated with injection of CO_2 into the subsurface are the possibility of induced earthquakes compromising long-term seal integrity, and the displacement of saline brines resulting in contamination of shallow groundwater. Both induced seismicity and brine migration are caused by elevated pressures in the storage formation owing to the relative incompressibility of water. Here, [the authors] describe a strategy, termed passive injection that can be used to inject large amounts of CO_2 in a storage formation with no increase, temporary or long-term, in reservoir pressure. Passive injection relies on the strategic placement of brine production wells to create negative pressure gradients that result in CO_2 entering the formation at ambient pressure. Injection occurs at the intersection of pressure-depth profiles for a surface-pressurized, low-density CO_2 column and a hydrostatic column of formation fluid. A multi-stage, square-ring well configuration is envisaged, in which brine production wells are repurposed for CO_2 injection upon CO_2 breakthrough, and the next concentric ring of production wells installed at a greater distance. Numerical simulations of passive injection are presented using the coupled thermo-hydro-mechanical (THM), multi-fluid, multi-phase numerical simulator FEHM. [The authors] consider CO_2 injection into a 3 km-deep, closed reservoir over a period of 50 years, with up to four stages of injection and production depending on well-spacing and production pressures. Storage rates as high as 4 Mt yr^{-1} at 70 [percent] utilization of the reservoir pore volume are achieved under optimum conditions. Long-term mass production of brine is approximately 1.7 times that of CO_2 [stored]. Geomechanical effects due to reservoir drawdown, cooling near injection wells, and surface subsidence are modeled. The risk of induced seismicity is quantified in terms of the Coulomb Failure Stress (CFS) for an optimally oriented fault in an extensional tectonic regime. Injection and production-induced changes in pressure and CFS confirm that, both during and at the conclusion of injection, (i) reservoir pressure is everywhere less than or equal to its initial value; and (ii) the risk of induced seismicity is everywhere reduced or unchanged. Thus, the primary risks of brine migration outside the primary reservoir and induced seismicity compromising seal integrity are neutralized. Passive injection produces large quantities of brine, the treatment and disposal of which represents an additional economic burden to CO_2 geologic storage operations. Unless additional revenue streams or economies of scale can be leveraged, these costs are likely to limit the viability of the proposed scheme to only the most economically favorable sites." **David Dempsey, Sharad Kelkar, and Rajesh Pawar**, *International Journal of Green Gas Control*. (Subscription may be required.)

"Modeling of the pressure propagation due to CO_2 injection and the effect of fault permeability in a case study of the Vedsted structure, Northern Denmark."

The following is the Abstract of this article: "Assessing the pressure buildup in CO_2 storage sites and especially the vertical propagation is vital for evaluation of site behavior and security. Vedsted structure in the Northern part of Jylland in Denmark consists of 290 m thick Gassum Formation at 2100 m depth forming the primary reservoir and is sealed by the 530 m thick Fjerritslev Formation which is mainly shale lithology with very low permeability. Overlying the caprock is a number of formations forming secondary reservoirs and seals including a 420 m thick Chalk Group which is overlain by 20–50 m Quaternary deposits. Seismic profiling of the structure shows the presence of northwest-southeast trending faults of which some originate in the upper layer of the Gassum reservoir and some reach the base Chalk Group layer. Two faults in the upper Gassum reservoir have been interpreted to be connected to the base Chalk Group. In order to evaluate potential risks associated with vertical pressure transmission via the faults through the caprock, a number of simulation cases have been run with various fault permeabilities spanning orders of magnitude to represent both the worst and best case scenarios. Fault rock permeability data were obtained from a literature study and range from 1000 mD (maximum value reported from sedimentary rock environment) for the worst case scenario down to 0.001 mD (sealing faults in sedimentary rock environment) for the best case scenario. The results show that after injecting 60 million tons (Mt) of CO_2 at a rate of 1.5 Mt/year for 40 years, overpressure is developed in the reservoir and about 5 bar is transmitted to the base Chalk Group for the 1000 mD fault permeability (open fault) case, while for the 0.001 mD (sealing fault) case the pressure buildup is confined within the primary caprock. The results also show that, approximately 0.3–5.0 bar overpressure can be transmitted to the base Chalk Group when the fault permeability is above 1.0 mD." **Ernest N. Mbia, Peter Frykman, Carsten M. Nielsen, Ida L. Fabricius, Gillian E. Pickup, and Ann T. Sørensen**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

"Uncertainty quantification for the impact of injection rate fluctuation on the geomechanical response of geologic carbon sequestration."

The following is the Abstract of this article: "[The authors] present an analysis of the geomechanical effects of injection rate fluctuations for geological [storage] of CO_2. Initially, [the authors] present analytical solutions for the effects of injection rate fluctuations on CO_2 fluid pressure spatial distribution and temporal evolution for a typical injection scenario. Numerical calculations are performed using a finite element method to investigate the effects of injection rate fluctuations on geomechanical deformation, stresses, and potential failure of the [formation] and caprock layers. The numerical method was first validated by the fluid pressure distribution's good agreement with the analytical solution…The proportional constants are identified, and the fluctuations have the most pronounced effect on the geomechanical stresses, and, therefore, on the potential failure of the [formation] and caprock layers. Instead of expensive computational simulation, this study provides an efficient tool to estimate the geomechanical response variance to injection rate fluctuation. A failure analysis was presented based on the numerical results, where probability of failure was estimated for fluctuating injection rates with different mean and variance during the entire injection period. It was found that with increasing injection rate fluctuation, the failure probability increases significantly. Therefore, the risk associated with injection rate fluctuations should be carefully evaluated." **Bao J, Y Chu, Z Xu, AM Tartakovsky, and Y Fang**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

TERRESTRIAL

"The fate of soil organic carbon upon erosion, transport and deposition in agricultural landscapes – A review of different concepts."

The following is the Abstract of this article: "Erosion and deposition redistribute large quantities of sediment and soil organic carbon (SOC) in agricultural landscapes. In the perspective of global carbon cycling, the coupling between erosion processes and the fate of SOC is of particular interest. However, different concepts have been proposed to assess the impact by erosion-induced lateral and vertical carbon fluxes. On landscape scale, this resulted in contrasting conclusions if agricultural soils represent either a carbon sink or source. The large global area of arable soil and generally high erosion rates, make these insights important. In this review, [the authors] aim to give an overview of the different conceptual relations described governing C dynamics at sites of erosion, along the transport pathway and at depositional sites and the current state of knowledge on the fate of SOC upon erosion, transport and deposition in agricultural landscapes. The impact of erosion on SOC dynamics differs for sites of erosion, deposition and during transport, with further influences by agricultural practices (e.g. tillage and [fertilization]). Controlling processes are the detachment of sediment and SOC, net primary production resulting in dynamic replacement and changes in [mineralization] upon transport and deposition due to aggregate breakdown and deep burial, respectively. However, the exact magnitude and dominance of these processes are debated, resulting in a controversy whether arable land functions as a sink or source for atmospheric CO_2. Global estimations range between a net sink strength of 0.06–1 versus a source of 0.27–1.14 Gt C yr^{-1} for agricultural soils. An eco-geomorphologic approach, which encompasses physical- and biological-driven factors (e.g. spatio-temporal variation in biological, geomorphological and biological processes, environmental conditions, [mineralization], and net primary production) is of importance to balance the carbon budget and ascertain sink or source formation at landscape scale. High spatio-temporal variability on process-scale imposes constrains, to measure and model the fate of SOC upon erosion, with limited quantitative data available. Prospective research across the landscape (eroding sites, transport pathway, and depositional sites) should include all relevant processes at broad temporal and spatial scales. Definitive resolution of the sink/source controversy lies in further eco-geomorphologic research on the fate of SOC, [focusing] on long-term and spatial extensive monitoring studies, combined with advanced measuring, modelling and extrapolation techniques to cover broad spatio-temporal SOC dynamics. Ascertainment of carbon dynamics in agricultural landscapes provides important insights to balance the carbon budget and finally holds the answer on sink/source formation." **F.M.S.A. Kirkels, L.H. Cammeraat, and N.J. Kuhn**, *Geomorphology*. (Subscription may be required.)

TRADING

"CO_2 Allowances Sold for $4.88 in 25th RGGI Auction."

The states participating in RGGI announced that 100 percent of the CO_2 allowances offered for sale at their 25th auction (17,998,687 total CO_2 allowances) were sold at a clearing price of $4.88. The auction generated $87.8 million for reinvestment by the RGGI states in consumer-benefit initiatives, such as energy efficiency, renewable energy, direct bill assistance, and GHG abatement programs. Cumulative proceeds from all RGGI CO_2 allowance auctions total approximately $1.8 billion. According to the independent market monitor's report, titled, "Market Monitor Report for Auction 25," electricity generators and their corporate affiliates have won 78 percent of the CO_2 allowances sold in RGGI auctions since 2008. From *RGGI News Release* on September 5, 2014.

"California's Latest Carbon Auction Raises $331.8 Million."

According to California state officials, industrial companies and other businesses paid a combined $331.8 million for carbon credits in California's latest cap-and-trade auction. The California Air Resources Board (CARB) reported that companies paid $11.50 a ton for carbon credits that can be used this year and all of the 22.5 million credits available were sold. Carbon credits to be used in 2017 sold for $11.34 a ton, with approximately two-thirds of the 9.3 million available credits being purchased. The market is the centerpiece of AB 32, California's law that placed a ceiling on the total amount of carbon that can be emitted each year by more than 400 manufacturers, food processors, and others. For more information on CARB Quarterly Auction 8, view the Summary Results Report. From *The Sacramento Bee* on September 9, 2014.

"A real option-based model to valuate CDM projects under uncertain energy policies for emission trading."

The following is the Abstract of this article: "Emission trading has been considered a primary policy tool for emission reduction. Governments establish national targets for emission reduction and assign emission reduction goals to private entities to accomplish the targets. To attain the goal, private entities should perform offset projects that can produce emission credits or buy emission credits from the market. However, it is not easy for private entities to decide to implement the projects because energy policies associated with emission trading keep changing; thus, the future benefits of the offset projects are quite uncertain. This study presents a real option-based model to investigate how uncertain energy policies affect the financial viability of an offset project. A case study showed that the establishment of a target emission was attractive to the government because it could make the CDM project financially viable with a small amount of government subsidy. In addition, the level of the government subsidy could determine the investment timing for the CDM project. In this context, governments should be cautious in designing energy policies, because even the same energy policies could have different impacts on private entities. Overall, this study is expected to assist private entities in establishing proper investment strategies for CDM projects under uncertain energy policies." **Taeil Park, Changyoon Kim, and Hyoungkwan Kim**, *Applied Energy*. (Subscription may be required.)

Recent Publications

"CO_2 Emissions from Electricity Generation and Imports in the Regional Greenhouse Gas Initiative: 2012 Monitoring Report."
The following is from the Executive Summary of this document: "This report, the fourth report in a series of annual monitoring reports, summarizes data for the period from 2005 through 2012, for electricity generation, electricity imports, and related CO_2 emissions for the nine states that participated in the RGGI second control period. These monitoring reports were called for in the 2005 RGGI Memorandum of Understanding (MOU) in response to expressed concerns about the potential for the RGGI CO_2 Budget Trading Program to result in 'emissions leakage'. This report for 2012 is the first of the annual monitoring reports to review the data as a [nine]-state program after withdrawal of the New Jersey from the program. A comparative 10-state data set similar to previous iterations of this report can be found in Appendix E [of the full report]. In the Northeast and Mid-Atlantic states, CO_2 emissions from the regional electric power sector are a function of highly dynamic wholesale electricity markets. The cost of compliance with the RGGI CO_2 Budget Trading Program is only one of multiple factors that influence the dispatch of electric generation, and resulting CO_2 emissions, through the operation of these markets. As a result, this report presents data without assigning causality to any one of the factors influencing observed trends. The observed trends in electricity demand, net electricity imports, and electricity generation from multiple categories of generation sources (including electricity imports), show there has been no significant change in CO_2 emissions or the CO_2 emission rate (pounds of CO_2 per megawatt hour or lb CO_2/MWh) from total non-RGGI electric generation serving load in the nine-state RGGI region during the period of the RGGI program, 2010 – 2012."

"Meeting Global Carbon Reduction Goals: A Technology Driven Climate Paradigm."

The following is from the Executive Summary of this document: "Policymakers concerned about climate change have expressed frustration regarding continued growth in global anthropogenic GHG emissions, despite calls for dramatic reductions. Equally clear is the world's continued reliance on fossil fuels. Both the United States and the world rely on fossil fuels for about 84 percent of their energy. In the United States, 39 percent of electric power in 2013 was produced from coal, and an additional 28 percent was from natural gas. The federal executive branch has chosen to move forward with GHG regulations, with or without Congressional action…EPA has responded and developed a series of new rules under the CAA. But the cited provisions within the CAA date back to its 1970 amendments, and perhaps because during that era the main climate concern related to planetary cooling, not warming, the CAA is poorly suited to addressing GHG emissions from large stationary sources, such as power plants, factories, refineries, etc. The administration's goal, which lacks legislative support, is to reduce U.S. GHG emissions in 2050 by 83 percent, compared to U.S. emissions in 2005. In January 2014, EPA proposed CO_2 limits for new fossil-fueled electric power plants, and in June 2014, EPA proposed guidelines for states to follow in setting standards for CO_2 emissions from existing fossil fueled power plants. Even though these rules are at only the proposal stage, states and others have already filed legal challenges. History suggests that while these CO_2 standards for new and existing power plants are being finalized and litigated, there may be a period of at least 5-10 years during which the ultimate emissions requirements will remain uncertain. This period of uncertainty will contribute to an absence of private-sector interest as well as underinvestment in further advancing CCS technologies."

Legislative Activity

"Senate Bill Would Create Fund for Carbon Capture and Storage."

On August 1, 2014, a bill was introduced to establish a CCS Deployment Acceleration Fund. The bill, S. 2776, is intended to promote the establishment of at least 10 commercial-scale CCS units in the United States over the next decade. The bill was referred to the Committee on Energy and Natural Resources. From *Govtrack.us* on August 1, 2014. .

"The Dynamics and Global Implications of Subglobal Carbon-Restricting Regimes."

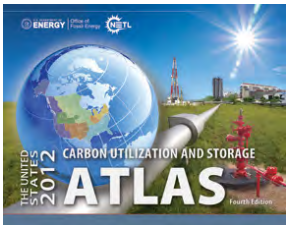
The following is the Abstract of this article: "The European Union and Australia have enacted comprehensive carbon-restricting reforms that will affect both domestic and foreign industries. After describing these reforms in detail, the article develops a microeconomic analytical model that explains the impact these regimes have on the dynamics of inter-firm competition in carbon-restricting nations and how they will also influence technology choices by certain industries in carbon-friendly nations. Specifically, exporters and producers operating in vertically-integrated industries in carbon-friendly nations will increasingly elect carbon-efficient technologies to minimize costs as they adjust to a changing international regulatory environment. The article hypothesizes that this shift in the carbon intensity of production will cause these industries to form coalitions with other pro-environment groups to pressure national governments for legislative and global carbon-restricting reforms that reduce carbon [release] and losses from trading with industries in carbon-laggard nations. Because these cumulative developments will eventually lead to a binding global emissions-stabilizing agreement, pursuant to which border measures will be taken, the article offers a few suggestions for reducing potential conflicts between the trade and climate change regimes." **Juscelino F. Colares**, *Georgetown International Environmental Law Review 417 (2013)*. (Subscription may be required.)

About DOE's Carbon Storage Program

The Carbon Storage Program is implemented by the U.S. Department of Energy's Office of Fossil Energy and managed by the National Energy Technology Laboratory. The program is developing technologies to capture, separate, and store CO_2 in order to reduce greenhouse gas emissions without adversely influencing energy use or hindering economic growth. NETL envisions having a technology portfolio of safe, cost-effective, carbon dioxide capture, transport, and storage technologies that will be available for commercial deployment.

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

Carbon Storage Program Resources



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

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

Get answers to your carbon capture and storage questions at NETL's Frequently Asked Questions webpage.

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

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About NETL's Carbon Storage Newsletter

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

National Energy Technology Laboratory

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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

420 L Street, Suite 305
Anchorage, AK 99501

1450 Queen Avenue SW
Albany, OR 97321-2198

Contacts

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

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