NETL the ENERGY lab

Carbon Storage Newsletter

July 2014

What's Inside?

Highlights

"Energy Department Project Captures and Stores more than One Million Metric Tons of CO_2."

The U.S. Department of Energy (DOE) – in partnership with Air Products and Chemicals, Inc. – announced that more than 1 million metric tons of carbon dioxide (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 enhanced oil recovery (EOR) at the depleted West Hastings Field in southeast Texas. By using EOR, West Hastings is likely to yield as much oil as it would from traditional production activities; it is estimated that the West Hastings Field could produce in the range of 60 to 90 million additional barrels of oil using CO_2 injection. Air Products' vacuum swing adsorption project, supported through DOE's Industrial Carbon Capture and Storage (ICCS) Program, is one of several ICCS projects advancing and deploying carbon capture and storage (CCS) technologies. From *U.S. Department of Energy Press Release* on June 26, 2014.

"DOE-Sponsored Project Shows Huge Potential for Carbon Storage in Wyoming."

A DOE-sponsored study revealed that the Wyoming Rock Springs Uplift (a geologic feature in southwestern Wyoming) could potentially store 14 to 17 billion metric tons of CO_2. The project team, led by the University of Wyoming's Carbon Management Institute and sponsored by the Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL), gathered geologic, hydrologic, and geochemical data from a stratigraphic test well. The Rock Springs Uplift was found to have ideal geological characteristics for carbon storage and proximity to large, anthropogenic CO_2 emission sources. The team performed digital imaging of a core sample to learn about the formation's grain size, mineralogy, facies distribution, and porosity and evaluate the site's potential for CO_2 storage. The team also studied geophysical data from the test well and the overlying formations that would trap the CO_2. The researchers found that the deep saline waters of the Rock Springs Uplift contain high, commercially viable concentrations of lithium; for every 1 million metric tons of CO_2 stored, approximately 250 metric tons of lithium carbonate could be recovered from processed brine. Lithium, which is used in batteries and other electronics applications, could generate revenue to offset the cost of CO_2 storage and help reduce the need for lithium import. In addition to the testing completed within the characterization well and the samples removed from it, the project team performed a three-dimensional seismic survey around the test site, allowing researchers to extrapolate the geologic properties measured in the well (e.g., porosity, permeability, and fluid saturation). The Wyoming Rock Springs Uplift storage potential is equal to 250 to 300 years' worth of CO_2 emissions produced by Wyoming's coal-fired power plants and other large regional anthropogenic CO_2 sources at current emission levels. This research effort was funded by the American Recovery and Reinvestment Act of 2009 (ARRA). From *U.S. Department of Energy Press Release* on June 3, 2014.

Announcements

DOE/NETL Carbon Storage R&D Project Review Meeting.

DOE's 2014 Carbon Storage R&D Project Review meeting will be held at the Sheraton Station Square Hotel in Pittsburgh, Pennsylvania, USA, on August 12-14, 2014. Among a number of other technical sessions, this year's meeting will include plenary sessions on a number of carbon storage topics and lessons learned over the past 10 years from the Regional Carbon Sequestration Partnerships (RCSPs). Participants will share knowledge and resources to assist in planning future carbon storage efforts. Based on past attendance, this meeting is expected to attract 200 or more attendees.

DOE Reaches Agreement to Test Carbon Capture and Gasification Technologies.

DOE signed a new five-year cooperative agreement with Southern Company to evaluate advanced carbon capture and gasification technologies at the National Carbon Capture Center (NCCC) in Wilsonville, Alabama, USA. Under the NETL-managed agreement, Southern Company will test pre- and post-combustion carbon-capture technologies, materials, and processes that support advanced fossil-fuel conversion systems, primarily coal gasification.

DOE Announces Demonstration Project Startup.

DOE and Tampa Electric Company (TECO) announced the startup of a pilot project to demonstrate carbon capture technology in a coal gasification unit at the Polk Power Plant Unit-1 in Tampa, Florida. The Polk Power Station is the first coal integrated gasification combined cycle (IGCC) plant in the United States. IGCC technology has the potential to improve the energy efficiency of removing pollutants from coal power plant emissions, while increasing reliability and reducing the overall cost of capturing CO_2 and other contaminant emissions.

BSCSP Kevin Dome Carbon Storage Project Blog Available.

The Big Sky Carbon Sequestration Partnership (BSCSP) 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.

PCOR Partnership Annual Membership Meeting.

The Plain CO_2 Reduction (PCOR) Partnership Annual Membership Meeting is scheduled for September 16-17, 2014, at the Embassy Suites Denver – Downtown/Convention Center in Denver, Colorado, USA. The meeting will highlight recent program accomplishments, storage strategies and technologies, regulatory developments, and carbon storage infrastructure. Registration, hotel information, and an agenda are available via the link.

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.

Carbon Storage in the News

"UT Austin Receives $12 Million to Help U.S. Curtail Greenhouse Gas Emissions."

DOE awarded the University of Texas (UT) at Austin a grant to fund carbon storage research at the Center for Frontiers of Subsurface Energy Security. A team from the Cockrell School, UT Austin's Jackson School of Geosciences, and Sandia National Laboratory will collaborate on the project. The research project includes 20 faculty members from across the university and will begin this fall. UT Austin's center is one of 32 Energy Frontier Research Centers (EFRCs) across the United States that will receive funding to accelerate the scientific breakthroughs needed to build a 21st-century energy economy. From *University of Texas News Release* on June 19, 2014.

"UK CCS Project Secures €300m EU Funding."

The White Rose CCS project in the United Kingdom (UK) has been awarded funding of approximately $400 million by the European Commission. The project is located next to the existing Drax Power Station in North Yorkshire, UK, and includes the development of a new 426-megawatt, coal-fired power plant. The plant is expected to capture up

Carbon Storage in the News (Continued)

to 90 percent of the CO_2 emissions from the site; the CO_2 will then be transported via pipeline for permanent storage under the North Sea. White Rose is the only CCS project in Europe to receive funds under the program. From *Energy Live News* on July 8, 2014.

"Wyoming Files Application to Establish CO_2 Pipeline Corridor Network on Federal Lands."

Wyoming's Governor announced that a plan to establish pipeline corridors through Federal lands is complete. The Bureau of Land Management (BLM) application seeks to establish 1,150 miles of pipeline corridors on Federal lands in Wyoming. All of the corridors run parallel to existing pipelines and will reduce permitting timeframes. The project, called the Wyoming Pipeline Corridor Initiative (WPCI), would cross Federal lands in most of Wyoming's counties and involve nine BLM field offices. One of the primary purposes of the WPCI is to facilitate EOR in Wyoming. It is expected that some of the corridors will be available as soon as approvals are issued. The application is part of a multi-year collaboration between the state of Wyoming, BLM, and other Federal agencies. The pipeline plan is part of the Governor's Energy Strategy. From *Wyoming Governor Matt Mead News Release* on June 12, 2014.

"Montana Tech Engineers Explore EOR Options."

The Montana Tech Petroleum Engineering Department is conducting a pilot project to assess EOR options for the Elm Coulee oilfield in Eastern Montana, USA. The pilot project will inject either CO_2 or natural gas into shale surrounding original wells; conventional drilling and production methods in Montana's Bakken oilfield extract 9 to 15 percent of available oil. The project is funded by the Montana Department of Natural Resources and Conservation through the Montana Board of Oil and Gas Conservation. The team is halfway through the five-year research effort. From *The Bakken Magazine* on June 24, 2014.

"UKCCSRC Announces £2.57M Funding for CCS Research."

The UK Carbon Capture and Storage Research Centre (UKCCSRC) announced the distribution of approximately $4.4 million from its research budget to support 14 new CCS research projects, including 7 for CO_2 capture, 5 for CO_2 cross-cutting issues, and 2 for CO_2 storage. The projects address research needs identified by the Advanced Power Generation Technology Forum (APGTF) and the UK's Department of Energy and Climate Change (DECC) CCS Roadmap for Innovation and Research and Development (R&D). Two of the projects include academic collaboration with Australia and China. Project details are available via the link; the projects' progress and research outcomes will be made publicly available via the UKCCSRC website. The call builds upon initial funding for 13 projects in 2012. From *UKCCSRC Media Release* on June 19, 2014.

"Muon Detector Could Help Identify CO_2 Storage Sites."

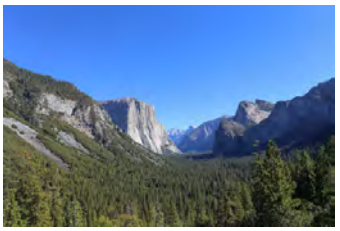
Physicists at Sheffield University are developing an advanced probe that can detect the properties of cosmic ray muons (naturally occurring sub-atomic particles that pass through Earth) as an option to existing seismic monitoring techniques for CCS. The Sheffield University team has been testing the technology at an underground research facility with funding from the UK's DECC and Premier Oil. The detectors have been deployed underground where they monitor muons travelling through the North Sea and then through approximately 1 kilometer of rock to reach a cavern in the Boulby Mine. Variations are detected by the system when the tide changes above the mine and the amount of water that muons must travel through changes. The team plans to design a system that could be used as a probe in an oilfield and other potential geologic CO_2 storage formations. The researchers are aiming to develop a working prototype by 2015. From *The Engineer* on June 13, 2014.

Science

"Coastal Winds Intensifying with Climate Change, Study Says."

Summer winds are increasing along the west coasts of North and South America and southern Africa, and a recent study cites that potential climate change could be the cause. The winds have strengthened over the last 60 years in three out of the five regions of world, according to the analysis. While stronger winds offer potential benefits to coastal areas by bringing a surge of nutrients and boosting populations of plankton, fish, and other species, the study says they could also affect marine life by causing turbulence in surface waters, disrupting feeding, impacting acidification, and lowering oxygen levels. The study, titled, "Climate change and wind intensification in coastal upwelling ecosystems," was published in the journal *Science*. From *The Sydney Morning Herald* on July 7, 2014.

"Climate Change Threatens U.S. National Parks."



According to a new National Park Service report, present-day temperatures are at the high end of the range of temperatures measured since 1901. In the report, titled, "Climate Exposure of U.S. National Parks in a New Era of Change," scientists took climate data of 289 national parks over the past 10 to 30 years and compared it to the historical range of variability from 1901 to 2012. Scientists were able to determine that 235 of the parks (81 percent) have experienced extreme recent warm conditions, 78 have undergone recent extreme wet conditions, 43 experienced recent extreme dry conditions, and 35 experienced recent warm and dry conditions. To view the report, which was published in the scientific journal PLOS ONE, click here. From *Scientific American* on July 3, 2014.

Policy

"CCS Hub Study for Scotland and the Central North Sea."

A comprehensive analysis into the development of CCS in the UK, titled, "Scotland and Central North Sea CCS Hub Study," was completed by Element Energy Ltd, working with partners SCCS, AMEC, and Dundas Consultants. The report examines scenarios for how CCS might develop and uses these scenarios to create blueprints and business plans for delivering CCS. The report details how the combination of CCS with EOR in the Central North Sea (CNS) provides a beneficial opportunity because the region has a variety of stakeholder interests, legacy facilities (pipelines, platforms, and wells), and commercial and regulatory frameworks for CCS development. The report provides a series of recommendations for Scotland based on the following: (1) support for early CCS demonstration in Scotland; (2) maximizing the UK and European market for CCS in the 2010s and 2020s; (3) supporting infrastructure targeting CNS; (4) improving CCS readiness and optimizing infrastructure; and (5) improving the commercial attractiveness of CO_2 transport, storage, and EOR. From *Element Energy Press Release* on June 1, 2014.

"Political economy constraints on carbon pricing policies: What are the implications for economic efficiency, environmental efficacy, and climate policy design?"

The following is the Abstract of this article: "Economists traditionally view a Pigouvian fee on [CO_2] and other greenhouse gas emissions, either via carbon taxes or emissions caps and permit trading ('cap-and-trade'), as the economically optimal or 'first-best' policy to address climate change-related externalities. Yet several political economy factors can severely constrain the implementation of these carbon pricing policies, including opposition of industrial sectors with a concentration of assets that would lose considerable value under such policies; the collective action nature of climate mitigation efforts; principal agent failures; and a low willingness-to-pay for climate mitigation by citizens. Real-world implementations of carbon pricing policies can thus fall short of the economically optimal outcomes envisioned in theory. Consistent with the general theory of the second-best, the presence of binding political economy constraints opens a significant 'opportunity space' for the design of creative climate policy instruments with superior political feasibility, economic efficiency, and environmental efficacy relative to the constrained implementation of carbon pricing policies. This paper presents theoretical political economy frameworks relevant to climate policy design and provides corroborating evidence from the United States context. It concludes with a series of implications for climate policy making and argues for the creative pursuit of a mix of second-best policy instruments." **Jesse D. Jenkins**, *Energy Policy*. (Subscription may be required.)

"The prospects for coal-fired power plants with carbon capture and storage: A UK perspective."

The following is the Abstract of this article: "CCS facilities coupled to coal-fired power plants provide a climate change mitigation strategy that potentially permits the continued use of fossil fuels whilst reducing the CO_2 emissions. Potential design routes for the capture, transport and storage of CO_2 from UK power plants are examined. Energy and carbon analyses were performed on coal-fired power stations with and without CCS. Both currently available and novel CCS technologies are evaluated. Due to lower operating efficiencies, the CCS plants showed a longer energy payback period and a lower energy gain ratio than conventional plant. Cost estimates are reported in the context of recent UK industry-led attempts to determine opportunities for cost reductions across the whole CCS chain, alongside international [endeavors] to devise common CCS cost estimation methods. These cost figures should be viewed as 'indicative' or suggestive. They are nevertheless helpful to various CCS stakeholder groups [such as those in industry, policy makers (civil servants and the staff of various government agencies), and civil society and environmental 'non-governmental [organizations'] (NGOs)] in order to enable them to assess the role of this technology in national energy strategies and its impact on local communities." **Geoffrey P. Hammond and Jack Spargo**, *Energy Conversion and Management*. (Subscription may be required.)

"Communication approaches for carbon capture and storage: Underlying assumptions of limited versus extensive public engagement."

The following is the Abstract of this article: "A pertinent issue in the literature on communication on emerging technologies such as CCS concerns the degree to which the public is actively involved in the communication process. While researchers have highlighted the pros and cons of limited versus extensive public engagement, the assumptions underlying various communication approaches have been largely neglected. Illuminating assumptions are important for scholarly understandings of what influences communication and for practitioner reflexive awareness in designing communication plans. This paper explores assumptions made about senders and receivers when involving the public to various degrees in CCS communication and how these assumptions relate to different communication objectives. [The authors] describe two contrasting communication approaches, the transmission and participatory approaches, relating them to CCS characteristics and research. [The authors] find that CCS communication may, deliberately or not, be based on different assumptions about the social framing of CCS concerning who should formulate the message, the public's ability to understand complex science, the public's interest in helping frame CCS, and whether public opinions should be taken into account. These assumptions also relate to different communication objectives – convincing the public or increasing dialogue – implying different communication fora, predictability, and input." **Katarina Buhr and Victoria Wibeck**, *Energy Research & Social Science*. (Subscription may be required.)

Geology

"Groundwater hydrogeochemistry in injection experiments simulating CO_2 [release] from geological storage reservoir."

The following is the Abstract of this article: "Geologic carbon [storage] has the potential to reduce [GHG] concentrations in the atmosphere. However, one barrier to large scale implementation is concern for water quality degradation from [the release] of high CO_2 fluids into drinking

Geology (Continued)

water [formations]. The hydrogeochemical response to simulated CO_2 [release] was studied to estimate major and trace element release and to develop criteria for water quality monitoring and risk assessment. In this study, approximately 3100 L [formation] water enhanced with 1 atmosphere pressure CO_2 gas was injected into a fracture zone located at 362–366 m below the ground surface in a sandstone/siltstone/mudstone interbedded [formation] in the Newark Basin. This was followed by a 3–6 week long incubation and then continuous monitoring of the hydrogeochemistry in the pumped-back water samples. Relative to background conditions, the recovered [formation] water displayed a decrease of pH, increase of alkalinity, Ca, Mg and Si concentrations, decrease of sulfate and Mo concentrations, and increased concentrations of trace elements including Fe, Mn, Cr, Co, Ni, Cu, Zn, Rb, Sr, Ba and U. These changes in [formation] water geochemistry can be explained by (a) dissolution of silicate and carbonate minerals and (b) trace element release that appear to be dependent on pH and pCO_2 and affected by the altered redox conditions in the [formation]]. Rapid and simultaneous changes of pH, specific conductance, major and trace metal release in [formation] water could be used as indicators of CO_2 [release] from geologic [storage] sites. Hydrogeochemical parameters including pH, total dissolved solids and trace elements, particularly Fe, Mn, and Zn, need to be monitored in compliance with the U.S. Environmental Protection Agency (EPA) drinking water regulations." **Qiang Yang, Juerg Matter, Martin Stute, Taro Takahashi, Gregory O'Mullan, Kelsey Umemoto, Kale Clauson, M. Elias Dueker, Natalie Zakharova, John Goddard, and David Goldberg**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

"Comparison of different methods for determining key parameters affecting CO_2 storage capacity in oil reservoirs."

The following is the Abstract of this article: "Storing CO_2 in oil reservoirs is not only an effective method for reducing CO_2 emissions and greenhouse effects, but also a means to be more economical by enhancing oil recovery. The evaluation of CO_2 storage capacity in oil reservoirs which is very important for the implementation of CO_2 storage includes the evaluation of theoretical, effective, practical and matched storage capacities. Based on the volumetric balance theory, considering CO_2 dissolved in remaining oil and water, sweep efficiency and displacement efficiency, this paper utilizes three methods to calculate theoretical and effective CO_2 storage capacity in oil reservoirs, in which CO_2 volumetric sweep efficiency, oil recovery factor and [storage] factor are key parameters. This work presents a reservoir numerical simulation method, an empirical formula method, and a stepwise regression method. The feasibility, superiority and limitations of the methods for calculating these three key parameters and storage capacities – including theoretical and actual CO_2 storage capacities – were analyzed through simulated applications in three reservoirs of the Xinjiang Oilfield of China. The results indicated that the assessment results of stepwise regression has a high level of accuracy, and that this oilfield can provide a large storage capacity and is thereby worthy of further study." **Changlin Liao, Xinwei Liao, Xiaoliang Zhao, Hongna Ding, Xiaopeng Liu, Yongge Liu, Jing Chen, and Ning Lu**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

Technology

"Fuzzy optimization of multi-period carbon capture and storage systems with parametric uncertainties."

The following is the Abstract of this article: "CCS is an important technology option for reducing industrial [GHG] emissions. In practice, CO_2 sources are easy to characterize, while the estimation of relevant properties of storage sites, such as capacity and injection rate limit (i.e., injectivity), is subject to considerable uncertainty. Such uncertainties need to be accounted for in planning CCS deployment on a large scale for effective use of available storage sites. In particular, the uncertainty introduces technical risks that may result from overestimating the limits of given storage sites. In this work, a fuzzy mixed integer linear program (FMILP) is developed for multi-period CCS systems, accounting for the technical risk arising from uncertainties in estimates of sink parameters, while still attaining satisfactory CO_2 emissions reduction. In the model, sources are assumed to have precisely known CO_2 flow rates and operating lives, while geological sinks are characterized with imprecise fuzzy capacity and injectivity data. Three case studies are then presented to illustrate the model. Results of these examples illustrate the tradeoff inherent in planning CCS systems under parametric uncertainty." **John Frederick D. Tapia and Raymond R. Tan**, *Process Safety and Environmental Protection*. (Subscription may be required.)

"CO_2 [Release] Identification in Geosequestration Based on Real Time Correlation Analysis Between Atmospheric O_2 and CO_2."

The following is the Abstract of this article: "The paper describes a method for monitoring CO_2 [release] in geological [CO_2 storage]. A real time monitoring parameter, apparent leakage flux (ALF), is presented to monitor abnormal CO_2 [release], which can be calculated by atmospheric CO_2 and O_2 data. The computation shows that all ALF values are close to zero-line without the [release]. With a step change or linear perturbation of concentration to the initial CO_2 concentration data with no [release], ALF will deviate from background line. Perturbation tests prove that ALF method is sensitive to linear perturbation but insensitive to step change of concentration. An improved method is proposed based on real time analysis of surplus CO_2 concentration in least square regression process, called apparent [release] flux from surplus analysis (ALFs), which is sensitive to both step perturbation and linear perturbations of concentration. ALF is capable of detecting concentration increase when the [release] occurs while ALFs is useful in all periods of [release]. Both ALF and ALFs are potential approaches to monitor CO_2 [release] in geosequestration project." **Denglong MA, Jianqiang DENG, and Zaoxiao ZHANG**, *Chinese Journal of Chemical Engineering*. (Subscription may be required.)

Terrestrial

"Carbon and nitrogen [storage] in soils under different management in the semi-arid Pampa (Argentina)."

The following is the Abstract of this article: "Soil management affects distribution and the stocks of soil organic carbon and total nitrogen.

Terrestrial (Continued)

The aim of this study was to evaluate the effect of different crop sequences and tillage systems on the vertical distribution and stocks of soil carbon and nitrogen. [The authors] hypothesized that no-tillage promotes surface organic carbon and total nitrogen accumulation, but does not affect the C and N stocks, when compared with reduced tillage. In addition, the incorporation of maize in the crop sequence increases total organic carbon and total nitrogen stocks. Observations were carried out in 2010 in an experiment located in the semiarid Argentine Pampa, on an Entic Haplustoll. A combination of three tillage systems (no tillage, no tillage with cover crop in winter and reduced tillage) and two crop sequences (soybean–maize and soybean monoculture) were assessed. After 15 years of management treatments, soil samples to a depth of 100 cm at seven intervals, were taken and analyzed for bulk density, organic carbon and total nitrogen. Total organic carbon stock up to a depth of 100 cm showed significant differences between soils under different tillage systems (reduced tillage < no tillage = no tillage with cover crop), the last ones having [eight percent] more than the reduced tillage treatment. Soybean–maize had [three percent] more organic C up to 100 cm depth than the soybean monoculture. Total nitrogen stock was higher under no-till treatments than under reduced tillage, both at 0–50 and 0–100 cm depths. Total organic carbon stratification ratios (0–5 cm/5–10 cm) were around 1.6 under no-till and lower under reduced tillage. The stratification ratio explains less than 40 [percent] of soil carbon stock. Tillage system had a greater impact on soil carbon stock than crop sequence." **Carolina Alvarez, Carina R. Alvarez, Alejandro Costantini, and María Basanta**, *Soil and Tillage Research*. (Subscription may be required.)

"Trees increase soil carbon and its stability in three agroforestry systems in central Alberta, Canada."

"Trees increase soil carbon and its stability in three agroforestry systems in central Alberta, Canada." The following is the Abstract of this article: "Agroforestry land-use systems have significant potential for increasing soil carbon (C) storage and mitigating increases in atmospheric GHG concentrations. [The authors] studied the impact of three agroforestry systems (hedgerow, shelterbelt, and silvopasture) on soil organic C (SOC) and nitrogen (N) in the 0–10 cm mineral layer, by comparing SOC and N distributions in whole soils and three particle-size fractions (<53, 53–250, 250–2000 μm) to assess the potential role of physical protection on soil C and N storage. [The authors] assessed [35] sites (12 hedgerows, 11 shelterbelts and 12 silvopastures), each comprised of 2 paired plots (forest and adjacent agricultural herbland), that were distributed along a 270 km long north–south soil/climate gradient in central Alberta, Canada. Across all sites, 48.4 [percent], 28.5 [percent], and 23.1 [percent] of SOC was found in the fine (<53 μm), medium (53–250 μm) and coarse fractions (250–2000 μm), respectively. Mean SOC in the whole soil was 62.5, 47.7 and 81.3 g kg^{-1} in hedgerow, shelterbelt and silvopasture systems, respectively. Soil C in the more stable fine fraction was 34.3, 28.8 and 29.3 g kg^{-1} in the hedgerow, shelterbelt and silvopasture systems, respectively. Within each agroforestry system, the forested land-use consistently had greater total SOC and SOC in all size fractions than the agricultural component. [The authors'] results demonstrate the potential for trees to increase soil C [storage] in agroforestry systems within the agricultural landscape." **Mark Baah-Acheamfour, Cameron N. Carlyle. Edward W. Bork, Scott X. Chang,** *Forest Ecology and Management*. (Subscription may be required.)

Trading

"Auction Notice for CO_2 Allowance Auction 25 on September 3, 2014."

The states participating in the Regional Greenhouse Gas Initiative (RGGI) 2014 auctions have released the Auction Notice and application materials for their 25th quarterly CO_2 allowance auction, to be held on September 3, 2014. The Auction Notice for CO_2 Allowance Auction 25 provides potential participants with the information needed to submit a Qualification Application and indicate their intent to bid. To view the Auction Notice and bidder application materials, visit the RGGI website. From *RGGI News Release* on July 7, 2014.

"International carbon emissions trading and strategic incentives to subsidize green energy."

The following is the Abstract of this article: "[The authors] examine strategic incentives to subsidize green energy in a group of countries that operates an international carbon emissions trading scheme. In [the authors'] model, green subsidies of either sign on top of emissions cap regulation reduce the welfare of the group of countries, but this may not hold for individual countries. The cases of small and large countries turn out to exhibit significant differences. While small countries refrain from subsidizing green energy and thus implement the efficient allocation, large permit-importing countries may subsidize green energy in order to influence the permit price in their favor." **Thomas Eichner and Rüdiger Pethig**, *Resource and Energy Economics*. (Subscription may be required.)

Recent Publications

"CO_2-EOR Offshore Resource Assessment."

The following is a summary of this NETL-published document: "The Gulf of Mexico accounts for about 20 percent of total domestic crude oil production. Since reaching a peak of 1.54 million barrels a day in 2003, Gulf of Mexico's (GOM) outer continental shelf (OCS) oil production has declined to 1.23 MMB/D, as of mid-2013. While there is optimism that new discoveries in the deep and ultra-deep waters of the GOM OCS will reverse this decline, another option seems to offer even more promise -- the application of [CO_2-EOR]."

Recent Publications (Continued)

"Near-Term Projections of CO_2 Utilization for Enhanced Oil Recovery."

The following is a summary of this NETL-published document: "In 2013 a total of 113 CO_2-EOR projects inject 3.1 billion cubic feet per day (Bcfd) (60 million metric tons (MMmt) per year) of CO_2 for [EOR] in the United States. The associated crude oil production in 2012 was 282,000 barrels per day. Based on the increased volumes of CO_2 supplies, the completion of major CO_2 pipelines, and the announced new, large-scale CO_2-EOR floods, production of crude oil from CO_2-EOR floods is forecast to grow significantly, reaching 615,000 barrels per day from at least 124 active CO_2 floods by year 2020. While the Permian Basin remains the largest CO_2-EOR oil producer, much of the growth occurs in the Gulf Coast, the Rockies, and the Mid-Continent."

"Subsurface Sources of CO_2 in the Contiguous United States. Volume 1: Discovered Reservoirs."

The following is a summary of this NETL-published document: "Twenty-one CO_2 fields in the contiguous states contain an estimated 311 Tcf of CO_2 gas-initially-in-place (GIIP). Of that, 168 Tcf (54 percent) is estimated to be accessible and technically recoverable. The estimated economically recoverable resource (ERR) is 96.4 Tcf, based on a CO_2 price of 1.06 $/mcf ($20/tonne) at the field gate. Cumulative production to date is 18.9 Tcf, leaving 77.5 Tcf remaining or net ERR. The Big Piney-LaBarge field in Wyoming contains an estimated net ERR of 52 Tcf, 67 percent of the total for the United States. The remaining ERR in reservoirs that feed into the Permian Basin and Gulf Coast is on the order of 10 to 20 years of supply."

"Subsurface Sources of CO_2 in the United States. Volume II: Exploration of CO_2 Systems."

The following is a summary of this NETL-published document: "A study of the genesis and tectonic setting of subsurface CO_2 systems in the United States indicates that undiscovered CO_2 reservoirs could contribute materially to CO_2 supply for [EOR]. Five geographic areas are estimated to contain 42 Tcf of risked technically recoverable CO_2 resource (TRR). Two lead areas near the Permian Basin, Val Verde and San Juan, contain 34 Tcf CO_2 risked TRR, an amount roughly equivalent to the remaining TRR in discovered reservoirs that are currently supplying the region. The number of lead areas studied was limited and the aggregate TRR estimates are not comprehensive."

"Targeted Report: Financing Large Scale Integrated CCS Demonstration Projects."

The following is from the Introduction of this document: "It is clear that the Global Financial Crisis (GFC) and knock-on effects on the financial markets have created a difficult environment for the financing of large-scale infrastructure projects. Whilst financing is still available and conditions are improving, financial institutions have become increasingly focused on the technical, economic and commercial fundamentals of the projects being financed. Against this background, there are now a number of CCS projects around the world moving towards the execution phase and likely to be seeking external financing as a key part of their funding plan. The financing challenge facing these projects not only relates to the challenges of the financial markets, but is compounded, in many cases, by the 'first of a kind' nature of the early CCS development projects and associated non-standard risks (technology/scale up/integration) of the industry. CCS investors and authorities, therefore, need to be very [cognizant] of the requirements of the financial institutions (in the broadest sense) whilst structuring the regulatory and commercial terms of the early projects in order to be able to access the debt required to finance the projects under development, and the industry as a whole in the longer term… this report looks at among other things: [1] The perception of CCS in the financial community; [2] Structuring considerations to [optimize] the availability of finance; [3] The potential roles and requirements of various financing sources, including commercial banks, Export Credit Agencies, Public Finance Institutions and 'green banks'; [4] Likely appetite and capacity of identified financing sources now and in the future; and [5] The impact of funding source on debt terms including structure, tenor, covenants and pricing. [The authors] conclude by using three projects currently in development to illustrate, based on publically available information, how the findings of the work for this report could impact on the financing for the early CCS projects."

Legislative Activity

"Missouri Governor Signs Bill on Carbon Emissions."

The Governor of Missouri signed legislation that directs Missouri regulators to develop standards for CO_2 emissions from power plants. The bill follows the U.S. Environmental Protection Agency's (EPA) proposed rules, which would require Missouri to cut CO_2 emissions from power plants by more than 20 percent by 2030. Missouri legislators had passed the measure before the EPA-proposed regulations were released. The bill is available via the Missouri House of Representatives website. From *SF Gate* on July 7, 2014.

"The cost of carbon dioxide abatement from state renewable portfolio standards."

The following is the Abstract of this article: "Renewable portfolio standards (RPSs) have become a popular tool for state governments to promote renewable electricity generation and to decrease [CO_2] emissions within a state or region. Renewable portfolio standards are a policy tool likely to persist for many decades due to the long term goals of many state RPSs and the likely creation of a federal RPS alongside any comprehensive climate change bill. Even though RPSs have become a

Legislative Activity (Continued)

popular policy tool, there is little empirical evidence about their costs. Using the temporal and regional variation in RPS requirements, [the author estimates] the long-run price elasticity of supply of renewable electricity generation to be 2.67 (95% CI of 1.74, 3.60). Using [the author's] preferred elasticity estimate, [the author calculates] the marginal cost of abatement from RPSs is at least $11 per ton of CO_2 compared to a marginal cost of abatement of $3 per ton in the Regional Greenhouse Gas Initiative." **Erik Paul Johnson**, *Resource and Energy Economics*. (Subscription may be required.)

"Carbon strategies and management practices in an uncertain carbonomic environment – lessons learned from the coal-face."

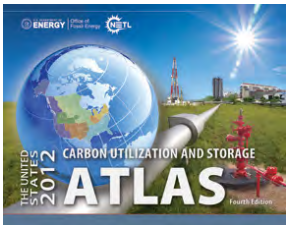
The following is the Abstract of this article: "For many businesses, carbon strategies are undertaken within a backdrop of an uncertain national carbon policy. Such was the case in Australia with the major political parties having radically different policies as to tackle the issue of climate change. However, despite such uncertainty, forward-thinking early movers have incorporated carbon awareness into their business decisions. This research investigates the carbon strategies and carbon management practices that were adopted by two firms operating at different levels of the Australian national energy market – one operates in energy transmission and distribution, and the other is an energy generator and retailer. The metaphor of 'the coal-face' is used to analogize the business practitioners from the studied firms who understand and are directly involved in day-to-day practices to handle carbon emissions issues in their organizations. The research findings highlight that while operating in the same industry, the firms employ different carbon strategies and carbon management practices to manage their compliance liabilities. Applying the lens of contingent resource-based view, the factors that explain their different carbon practices include the extent of carbon exposures, the sector-specific regulatory setting and the in-house capabilities to deal with carbon issues. In addition, this study synthesizes a general template of corporate carbon management framework, based on the real practices of studied firms, to provide practical guidelines for effectively developing carbon management strategies in an uncertain environment." **Dina Wahyuni and Janek Ratnatungab**, *Journal of Cleaner Production*. (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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