NETL the ENERGY lab

Carbon Storage Newsletter

OFFICE OF FOSSIL ENERGY

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HIGHLIGHTS

"Breakthrough Large-Scale Industrial Project Begins Carbon Capture and Utilization."


Port Arthur 2 plant

A carbon capture, utilization, and storage (CCUS) project at Air Products and Chemicals hydrogen production facility in Port Arthur, Texas, has begun capturing carbon dioxide (CO_2) and piping it to an oilfield for use in enhanced oil recovery (EOR). The project demonstrates both the effectiveness and commercial viability of CCUS technology as an option in helping mitigate atmospheric CO_2 emissions. In the project, CO_2 normally released to the atmosphere is separated from the gas stream of one of Air Products' steam methane reformers using "vacuum swing adsorption." The CO_2 is then delivered through a pipeline to Denbury Onshore's West Hastings, Texas, oilfield for EOR operations. A monitoring, verification, and accounting (MVA) program will ensure that the injected CO_2 remains safely underground. The project is expected to capture approximately 1 million metric tons of CO_2 per year that would otherwise be released in the atmosphere, as well as recover 1.6 to 3.1 million additional barrels of domestic oil annually. This event also marks a milestone in the U.S. Department of Energy's (DOE) Industrial Carbon Capture and Storage (ICCS) Program by progressing beyond research and development (R&D) to a demonstration scale that can be replicated and deployed within the industry. The ICCS Program's goals are to mitigate potential climate change through CCUS, create jobs, and position the United States as a world leader in carbon capture technologies. The project is funded in part through the American Recovery and Reinvestment Act (ARRA) and managed by the DOE Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL). From *NETL News Release* on January 25, 2013.

"New Set of Computational Tools and Models Expected to Help Enable Rapid Development and Deployment of Carbon Capture Technologies."

A new suite of 21 computational tools and models to help enable development and deployment of carbon capture technologies has been developed and made available by the Carbon Capture Simulation Initiative (CCSI), a public-private partnership led by NETL. The toolset, which aims to take carbon capture concepts from the laboratory to the power plant more quickly, at lower cost, and with reduced risk, is expected to make it easier for U.S. utilities to meet carbon capture requirements if/when they are enacted. In addition, the tools can also help technology companies doing business in countries where controls are already in place. The toolset includes tools to help identify promising concepts more quickly, reduce the time to design and troubleshoot new systems, and quantify the uncertainty of model predictions. It also includes tools with new capabilities, such as creating reduced-order models from reacting multi-phase flow simulations, and concurrently running thousands of process simulations for optimization and uncertainty quantification. From *NETL News Release* on January 28, 2013.

"DOE-Supported Project Advances Clean Coal, Carbon Capture Technology."

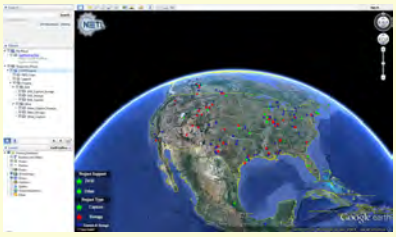
Ohio State University (OSU) researchers have successfully completed more than 200 hours of continuous operation of their patented Coal-Direct Chemical Looping (CDCL) technology, which is a one-step process to produce both

Highlights (Continued)

electric power and high-purity CO_2. The test was conducted at OSU's 25-kilowatt thermal (kWth) CDLC combustion sub-pilot unit under the auspices of DOE's NETL-managed Carbon Capture Program. According to OSU researchers, the CDCL plant's 200-plus hours of operation shows the robustness of its novel moving-bed design and non-mechanical valve operation. The combination resulted in nearly 100 percent solid fuel conversion and a CO_2 stream more than 99 percent pure, making it attractive to CO2-EOR operations. From *NETL News Release* on January 29, 2013.

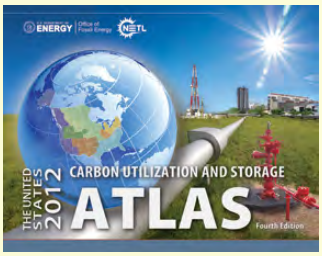
Announcements

NETL's Carbon Capture, Utilization, and Storage Database – Version 4.



NETL has released the fourth version of the CCUS Database, which includes active, proposed, canceled, and terminated CCUS projects worldwide. Information in the database regarding technologies being developed for capture, evaluation of sites for CO_2 storage, estimation of project costs, and anticipated dates of completion is sourced from publically available information. The CCUS Database provides the public with information regarding efforts by various industries, public groups, and governments towards development and eventual deployment of CCUS technology. As of November 2012, the database contained 268 CCUS projects worldwide. The 268 projects include 68 capture, 61 storage, and 139 for capture and storage in more than 30 countries across 6 continents. While most of the projects are still in the planning and development stage, or have recently been proposed, 37 are actively capturing and injecting CO_2. Users can download the CCUS database as a Google Earth layer or download a copy in Microsoft Excel file format.

DOE Releases Carbon Utilization and Storage Atlas.



DOE's 2012 United States Carbon Utilization and Storage Atlas (Atlas IV) states that the United States has at least 2,400 billion metric tons of potential CO_2 storage resource in saline formations, oil and gas reservoirs, and unmineable coal. Atlas IV was created by FE's NETL with input from DOE's seven Regional Carbon Sequestration Partnerships (RCSPs) and ARRA-funded site characterization projects. Click here to access the NATCARB Viewer.

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).

RGGI States Initiate Bidding Process for Auction 19.

The states participating in the Regional Greenhouse Gas Initiative (RGGI) released the Auction Notice and application materials for their 19th quarterly CO_2 allowance auction scheduled for March 13, 2013. The Auction Notice for CO_2 Allowance Auction 19 provides potential auction participants with the information needed to submit a Qualification Application and indicate their intent to bid in Auction 19. The states will offer 37,835,405 CO_2 allowances for sale with a reserve price of $1.98 for the March auction.

Carbon Storage in the News

"CCS Projects Financed Through Government [Program]."

Costain, a UK engineering solutions provider, has secured financing from the UK Department of Environment and Climate Change (DECC) through a [~$26] million program for finding solutions to reduce the cost of CCS. Costain will collaborate with UK universities to develop two innovative technologies that aim to reduce the cost of low-carbon electricity generation through reducing costs associated with carbon capture. With the funding, Costain will: (1) investigate a concept for the design and construction of absorber columns for post-combustion carbon capture in coal and gas power plants; and (2) develop an oxy-fuel capture technology to study CO_2 separation and compression technology. From *Costain News Release* on January 8, 2013.

"RWE Starts Carbon Capture at UK Coal Plant" and **"First [Metric Ton] of CO_2 Captured at RWE npower Pilot Project."**

The first metric ton of CO_2 has been captured at RWE npower's carbon capture pilot plant at Aberthaw Power Station in Wales, UK. When commissioning with live flue gas is complete, the plant will capture approximately 50 metric tons of CO_2 per day (or the amount of CO_2 produced by 3 megawatts [MW] of electricity generation). RWE will optimize the performance of the technology during the R&D program, using the facility to gather a better understanding of the implications of operating a full-scale carbon capture facility in conjunction with

Carbon Storage in the News (Continued)

normal power plant operations. In addition, RWE will work with the UK's Environment Agency to track the impact of the carbon capture process on the power plant's surroundings. From *Reuters* on January 17, 2013, and *Carbon Capture Journal* on January 20, 2013.

"CO_2 Solutions Receives $4.7 Million from the Harper Government for Oil Sands Carbon Capture Project."

The Harper Government has made a $4.7 million investment to support the development of CO_2 Solutions' carbon capture technology in the Alberta oil sands. CO_2 Solutions is developing enzyme-enabled carbon capture technology for use in oil sands production, including in-situ methods such as Steam-Assisted Gravity Drainage (SAGD), and bitumen upgrading. Project results will also support the company's technology in other natural gas combustion sources, such as gas-fired power plants. CO_2 Solutions' management anticipates the project to cost $7.5 million; additional funds are being obtained through grants from other organizations. From *Canada Newswire* on January 24, 2013.

"[Technology Centre Mongstad] Launches International Test Centre Network."

CO_2 Technology Centre Mongstad (TCM) has formed an international test center network for carbon capture test facilities around the world to share knowledge of technological developments, construction and operational experience, establish performance indicators, and promote technology standardization. The aim of the network is to reduce costs and investigate the technical, environmental, and financial risks associated with CCS. The eight founding members of the Test Centre Network are TCM (Norway), National Carbon Capture Center (Alabama, USA), Southern Company's 25-MW CCS demonstration facility (Alabama, USA), SaskPower, J-Power (Japan), ENEL Engineering and Research (IT), E.ON (Germany), and Doosan Power Systems (UK). TCM is comprised of two CO_2 capture plants, each with a capacity to capture approximately 80,000 tons of CO_2 from a nearby refinery or 20,000 tons from a gas-fired power plant. From *CO_2 Technology Centre Mongstad Press Release* on January 31, 2013.

Science

"Earliest Blooms Recorded in [United States] Due to Global Warming."

According to a new study, plants in the eastern United States produced flowers earlier in 2010 and 2012 than at any point in recorded history. The study, published in the journal "PLoS ONE," compared modern record-breaking high spring temperatures in Massachusetts and Wisconsin during 2010 and 2012 with historical bloom times in the same areas from as far back as 1852. The data showed that many spring-flowering plants were triggered by the two recent warm spells to blossom up to 4.1 days earlier for every one degree Celsius rise in average spring temperatures (2.3 days for every one degree Fahrenheit). From *National Geographic News* on January 16, 2013.

"Climate Change to Profoundly Affect the Midwest, New Report Says."

A recently released draft National Climate Assessment report claims that potential climate change may lead to more frequent and more intense heat waves throughout the Midwest. In addition, the draft report, the development of which was overseen by the National Climate Assessment and Development Advisory Committee (NCADAC), also claims that air and water quality could degrade and intense rainstorms and floods could become more common. The draft report assesses key impacts in every region of the United States, analyzing its effects on human health, water, energy, transportation, agriculture, forests, ecosystems, and biodiversity. The draft report is available for download on the NCADAC website; public comments are being accepted through April 12, 2013. From *University of Michigan News Release* on January 18, 2013.

"Wolverines Threatened By Climate Change, Officials Propose Endangered Species Act Protection" and **Climate Change Threatens Wolverines; Protections Proposed**

Federal wildlife officials have proposed Endangered Species Act protections for the wolverine throughout the contiguous United States. There are approximately 250 to 300 wolverines clustered in small, isolated groups located primarily in the Northern Rockies of Montana, Idaho, Wyoming, and Washington; larger populations exist in Alaska and Canada. According to scientists, potential warmer temperatures could lead to declines in the deep-mountain snows that female wolverine require to establish dens and raise their young. According to the U.S. Fish and Wildlife service, potential climate change, which would cause earlier spring melt, could also reduce the wolverine habitat in the contiguous United States by 31 percent over the next 30 years and 63 percent over the next 75 years. The proposed protections would eliminate wolverine trapping, which is still legal in Montana, and could allow reintroduction of the species to alpine regions where it is not currently found. From *The Huffington Post* on February 1, 2013, and *Los Angeles Times* on February 1, 2013.

Policy

"DNV KEMA Launches New Risk Management Guidance for the CCS Industry."

DNV has released new risk management guidance as a comprehensive resource for CCS projects and operations across the world. The guidance results from the CO_2 Risk Management (CO2RISKMAN) Joint Industry Project (JIP), whose goal was to develop a publicly available guidance on risk management of the CO_2 stream within CSS projects. According to DNV, the CO2RISKMAN guidance systematically presents and explains issues associated with CO_2 that need to be considered within a hazard management process. The guidance discusses potential safety and environmental hazards, their causes, escalation routes, and possible consequences. The guidance also provides assistance on hazard identification, risk assessment, and what can be done to reduce the risks down to an acceptable

Policy (Continued)

level during each stage of the CCS chain. The CO2RISKMAN JIP guidance complements DNV's other JIPs: CO2CAPTURE, CO2PIPETRANS, CO2WELLS, and CO2QUALSTORE; all are available for free download via the DNV website. The guidance was developed over the course of 15 months through a JIP with support from 16 industry and regulator organizations. From *DNV Press Release* on January 31, 2013.

"Brussels Steers Towards 'Resolute' New CCS Targets by 2014."

According to draft European Union (EU) communications, Europe's plans to encourage CO_2 storage could be supported by new laws for emissions performance standards or mandatory CCS certificates. If approved, the Commission would be required to prepare an impact assessment and legislative proposals "before the end of the current mandate," in 2014, so that CCS could be deployed after 2020. The performance standards mentioned in the communications could set mandatory and potentially tradable limits to emissions from energy firms. In addition, the draft communications also covered a mandatory CCS system that would align with the current Emissions Trading System (ETS). From *EurActiv.com* on January 15, 2013.

"Rep. Waxman and Sen. Whitehouse Form Bicameral Climate Change Task Force."

A bicameral Task Force on Climate Change has been formed to address potential climate change. The Task Force will be dedicated to focusing Congressional and public attention on potential climate change and developing effective policy responses. The Task Force will be open to all members of Congress interested in collaborating on these issues. Meetings will be convened in the coming months to seek relevant information and to release periodic reports, memoranda, and correspondence to advance the group's goal of increasing awareness and developing policy responses to potential climate change. From *U.S. Representative Henry A. Waxman Press Release* on January 24, 2013.

"U.S. DOE's Efforts to Promote Knowledge Sharing Opportunities from R&D Efforts: Development of the U.S. Carbon Utilization and Storage Atlas and Best Practices Manuals."

The following is the Abstract of this article: "Knowledge sharing among various stakeholders is essential to promote the commercialization of CCUS technologies. DOE promotes information and knowledge sharing through various avenues, including the development and distribution of Best Practices Manuals (BPMs), the development of online tools and resources, involvement in working groups on CCUS, and other public outreach and education efforts. One of NETL's main initiatives to promote information and knowledge sharing is the development of a series of BPMs that outline uniform approaches to address a variety of CCUS-related issues and challenges. A major online resource developed by DOE is the National Carbon Sequestration Database and Geographic Information System (NATCARB), which is a geographic information system (GIS)-based tool developed to provide an interactive visual representation of CCUS potential. The series of past and future carbon storage Atlases featuring the RCSPs, such as the to be released 'United States Carbon Utilization and Storage Atlas,' complements NATCARB, and contains additional information regarding commercialization opportunities for CCUS technologies from each of DOE's RCSPs. Building on past successes, NETL is expanding the NATCARB effort through the North American Carbon Atlas Partnership (NACAP) to better assess CCUS potential throughout all of North America. NETL has been actively disseminating knowledge and developing the future required workforce through training centers that are focused on training personnel for future implementation of CCUS technology." **John Litynski, Andrea McNemar, Traci Rodosta, Dawn Deel, Derek Vikara, Larry Myer, and Robert Kane**, presented at the 11th Greenhouse Gas Control Technologies Conference (GHGT-11), held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"U.S. DOE's R&D Program to Develop Infrastructure for Carbon Storage: Overview of the Regional Carbon Sequestration Partnerships and other R&D Field Projects."

The following is the Abstract of this article: "The Carbon Storage Program being implemented by [DOE's FE] and managed by NETL is focused on developing technologies to capture, separate, and store CO2 in order to reduce greenhouse gas [(GHG)] emissions without adversely affecting energy use or hindering economic growth. NETL envisions having a technology portfolio of safe, cost-effective, [GHG] capture, transport, and storage technologies that will be available for commercial deployment. The Carbon Storage Program involves three key technology development elements: (1) Core R&D, (2) Infrastructure, and (3) Global Collaborations. The integration of these elements is addressing technological and marketplace challenges…DOE's Carbon Storage Program has positioned the United States on a path toward ensuring that these enabling technologies will be available to effect broad CCUS deployment. NETL is helping to promote widespread CCUS deployment through the Carbon Storage Program's Infrastructure element, which to date has: (1) safely and efficiently injected and stored close to more than 3 million metric tons of CO_2 across 22 active or completed field projects; (2) generated lessons learned from those field projects and documented them in best-practices manuals; (3) refined national CO_2 storage assessments through characterization field projects; and (4) trained nearly 3,000 students through the Regional Carbon Sequestration Training Centers." **John Litynski, Traci Rodosta, Derek Vikara, and Rameshwar Srivastava**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

Geology

"ULTimateCO_2 project: Field experiment in an underground rock laboratory to study the well integrity in the context of CO_2 geological storage."

The following is the Abstract of this article: "Wells drilled through low-permeable caprock are potential connections between the CO_2 storage reservoir and overlying sensitive targets like [formations] and targets located at the surface. The wellbore integrity can be compromised dueto in situ operations, including drilling, completion, operations and abandonment or to geochemical degradation of the caprock-cement-

Geology (Continued)

casing system. [The authors] present here an experimental set-up in the underground rock laboratory of Mont-Terri (St Ursanne, canton of Jura, Switzerland): the drilling and well completion in the laboratory will be done in the aim of reconstructing interfaces between the caprock, the cement and the casing steel that would be close to the ones observed in situ. These well features will then be dipped within a CO_2 stream, during a given time period before a final over-coring. Such an experiment should provide new insights on the quality of bounding between casing/cement/clay interfaces and its evolution due to geochemical reactions. In parallel, a modeling effort is performed focused on both geochemical and transport aspects of the interactions between the fluids and the well compartments." **JC. Manceau, P. Audigane, F. Claret, M. Parmentier, T.J. Tambach, L. Wasch, F. Gherardi, A. Dimier, O. Ukelis, E. Jeandel, F. Cladt, R. Zorn, T. Yalamas, C. Nussbaum, A. Laurent, T. Fierz, and M. Piedevache**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"Tracing back the pressure-impact zone of the CO_2 geological storage through a cyclic injection strategy."

The following is the Abstract of this article: "Industrial-scale CO_2 injection into deep [formations] might induce far-field pressure perturbations on the basin scale, potentially impacting other underground uses present within the [same formation]. In the present paper, [the authors] investigate an approach to trace back the area of elevated pressure induced by CO_2 storage operations through an injection strategy in a cyclic manner over time. In this manner, the CO_2 injection-induced pressure field is characterized by a low magnitude harmonic signature very specific to the considered CO_2 storage, the frequency being chosen as different to naturally fluctuating phenomena or other anthropogenic underground activities. [The authors] rely on the combination of de-trending and FFT technique to detect the harmonic pattern associated the CO_2 storage injections. [The authors] apply the methodology on synthetic pressure signal numerically generated using a typical injection scenario in the Paris basin case. On this basis, [the authors] discuss how trace back the CO_2 storage site causing the pressure impact, in particular regarding the existing sources of noise." **Jeremy Rohmer and Jean-Charles Manceau**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"Natural mitigation of CO_2 [release] accumulations."

The following is the Abstract of this article: "This study aims at investigating the role played by the overlying formation as a safety barrier in case of CO_2 [release] accumulation (i.e. CO_2 accumulated in an overlying [formation] after its [release] from the CO_2 storage reservoir) by focusing on its natural capacity to prevent any further upward migration. Based on numerical simulations performed using TOUGH2/ECO2N incl. hysteretic module, [the authors] assess the processes influencing the quantity of mobile CO_2 within the [releasing] plume and perform a sensitivity analysis to point out the key-parameters and conditions for an efficient natural trapping by dissolution and residual trapping. Additional simulations of a [release] – active remediation scenario on a complete system (storing reservoir connected to an overlying [formation]) show the importance of the natural trapping capacity of the overlying [formation]. This capacity could be integrated in the mitigation strategy, associating natural and engineered safety barriers. Gaining more knowledge on these formations can support first estimations of this natural capacity, and hence can help building the corrective measure plan and designing potential interventions during operations." **Jean-Charles Manceau, Jérémy Rohmer, Arnaud Réveillère**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"Geochemical effects of storing CO_2 in the Basal Aquifer that underlies the Prairie Region in Canada."

The following is the Abstract of this article: "In the area underlain by the Basal [Formation] in the Prairie region of Canada, there are 20 large CO_2 sources (coal-fired power plants, oil sands and heavy oil production and upgraders, refineries, chemical and petrochemical plants, fertilizer plants and cement plants) that emit more than 1 Mt CO_2/year each, for a total of 83 Mt CO_2/year, which represents 12 [percent] of Canada's annual [GHG] emissions. If post-combustion capture technologies are used, 75 Gt CO_2/year can be captured from these sources, with a composition ([percent] mass) estimated to be 99.95 [percent] CO_2, 0.02 [percent] N_2/Ar/O_2, and 0.03 [percent] H_2O. The Basal [Formation] comprises Middle Cambrian sandstones that overlie the crystalline Precambrian basement in the Alberta basin and the Canadian part of the Williston basin. Shales constitute the primary caprock of the Basal [Formation]. Pressures in the [formation] generally follow a gradient of 10.8 kPa/m. Temperatures in the [formation] vary between >150°C in the deepest part of the Alberta Basin to less than 10°C in outcrop areas. Water salinity ranges from > 300,000 mg/L in central Alberta to < 10,000 mg/L in the southwest and in the east. The formation water in the [formation] region suitable for CO_2 storage is NaCl dominated. Generally, at in-situ conditions, these waters are saturated with $CaSO_4$ (anhydrite), with some at NaCl (halite) saturation. The mineralogy of the [formation] rocks and caprock were determined using a suite of laboratory analyses and normative calculations on core samples. The dominant mineral in the Basal formation in regions suitable for CO_2 storage is quartz, which is generally present in the 65 [percent] to 95 [percent] range, while potassium feldspar is the next most common silicate. Pyrite is present in trace amounts in many of the samples. Calcite and illite, when present, are primarily pore-filling minerals. Calcium sulphate (anhydrite) is present in many of the samples, and, when present, is a pore-filling phase. In regard to the caprock, quartz is still a predominant mineral phase, comprising of at least one third of the rock for all samples. Potassium feldspar, illite and kaolinite are the next most common minerals. The ability of the rocks of the Basal [Formation] to react with CO_2 is limited, with potassium feldspar and complex clays providing the bulk the reactive capacity via the formation of kaolinite, or potentially a coupled reaction forming alunite and calcite in anhydrite-bearing zones. The effect of these reactions on CO_2 storage capacity, [formation] porosity and permeability is limited, allowing decoupling of flow from geochemical processes. Caprock reactivity towards CO_2 is much greater due to its more complex mineralogy, however they will not propagate far into the caprock due to its low permeability, thus allowing decoupling of flow and geochemical processes." **Stephen Talman, Ernie Perkins, Andrew Wigston, David Ryan, and Stefan Bachu** presented at GHGT-11, held at the Kyoto

Geology (Continued)

International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

Technology

"Development of CO_2 terminal and CO_2 carrier for future commercialized CCS market."

The following is the Abstract of this article: "So far CO_2 shipping has only been introduced as a secondary option for long distances and small amounts because of the prevailing idea that CO_2 shipping is more expensive than CO_2 pipeline for transporting large amount CO_2. This paper shows that CO_2 terminal and large CO_2 carrier can play a role of collecting CO_2 from several sources and transporting CO_2 in large volume so transport cost per tonnage of CO_2 can be reduce in commercialized CCS market. Multi-stage CO_2 liquefaction processes are developed to reduce total cost of CO_2 compression and transport. For high pressure CO_2 inlet stream, newly developed multi-stage liquefaction process with serial flash tanks enables power consumption reduced to 44 [percent] compared to single stage liquefaction process. By adopting new design concept of very large CO_2 Carrier more than 40,000 m3, optimal size of CO_2 carrier can be provided for each voyage route and total cost of CO_2 compression and transport is reduced. The results of economic assessment of CO_2 transport show that CO_2 shipping is economically competitive to CO_2 pipeline even in the distance of 200–300 km for large amount of CO_2 transport such as 10 Mt CO_2/year or 20 Mt CO_2/year. [Carbon dioxide] transport by ship should be seriously re-considered as an effective transport method for commercialized CCS projects as well as early demonstration projects." **Byeong-Yong Yoo, Dong-Kyu Choi, Hyun-Jin Kim, Young-Sik Moon, Hee-Seung Na, and Sung-Geun Lee**, *International Journal of Greenhouse Gas Control*, (Subscription may be required to view article.)

"U.S. Department of Energy Efforts to Advance Remote Sensing Technologies for Monitoring Geologic Storage Operations."

The following is the Abstract of this article: "DOE is the lead [Federal] agency for the research, development, demonstration, and deployment (RDD&D) of carbon storage technologies. Monitoring, verification, accounting and assessment (MVA) is an essential element of geologic CO_2 storage projects, since without MVA it is not possible to understand the fate of CO_2 in the injection formation or to monitor any potential CO_2 releases to underground sources of drinking water (USDW) or the atmosphere. Determining the location of CO_2 in the subsurface and identifying indicators of the potential release of CO_2 to the atmosphere are significant challenges requiring the adoption of existing technologies as well as novel approaches for monitoring large areas above a storage reservoir. Remote sensing technologies could offer a solution. Remote sensing refers to the use of monitoring tools that can gather data at a location remote to the area of interest, and could provide an option for non-invasive and large scale spatial monitoring. NETL has been developing and deploying remote sensing applications over the past decade to improve monitoring of both geologic and terrestrial carbon storage projects. MVA remote sensing tools being developed or improved by NETL sponsored research include interferometric synthetic aperture radar (InSAR), tiltmeters/GPS, remote operated vehicles (ROVs), SEQURE™, light detection and ranging (LIDAR), and multi-spectral/hyper-spectral scanning. Benefits associated with NETL's remote sensing effort include development and deployment of non-intrusive tracking and monitoring technologies, reduced manpower requirements needed to meet potential regulated MVA requirements, and reduced costs to implement monitoring technologies. These technologies can provide early detection of CO_2 releases which, in turn, will allow for further refinement of project monitoring protocols using more conventional detection and mitigation technologies to better pinpoint CO_2 location. This paper addresses selected remote sensing techniques under NETL development and field deployment of these Technologies." **John Litynski, Derek Vikara, Malcolm Webster, and Rameshwar Srivastava**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"The Synergistic Pursuit of Advances in MMV Technologies for CO_2-Enhanced Recovery and CO_2 Storage."

The following is the Abstract of this article: "The importance of using a full suite of reservoir diagnostic and feedback systems [monitoring, verification, and accounting (MMV)] for CO_2-EOR and CO_2 storage was first learned at the classic CO_2 flood at SACROC in the Permian Basin of West Texas. With information gained from MMV leading to well remediation and changes in operating practices, the new operator of the SACROC CO_2 flood (Kinder-Morgan) converted a low performing, being terminated CO_2 flood producing 3,000 B/D into a CO_2 flood that currently provides 25,000 B/D. Since then, a significant number of companies have begun to incorporate sophisticated MMV technologies into management of [CO_2-EOR]. Comparable advances in MMV technologies for CO_2 storage are being supported by [DOE/NETL's] CCUS Regional Partnership Program. As a result, The DOE-funded research into technologies that 'see' CO_2 underground, developed for the purpose of ensuring CO_2 [storage] within the target formation, are gaining significant spill-over applications for optimizing [CO_2-EOR] operations." **Vello Kuuskraa, Phil Dipietro, and John Litynski**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

Terrestrial

"The Laboratory Simulation and Field Verification of Seasonal Soil-Respired CO_2 flux at a Proposed CCS Project Site."

The following is the Abstract of this article: "As part of any terrestrial CCS project, a risk-driven Measurement Monitoring and Verification (MMV) [(referred to as "Monitoring, Verification, and Accounting by DOE)] plan may include the measurement of soil gas and related surface CO_2 efflux in order to determine the natural (or baseline) concentration range and variation of CO_2. Subsequent measurements of these parameters may then act as a measure

TERRESTRIAL (CONTINUED)

of stored CO_2 containment and conformance during operational, closure and post-closure phases. There are several practical challenges involved in the collection of representative soil-respired CO_2 efflux measurements. These include (i) the assessment of natural baseline variations of soil-respired CO_2 efflux across potentially large areas expected for commercial CCS operations, (ii) even if field measurements of soil-respired CO_2 are recorded over one season or several seasonal cycles, the full concentration and CO_2 flux range may not be captured due to reliance upon environmental (i.e. climate) conditions prevalent during field surveys, and (iii) when field based soil CO_2 flux measurements are taken, climatic and environmental conditions are likely to change throughout the day, resulting in a number of dislocated flux measurements taken under different conditions. Ideally, it would be useful to be able to carry out an initial field survey measurements, collect soil samples at a project site and develop a simulated baseline in the laboratory under controlled conditions, reducing the seasonal baseline survey duration from one or two years down to several weeks of simulation supported by field verification. Soil cores and bulk material from each soil horizon at selected locations were sampled from the previously proposed Heartland Area Redwater Project (HARP) near Edmonton, Alberta. Soil columns were reconstituted in the laboratory and subjected to a range of temperature and moisture conditions similar to those expected for the CCS project area over a seasonal cycle. Efflux data were directly compared to field-based measurements collected over a [12-month] period under a range of climatic conditions. Comparisons between laboratory simulations and field data suggest a strong temperature-efflux correlation consistent with many studies related to the carbon cycle and ecosystem productivity. It is suggested that the simulation of environmental conditions using soils from a CCS area of review may be a useful tool for the prediction of the range of CO_2 efflux expected as a function of soil characteristics and environmental conditions, thereby accelerating baseline studies, establishing the range of CO_2 efflux to guide monitoring strategies and for the facilitation and validation of remote sensing data in support of large scale CCS site characterization." **James Brydie, Bob Faught, Mark Olson, Andrew Underwood, and Bonnie Drozdowski**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

TRADING

"Georgia's Largest Power Plant to Trade Carbon Credits."

Enguri Hydro Power Plant, Georgia's largest power plant, will sell carbon credits earned from a European Bank for Reconstruction and Development (EBRD)-financed energy efficiency project. The $70 million investment was used to upgrade and increase the plant's operational capacity. The project has now been registered under the Kyoto Protocols' Clean Development Mechanism (CDM) and is estimated to generate more than 5.8 million carbon credits over the 10-year crediting period. These credits can now be sold on global carbon markets to businesses and governments that are close to exceeding their GHG emission quotas. The Enguri Hydro Power Plant is located on the Enguri River and provides a large portion of Georgia's domestic power supply. The rehabilitation of the Enguri Hydro Power Plant is the fourth CDM registered project located in Georgia. From *European Bank for Reconstruction and Development Press Release* on January 31, 2013.

"RGGI States Propose Lowering Regional CO_2 Emissions Cap 45 [Percent], Implementing a More Flexible Cost-Control Mechanism."

After a two-year program review, the states participating in RGGI released an updated RGGI Model Rule and Program Review Recommendations Summary. The Updated Model Rule will guide the RGGI states as they follow state-specific statutory and regulatory processes to propose updates to their CO_2 Budget Trading Programs. The comprehensive list of improvements made to the RGGI program is available via the hyperlink above. From *RGGI Press Release* on February 7, 2013.

"CCS in Carbon Markets."

The following is the Abstract of this article: "CCS technologies constitute an important component of the decarbonization efforts that are needed to keep the temperature increase to below [2°C]. According to the IEA estimates, CCS could contribute one-fifth of the total energy sector emission reductions globally through 2050. Analysis by the IEA and other institutions show that both short and long-term policy interventions are needed to provide sufficient incentives to the private sector to invest in CCS. However, it is understood that eventually technology neutral policy instruments, such as carbon price, would be able to provide sufficient incentives for CCS to be selected as a GHG emission mitigation option. Currently there are two main types of mechanisms to price carbon emissions: CO_2 taxes and GHG emission trading schemes. Both are aimed at reducing CO_2 emissions by making the cost of emitting prohibitive. Carbon taxes set a fixed price on carbon; thus under a tax, the carbon price is certain while the ultimate level of emission reductions remains uncertain. Emission trading schemes inversely set caps on emissions, but carbon price fluctuates depending on availability of emission reduction options and their costs. Emission trading schemes imply certainty of achieved emission reductions (unless they are based on intensity-based caps, in this case relative emission reductions are known but not absolute levels) but leave carbon prices uncertain. While experience shows that carbon taxes can drive CCS, given the availability of other favorable conditions at the same time, emission trading schemes so far have not been successful with facilitating CCS development, largely due to the low level of CO_2 prices. A further relevant issue is the emergence of international carbon market mechanisms under the [United Nations Framework Convention on Climate Change (UNFCCC)] process. While some of these carbon market mechanisms may help CCS, they all have particular challenges to overcome. It is likely that technology-specific support policies will be needed for CCS in short to mid-term, before carbon pricing mechanisms, although at much higher levels than currently observed, can alone drive CCS technologies into the market." **Ellina Levina and Juho Lipponen**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

"Role of CCS in New International Climate Regime."

The following is from the Abstract of this article: "This paper examines the role of CCS in a new post-2012 international climate regime.

Trading (Continued)

Instead of the traditional 450ppm equilibrium stabilization of [the Intergovernmental Panel on Climate Change (IPCC)], a new scenario based on zero-emission and overshoot schemes was proposed recently. The scientific examinations demonstrated that the [so-called] Z650 scenario could avoid long-term risks while meeting [short-term] need of relatively large emissions. A numerical experiment of global energy system optimization shows the technical feasibility of the Z650 scenario not only globally but also regionally. The obtained time series total primary energy mixes suggest that the consumption of fossil energy will peak at 2030, and the clean energies, especially the renewable energy will play an essential role during the second half of the century. The resulted regional emission curves reflect the differences of financial and technical capability among areas. The industrialized countries will reduce their emissions by 50 [percent] in 2050 compared with 2005 levels, while the emissions of developing countries will increase by 10 [percent] at the same time. The cost-effective analysis based on the simulation results of the energy model shows that the Z650 scenario is economically rational. Compared with the reference case, the additional investments in Z650 scenario could be covered by the fuel savings during the following 40 years (2010-[2050]) both globally and regionally. However, the comparison between the projection results and the national initiatives of major countries indicates that the policy measurements should be considered to promote the low carbon technology deployment and transfer. For this purpose, the existing CDM system should be enhanced on one hand, and a simpler and more efficient international scheme should be developed on the other hand." **Fengjun Duan, Tetsuo Yuhara, Hiroshi Ujita, Kazuhiro Tsuzuki, and Toshikazu Shindou**, presented at GHGT-11, held at the Kyoto International Conference Center, Japan, November 18-22, 2012. (Subscription may be required to view article.)

Recent Publications

"Making the business case for CCS."

The following is the Introduction of this document: "A considerable number of companies and investors around the world have ambitions to create [large-scale] power plants with CCS. To do so on a sustainable model requires them to obtain a suitable return on their investment in order to accommodate the risks inherent in the technology. But CCS faces a key hurdle that, without sufficient intervention, is preventing development of CCS facilities and the emergence of a new industry. The cost of CCS facilities is not sufficiently covered by electricity sales revenue at current wholesale power prices anywhere in the world, nor is it covered by the ability to earn income from avoiding or reducing CO_2 emissions. CCS investors, therefore, need to carefully build a suitable business case sufficient to meet the fundamental challenge of the mismatch between costs and revenues. 2Co Energy Limited (2Co) has written this knowledge product to share its real-life CCS business case for its CCS project in the UK, the Don Valley Power Project (DVPP), with the members of the Global CCS Institute. By sharing its business case in this way, 2Co hopes to provide practical information that can be of use to members of the Institute as they develop their own business cases for CCS around the world. The report covers the following: [1] A brief overview of 2Co and its CCS project in the UK, DVPP. [2] A summary of existing business case-related knowledge products previously published for the Institute by other CCS projects, [summarizing] the factors of most importance to their business cases. [3] A description of the market and regulatory context for CCS faced by DVPP and other projects in the UK. [4] A discussion of the financing challenge that 2Co faces and the resulting financing strategy. [5] The resulting business plan, including revenue and cost profiles, sensitivities and prospects for future cost reduction. [6] A description of the key risks to the project and mitigation plans."

"Toward a common method of cost estimation for CO_2 capture and storage at fossil fuel power plants."

The following is the Abstract of this document: "There are significant differences in the methods employed by various organizations to estimate the cost of CCS systems for fossil fuel power plants. Such differences often are not readily apparent in publicly reported CCS cost estimates. As a consequence, there is a significant degree of misunderstanding, confusion, and misrepresentation of CCS cost information, especially among audiences not familiar with the details of CCS costing. Given the international importance of CCS as an option for climate change mitigation, efforts to improve and systematize the estimation and communication of CCS costs are especially urgent and timely. This paper recommends a path forward to achieve that goal."

"Developing a risk program for a carbon capture and storage project: A case study of Project Pioneer."

The following is a summary of this document: "CCS projects could be considered a special type of oil and gas capital project. The standard approach used for risk management of oil and gas capital projects is applicable to CCS projects. Also the uniqueness of CCS projects as well as the characteristics of a particular project should influence the design of the Risk Management System (RMS). Both general CCS challenges and features specific to Project Pioneer were taken into account when shaping the project risk management system that is described in this report."

Recent Publications (Continued)

"GETICA CCS Demo Project: Financial scenarios report."

The following is a summary of this document: "Given that electricity generation in Romania is primarily based on coal, implementing CCS would greatly reduce CO_2 emissions while keeping coal-fired power plants operational. This financial scenarios report describes the optimum solution to financing a large-scale CCS project in Romania. It considered the challenges of finding and securing financing sources for the project. The existing financing sources, at EU and national level, were [analyzed] in terms of financing structure of the project, project eligibility, origin of financing (public/private), availability of funding, availability in time, and degree of certainty. Three scenarios were created, based on the prospected funding sources for CCS projects. A qualitative assessment was performed and, based on this assessment, the optimum scenario was chosen for the GETICA CCS Demonstration project."

Legislative Activity

"[Wyoming] State Primacy on Greenhouse Gas Regulation."

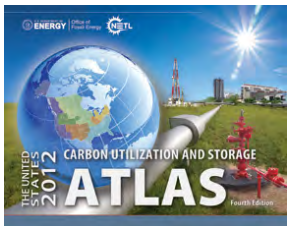
The Wyoming Senate Minerals Committee has approved House Bill 63. The bill proposes the transfer of regulatory authority for companies that release CO_2 and other GHGs from the U.S. Environmental Protection Agency (EPA) to the Wyoming Department of Environmental Quality. House Bill 36, which follows the repeal of a Wyoming state law last year that prohibited the regulation of GHGs, will advance to the Senate floor. From *Casper Star-Tribune Online* on February 1, 2013.

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. B ox 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

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

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