NETL the ENERGY lab

# Carbon Storage Newsletter

July 2013

## What's Inside?



# Highlights

**"MRCSP Begins Field Tests in Michigan"**

The Midwest Regional Carbon Sequestration Partnership (MRCSP), led by Battelle, announced the beginning of a large-scale carbon dioxide ($CO_2$) injection in Michigan's Northern Reef Trend. The project is designed to inject and monitor at least 1 million metric tons of $CO_2$ into a series of oil fields that are in different stages of their production life cycles. The first test in the series will inject up to 500,000 metric tons of $CO_2$ into an oil field that has undergone primary production and enhanced oil recovery (EOR) for several years and is now near the end of its productive life. During the last year, MRCSP has conducted baseline geologic characterization and advanced monitoring to prepare the wells for the injection phase. These fields are already permitted as part of the EOR operations. In this first leg of the field test, MRCSP expects injection rates of approximately 1,000 metric tons of $CO_2$ per day. MRCSP will be using state-of-the-art techniques to track the $CO_2$ and quantify the amount that is retained in the formation after the oil is removed. The $CO_2$ will be injected into the geologic structures known as the northern Niagaran pinnacle reef trend. These oil fields are located approximately 6,000 feet below the surface. This milestone builds on the work completed by MRCSP during earlier phases of the program, including small-scale testing and mapping of geologic formations across the region. MRCSP is one of seven Regional Carbon Sequestration Partnerships (RCSPs) established by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL). From *Battelle News Release* on July 9, 2013.

**"Research Without Borders: NETL Pens MOU with Brazilian Coal Association."**

On June 6, DOE's NETL and the Brazilian Coal Association (BCA) signed a Memorandum of Understanding (MOU) on carbon capture and storage (CCS) in Florianópolis, Brazil. Under the MOU, both parties will work together to assess the potential of CCS in fossil fuel-based systems over the next five years, as well as the development of clean coal technologies applicable to Brazilian coals. The MOU also covers the development of other technologies to reduce the environmental impact of fossil fuel production and use. The MOU follows an agreement signed by NETL and BCA in 2007, which resulted in scientific exchanges and several publications. From *NETL News Release* on July 18, 2013.

## Announcements

**CCS Browser: A Guide to CCS.**

The CCS Browser was created by the $CO_2$ Capture Project to help individuals learn more about CCS, including how the CCS process works, how $CO_2$ is securely stored, the techniques used to ensure safe CCS operations, and the differences that CCS can achieve.

# Announcements (Continued)

**President's Plan to Fight Climate Change.**

The White House announced a series of executive actions to reduce carbon emissions, prepare the United States for the impacts of climate change, and lead international efforts to address global climate change.

**RGGI States Initiate Bidding Process for Auction 21.**

The states participating in the Regional Greenhouse Gas Initiative's (RGGI) 2013 auctions released the Auction Notice and application materials for the 21st quarterly $CO_2$ allowance auction scheduled for September 4, 2013. The Auction Notice for $CO_2$ Allowance Auction 21 provides potential auction participants with the information needed to submit a Qualification Application and indicate intent to bid. The states will offer for sale 38,409,043 $CO_2$ allowances at a reserve price of $1.98.

**2013 Midwest Carbon Sequestration Science Conference.**

The Midwest Geological Sequestration Consortium (MGSC) annual Project Advisory Meeting is scheduled for October 7, 2013, at the I Hotel and Conference Center in Champaign, Illinois. This conference will include a full day of Illinois Basin Decatur Project (IBDP) research presentations covering the MGSC Phase III research activities. The conference will also include a Sequestration Training and Education Program (STEP)-sponsored workshop and an optional tour of the IBDP site.

**12th International Conference on Greenhouse Gas Control Technologies.**

GHGT-12 will be held on October 5-9, 2014, in Austin, Texas. 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 International Energy Agency Greenhouse Gas R&D Programme (IEAGHG).

# Carbon Storage in the News

**"Chaparral Energy Begins $CO_2$ Injection at Enhanced Oil Recovery Project in Historic North Burbank Oil Field."**

Chaparral Energy Inc. has begun injecting $CO_2$ into the North Burbank $CO_2$ EOR Project. The EOR project involved the installation of a $CO_2$ gathering facility at a fertilizer plant in Coffeyville, Kansas; the laying of an 8-inch, 68-mile $CO_2$ pipeline; and the construction of field infrastructure facilities for $CO_2$ injection into the North Burbank Unit (NBU). Chaparral expects to recover an additional 88 million barrels of oil from the NBU in Osage County, Oklahoma, which has already produced more than 319 million barrels. The $CO_2$ is captured by a 23,500-horsepower compressor station in Coffeyville, and is then pumped through the pipeline to the NBU for underground injection into a reservoir. From *Market Watch* on July 1, 2013.

**"New Drive for Australian Carbon Reduction Research."**

A network of research facilities was announced by the Australian Resources and Energy Minister to increase Australian development of commercial-scale CCS. The Cooperative Research Center for Greenhouse Gas Technologies (CO2CRC) is eligible for funding from the Australian Government's Clean Energy Future package, which is administered by the Education Investment Fund (EIF), to support the CCSNET network – a network made up of field facilities, onshore and offshore monitoring systems, and laboratories. While CCSNET will primarily support Victoria's CarbonNet Project, its facilities will also be made available for other Australian projects and, potentially, international collaborators. From *CO2CRC Media Release* on July 3, 2013.

**"Carbon Storage Database Launched for CCS Developers."**

The United Kingdom $CO_2$ Storage Evaluation Database, $CO_2$ Stored, is now available via the British Geological Survey (BGS) and The Crown Estate. This site is based on the database produced in the United Kingdom Storage Appraisal Project, which was commissioned and funded by the Energy Technologies Institute (ETI). Through this website, users can view and investigate more than 500 potential $CO_2$ storage sites around offshore United Kingdom., The Crown Estate and BGS will develop and update $CO_2$ Stored from 2013 to 2018 to improve the data and functionality of the original database according to the needs of stakeholders. From *co2stored.co.uk* on June 19, 2013.

**"New Heriot-Watt labs Take Global Approach to a Global Problem: Center for Innovation in Carbon Capture and Storage Set Up."**

Heriot-Watt University has opened a new research center, called the "The Center for Innovation in Carbon Capture and Storage," (CICCS) that allows researchers to study carbon capture technologies and how to transport, securely store, and develop $CO_2$ for future use. The facilities accommodate a team of 15 researchers. Research projects will investigate ways to make carbon capture cost-efficient for producers of $CO_2$ and understand the fate of the long-term storage in geologic formations under the seabed. Heriot-Watt University is one of the three partners in Scottish Carbon Capture & Storage (SCCS), a research partnership that also includes BGS and the University of Edinburgh. From *Scottish Carbon Capture & Storage* News Release on June 18, 2013.

# Carbon Storage in the News (Continued)

**"Malaysian Tapis Oil Field EOR Project Set to Start Up End 2013: ExxonMobil."**

According to ExxonMobil's Malaysian subsidiary, the Tapis EOR project, which will help sustain the current production level, is expected to start up by the end of 2013. In 2009, ExxonMobil and Malaysia's state-owned Petronas signed a production-sharing contract (PSC) for further development of several fields located offshore Malaysia. According to the terms of the PSC, ExxonMobil and Petronas committed to spending $2.1 billion on EOR project work, the rejuvenation of facilities, and further development and drilling activities aimed at sustaining the current production level. Since production began in 1978, approximately 400 million barrels of oil have been produced. From *Platts* on July 10, 2013.

# Science

**"Major Changes Needed For Coral Reef Survival."**

According to a study conducted by researchers from the Carnegie Institution for Science, a reduction in $CO_2$ emissions is required to prevent coral reefs from dying off. Published in the journal "Environmental Research Letters," the study claims that if the $CO_2$ emission trajectory continues along its current path, all existing coral reefs face inhospitable ocean chemistry conditions by the end of the century. Coral reefs are sensitive to changes in ocean chemistry that result from several conditions. Data was gathered by focusing on the acidification of open water surrounding coral reefs, and how it affects the reef's ability to survive. Using results from simulations that were conducted using a collection of models, researchers calculated ocean chemical conditions that would occur under different future scenarios, determining whether these chemical conditions could sustain coral reef growth. According to the results, chemical conditions that can support coral reef growth can only be sustained with a reduction in $CO_2$ emissions. From the *Carnegie Institution for Science* on June 28, 2013.

**"Climate Change Threatens Iberian Lynx."**

According to British researchers, the Iberian lynx could be extinct within the next 50 years unless steps are taken to address climate change and the impacts on prey. Published in the journal "Nature Climate Change," the study claims that the population decline of the Iberian lynx – the world's most endangered cat species – is related to a decline in the European rabbit. In addition, the researchers expect the habitat to become less hospitable. According to the study, there are approximately 250 Iberian lynx currently living in two communities in the wild; in the 1990s, there were nine communities. From *CBS News* on July 22, 2013.

# Policy

**"From demonstration to deployment: An economic analysis of support policies for carbon capture and storage."**

The following is the Abstract of this article: "This paper argues that an integrated policy architecture consisting of multiple policy phases and economic instruments is needed to support the development of CCS from its present demonstration phase to full-scale deployment. Building on an analysis of the different types of policy instruments to correct market failures specific to CCS in its various stages of development, [the authors] suggest a way to combine these into an integrated policy architecture. This policy architecture adapts to the need of a maturing technology, meets the requirement of policymakers to maintain flexibility to respond to changing circumstances while providing investors with the policy certainty that is needed to encourage private sector investment. This combination of flexibility and predictability is achieved through the use of 'policy gateways' which explicitly define rules and criteria for when and how policy settings will change. [The authors] findings extend to bioenergy-based CCS applications (BECCS), which could potentially achieve negative emissions. [The authors] argue that within a framework of correcting the carbon externality, the added environmental benefits of BECCS should be reflected in an extra incentive." **Max Krahé, Wolf Heidug, John Ward, and Robin Smale**, *Energy Policy*. (Subscription may be required to view article.)

**"Development of a greenhouse gas accounting GIS-based tool to support local policy making—application to an Italian municipality."**

The following is the Abstract of this article: "Climate change is the issue of the century and, according to Agenda 21, local actions are essential to impact global mitigation of GHG emissions ('think globally, act locally'). However, in order to plan and implement effective, sustainable actions, local authorities need detailed information on their GHG emissions and their sources. This paper presents the work that led to the development of a GIS-based tool for local GHG accounting, which provides data for local decision-makers in an innovative manner different from traditional GHG inventories. The original aspects of the study are the geo-referencing of all results and the possibility of calculating all emissions (carbon sources) and removals (carbon [formations]) with input data of different accuracy." **F. Asdrubali, A. Presciutti, and F. Scrucca**, *Energy Policy*. (Subscription may be required to view article.)

**"Stakeholder perspectives on carbon capture and storage in Indonesia."**

The following is the Abstract of this article: "CCS is being considered as an option to reduce $CO_2$ emissions worldwide. Yet recent cases show that CCS faces divergent public acceptance issues. This paper investigates stakeholder perspectives on CCS in Indonesia. Q methodology was adopted to [analyze] the diversity of stakeholder

# Policy (Continued)

perspectives. Four perspectives were identified: (1) '$CO_2$ emissions reduction through clean energy sources rather than CCS'; (2) 'CCS as one of the options in the transition to a sustainable energy system'; (3) 'CCS as the only optimal solution to reduce $CO_2$ emissions'; (4) 'CCS is only a tactic to keep burning coal forever.' Based on these results, [the authors] argue that stakeholder acceptance of CCS should be understood as a complex notion. This means that understanding whether or under what conditions stakeholders would be willing to support CCS, requires consideration of stakeholders' viewpoints about broader questions of $CO_2$ emission reduction and energy supply in Indonesia, rather than studying attitudes towards CCS in isolation. [The authors] discuss how the approach taken in this study can be used and followed up in policymaking on CCS in Indonesia." **Andri D. Setiawan and Eefje Cuppen**, *Energy Policy*. (Subscription may be required to view article.)

# Geology

**"Assessing the feasibility of $CO_2$ storage in the New Albany Shale (Devonian–Mississippian) with potential enhanced gas recovery using reservoir simulation."**

The following is the Abstract of this article: "The feasibility of storing $CO_2$ in geologic formations as a means to mitigate global climate change is being evaluated around the globe. One option that has received limited attention is to store $CO_2$ in shale formations that are currently productive unconventional shale gas plays. While $CO_2$ trapping mechanisms in saline [formations] are primarily structural, capillary, solubility, and mineral trapping, the mechanisms are fundamentally different in gas shales, and $CO_2$ adsorption onto organic materials and clay minerals plays a key role. Shale gas formations have a high content of organic matter that may store significant amounts of adsorbed natural gas, ranging from 20 percent to 80 percent of original-gas-in-place. Laboratory and theoretical calculations suggest that $CO_2$ is adsorbed preferentially over methane onto the organics and could displace the methane (with up to a 5:1 ratio by molecule). This mechanism could be the basis of a new method of CCS that stores the $CO_2$ in gas shales with the potential added benefit of enhanced gas recovery …" **Faye Liu, Kevin Ellett, Yitian Xiao, and John A. Rupp**, *International Journal of Greenhouse Gas Control*. (Subscription may be required to view article.)

**"Effect of oxygen co-injected with carbon dioxide on Gothic shale caprock-$CO_2$-brine interaction during geologic carbon [storage]."**

The following is the Abstract of this article: "Co-injection of oxygen, a significant component in $CO_2$ streams produced by the oxyfuel combustion process, can cause a significant alteration of the redox state in deep geologic formations during geologic carbon [storage]. The potential impact of co-injected oxygen on the interaction between synthetic $CO_2$–brine (0.1 M NaCl) and shale caprock (Gothic shale from the Aneth Unit in Utah) and mobilization of trace metals was investigated at ~ 10 MPa and ~ 75°C. A range of relative volume percentages of O2 to $CO_2$ (0, 1, 4 and 8 [percent]) were used in these experiments to address the effect of oxygen on shale–$CO_2$–brine interaction under various conditions. Major mineral phases in Gothic shale are quartz, calcite, dolomite, montmorillonite, and pyrite. During Gothic shale–$CO_2$–brine interaction in the presence of oxygen, pyrite oxidation occurred extensively and caused enhanced dissolution of calcite and dolomite. Pyrite oxidation and calcite dissolution subsequently resulted in the precipitation of Fe(III) oxides and gypsum ($CaSO_4 \cdot 2H_2O$). In the presence of oxygen, dissolved Mn and Ni were elevated because of oxidative dissolution of pyrite. The mobility of dissolved Ba was controlled by barite ($BaSO_4$) precipitation in the presence of oxygen. Dissolved U in the experimental brines increased to ~ 8–14 µg/L, with concentrations being slightly higher in the absence of oxygen than in the presence of oxygen. Experimental and modeling results indicate the interaction between shale caprock and oxygen co-injected with $CO_2$ during geologic carbon [storage] can exert significant impacts on brine pH, solubility of carbonate minerals, stability of sulfide minerals, and mobility of trace metals. The major impact of oxygen is most likely to occur in the zone near $CO_2$ injection wells where impurity gases can accumulate. Oxygen in $CO_2$–brine migrating away from the injection well will be continually consumed through the reactions with sulfide minerals in deep geologic formations." **Hun Bok Jung, Wooyong Um, and Kirk J. Cantrell**, *Chemical Geology*. (Subscription may be required to view article.)

**"Experimental Assessment of $CO_2$-Mineral-Toxic Ion Interactions in a Simplified Freshwater [Formation]: Implications for $CO_2$ [Release] from Deep Geological Storage."**

The following is the Abstract of this article: "The possible intrusion of $CO_2$ into a given freshwater [formation] due to [release] from deep geological storage involves a decrease in pH, which has been directly associated with the remobilization of hazardous trace elements via mineral dissolution and/or via desorption processes. In an effort to evaluate the potential risks to potable water quality, the present study is devoted to experimental investigation of the effects of $CO_2$ intrusion on the mobility of toxic ions in simplified equilibrated [formations]. [The authors] demonstrate that remobilization of trace elements by $CO_2$ intrusion is not a universal physicochemical effect. In fact goethite and calcite, two minerals frequently found in [formations], could successfully prevent the remobilization of adsorbed Cu(II), Cd(II), Se(IV), and As(V) if $CO_2$ is intruded into a drinking water [formation]. Furthermore, a decrease in pH resulting from $CO_2$ intrusion could reactivate the adsorption of Se(IV) and As(V) if goethite and calcite are sufficiently available in underground layers. [The authors'] results also suggest that adsorption of cadmium and copper could be promoted by calcite dissolution. These adsorbed ions on calcite are not remobilized when $CO_2$ is intruded into the system, but it intensifies calcite dissolution. On the other hand, arsenite As(III) is significantly adsorbed on goethite, but is partially remobilized by $CO_2$ intrusion." **German Montes-Hernandez, François Renard, and Romain Lafay**, *Environ. Sci. Technol*. (Subscription may be required to view article.)

# Technology

**"Heavy oil production by carbon dioxide injection."**

The following is the Abstract of this article: "With the depletion of light oil, heavy oil is becoming one of the most promising resources for

# Technology (Continued)

meeting future energy consumption. Heavy oil resources are abundant, but the traditional water flooding method can only achieve less than 20 [percent] of heavy oil recovery. Thermal recovery has proven effective in producing heavy oil, but not suitable for many heavy oil formations that are either thin or buried deep underground. Carbon Dioxide injection is a 'win-win' EOR technique for many heavy oil fields. Injected $CO_2$ not only increases heavy oil output, but also traps injected $CO_2$ underground. Carbon dioxide effectively recovers heavy oil thanks to several mechanisms, including oil swelling, viscosity reduction, and blow-down recovery. This review discusses the advances of $CO_2$ flooding at both laboratory scale and field scale. Laboratory tests show that $CO_2$ can significantly improve heavy oil recovery. Several field cases in the USA, Turkey, Trinidad, and China are reviewed. Field experiences show that $CO_2$ flooding is a successful EOR method for heavy oil fields. However, some issues were encountered in field applications, such as early gas breakthrough, corrosion, $CO_2$ availability, and high costs." **Changhong Gao, Xiangliang Li, Lanlei Guo, and Fangjian Zhao**, *Greenhouse Gases: Science and Technology*. (Subscription may be required to view article.)

**"Uncertainty in static $CO_2$ storage capacity estimates: Case study from the North Sea, UK."**

The following is the Abstract of this article: "[The authors] used a sub-salt Rotliegend Group sandstone saline [formation] in the North Sea as a case study site for Monte-Carlo-based $CO_2$ geostorage capacity assessment. In the area of interest, this unit is characterized by sparse, low resolution, subsurface data typical of the margins of global petroleum provinces, favored for $CO_2$ storage. Such data scarcity leads to uncertainty regarding the complex trap geometries and ultimate $CO_2$ storage capacity. The Rotliegend reservoir, estimated to have porosity and permeability ranges of 11–27 percent and 0.2 mD–125 mD, respectively, is sealed by Zechstein salt. The salt, predominantly halite, is a proven hydrocarbon seal in the central and southern North Sea hosting oil and gas columns of >140 m (>450 ft) and >150 m (>500 ft). Utilizing 2D-seismic data, boreholes and analogues, [the authors] estimate the pore volume of a 5-$km^2$ 4-way dip-closed structure through Monte-Carlo-based capacity simulations. [The authors] estimated storage capacity using published methodologies and compared this against a theoretical total storage calculation analogous to the gas in place equation used in the petroleum industry. [The authors] found that different methods yield a capacity range of $<10^4$ to $>10^9$ [metric tons] $CO_2$ where sensitivity analysis indicates variability in reservoir properties to be the dominant control. Thus static estimates based upon Monte-Carlo calculations present no advantage over theoretical pore volume estimations. This leaves 3D dynamic modeling of storage capacity populated by 3D seismic data and direct down-hole measurement of reservoir properties to improve confidence in capacity estimations as the recommended method." **Benjamin J. Hedley, Richard J. Davies, Simon A. Mathias, David Hanstock, and Jon G. Gluyas**, *Greenhouse Gases: Science and Technology*. (Subscription may be required to view article.)

**"Thermodynamic and transport property models for carbon capture and sequestration (CCS) processes with emphasis on $CO_2$ transport."**

The following is the Abstract of this article: "CCS is one of the most promising technologies for the reduction of $CO_2$ concentration in the atmosphere, so that global warming can be controlled and eventually eliminated. A crucial part in the CCS process design is the model that is used to calculate the physical properties (thermodynamic, transport etc.) of pure $CO_2$ and $CO_2$ mixtures with other components. In this work, an overview of various thermodynamic models together with calculations from cubic and higher order equations of state (EoS) are provided. Calculations are compared to experimental data and a discussion on the accuracy of the models is given. The $CO_2$ mixture properties studied include phase equilibria, density, isothermal compressibility, speed of sound, and Joule-Thomson inversion curve. The Peng-Robinson, Soave-Redlich-Kwong, and the Perturbed Chain-Statistical Associating Fluid Theory (PC-SAFT) are the EoS used for the calculations. In addition, various models for transport properties are discussed and calculations for viscosity and diffusion coefficient are presented." **Nikolaos I. Diamantonis, Georgios C. Boulougouris, Dimitrios M. Tsangaris, Mohamad J. El Kadi, Hisham Saadawi, Shahin Negahban, and Ioannis G. Economou**, *Chemical Engineering Research and Design*. (Subscription may be required to view article.)

# Terrestrial

**"Modifying the Soil and Water Assessment Tool to simulate cropland carbon flux: Model development and initial evaluation."**

The following is the Abstract of this article: "Climate change is one of the most compelling modern issues and has important implications for almost every aspect of natural and human systems. The Soil and Water Assessment Tool (SWAT) model has been applied worldwide to support sustainable land and water management in a changing climate. However, the inadequacies of the existing carbon algorithm in SWAT limit its application in assessing impacts of human activities on $CO_2$ emission, one important source of GHGs that traps heat in the earth system and results in global warming. In this research, [the authors] incorporate a revised version of the CENTURY carbon model into SWAT to describe dynamics of soil organic matter (SOM)-residue and simulate land–atmosphere carbon exchange. [The authors] test this new SWAT-C model with daily eddy covariance (EC) observations of net ecosystem exchange (NEE) and evapotranspiration (ET) and annual crop yield at six sites across the U.S. Midwest. Results show that SWAT-C simulates well multi-year average NEE and ET across the spatially distributed sites and capture the majority of temporal variation of these two variables at a daily time scale at each site. [The authors] analyses also reveal that performance of SWAT-C is influenced by multiple factors, such as crop management practices (irrigated vs. rainfed), completeness and accuracy of input data, crop species, and initialization of state variables. Overall, the new SWAT-C demonstrates favorable performance for simulating land–atmosphere carbon exchange across agricultural sites with different soils, climate, and management practices. SWAT-C is expected to serve as a useful tool for including carbon flux into consideration in sustainable watershed management under a changing climate. [The authors] also note that extensive assessment of SWAT-C with field observations is required for further improving the model and understanding potential uncertainties of applying it across large regions with complex

# Terrestrial (Continued)

landscapes." **Xuesong Zhang, R. César Izaurralde, Jeffrey G. Arnold, Jimmy R. Williams, and Raghavan Srinivasan**, *Science of The Total Environment*. (Subscription may be required to view article.)

# Trading

**"$CO_2$ Emissions from Electricity Generation and Imports in the Regional Greenhouse Gas Initiative: 2011 Monitoring Report."**

This RGGI report is the third in a series of annual monitoring reports called for in the 2005 RGGI MOU. The report summarizes data for electricity generation, electricity imports, and related $CO_2$ emissions in the 10 states participating in the RGGI control period from 2005 through 2011.

**"The impact of electricity demand reduction policies on the EU-ETS: Modelling electricity and carbon prices and the effect on industrial competitiveness."**

The following is the Abstract of this article: "The European electricity instruments in the EU aim at reducing the electricity consumption. This market is linked to a carbon market with a fixed cap that limits [GHG] emissions. At the same time, a number of energy efficiency policy article explores the interactions between the EU's carbon market on the one hand and instruments specifically targeted towards energy end-use efficiency on the other hand. [The authors'] theoretical analysis shows how electricity demand reduction triggered by energy efficiency policy instruments affects the emission trading scheme. Without adjustments of the fixed cap, decreasing electricity demand (relative to business-as-usual) reduces the carbon price without reducing total emissions. With lower carbon prices, costly low emission processes will be substituted by cheaper high emitting processes. Possible electricity and carbon price effects of electricity demand reduction scenarios under various carbon caps are quantified with a long-term electricity market simulation model. The results show that electricity efficiency policies allow for a significant reduction of the carbon cap. Compared to the 2005 emission level, 30 percent emission reductions can be achieved by 2020 within the emission trading scheme with similar or even lower costs for the industrial sector than were expected when the cap was initially set for a 21 percent emission reduction." **Johannes Thema, Felix Suerkemper, Katharina Grave, and Adrian Amelung,** *Energy Policy*. (Subscription may be required to view article.)

# Recent Publications

**"IEA 2013 CCS Technology Roadmap."**

The following is from the Introduction of this document: "Between 2009 when the first IEA Carbon Capture and Storage (CCS) roadmap was published, and 2013, the need for CCS has not diminished: the urgency of its deployment has in fact grown. There have been many developments and significant gains in CCS technology and the enabling policy frameworks. However, given today's level of fossil fuel [utilization], and that a carbon price as a key driver for CCS remains missing, the deployment of CCS is running far below the trajectory required to limit long-term global average temperature increases to 2°C. The goal of this updated CCS roadmap is to describe and [analyze] actions needed to accelerate CCS deployment to levels that would allow it to fulfill its $CO_2$ emissions reduction potential. The IEA is revising the 2009 roadmap to reflect developments in CCS that have occurred over the last four years and to develop a plan of action that fully reflects the current context. This roadmap provides a brief status report on CCS technologies, outlines a vision for CCS deployment between 2013 and 2050 consistent with limiting the average global temperature increase to 2°C, and suggests actions that need to be taken to facilitate this envisaged deployment, particularly between 2013 and 2020. [The authors] believe that the recommended near-term actions are of vital importance to the deployment of CCS not only to limit average global temperature increase to 2°C, but for any scenario designed to achieve [stabilization] of global temperature changes at 4°C or below."

**"$ICO_2N$ Perspectives on the GHG Impact of Storing $CO_2$ through Enhanced Oil Recovery."**

The following is from the Summary of this document: "$ICO_2N$ commissioned the Pembina Institute, a Canadian environmental think tank, to analyze the GHG impact of storing $CO_2$ through the process of EOR. The analysis looked at $CO_2$ emissions associated with operating an EOR site as well as those associated with the oil that is produced. Stakeholders have differing perspectives on how to view the GHG impact of $CO_2$-EOR and this work is an attempt to quantify five different scenarios. Using actual operational data, the intent of the study was not to legitimize any one viewpoint but rather to bring quantitative data into the discussion. The analysis considered the $CO_2$ emissions of five scenarios representing differing viewpoints; it did not include the upstream activities associated with the capture and transport of $CO_2$… When downstream production of EOR is taken into account there is a 0.5 [metric ton] increase in emissions for every [metric ton] of $CO_2$ brought to site. However, when assuming full displacement of competing sources of crude oil, storing $CO_2$ through EOR has a net GHG benefit of 1.175 TCO2e reduced for an oil sands barrel and 0.834 $TCO_2e$ for an average barrel…"

# Recent Publications (Continued)

**"State of Play on $CO_2$ Geological Storage in 28 European Countries."**

The following is from the Introduction of this document: "The current state of play on $CO_2$ geological storage in the CGS Europe countries is [summarized] in this report. More detailed country-specific information is provided in Annex I. In this report, a brief overview of the $CO_2$ storage options, potentials and capacities in Europe is provided in Chapter 2. Structure and organization of research funding related to $CO_2$ storage on a national level are outlined in Chapters 3 and 5 of the current report. Research topics addressed by the CGS Europe partners and other research institutions in the CGS Europe countries are introduced in Chapter 4, followed by a summary of current pilot, demo and test sites (Chapter 7) and an overview of the current state of transposition of the EU Directive on the geological storage of $CO_2$ in the CGS Europe other research institutions in the CGS Europe countries are introduced in Chapter 4, followed by a summary of current pilot, demo and test sites (Chapter 7) and an overview of the current state of transposition of the EU Directive on the geological storage of $CO_2$ in the CGS Europe other research institutions in the CGS Europe countries are introduced in Chapter 4, followed by a summary of current pilot, demo and test sites (Chapter 7) and an overview of the current state of transposition of the EU Directive on the geological storage of $CO_2$ in the CGS Europe countries (Chapter 8). Information on a national level is complemented by an overview of ongoing EU-funded research projects related to $CO_2$ storage and a summary of activities of the European Energy Research Alliance in Chapter 6."

**"Carbon Capture Through Innovative Commercial Structuring in the Canadian Oil Sands."**

The following is from the Introduction of this document: "Economic capture and use of $CO_2$ is the primary limiting challenge for meaningful large industrial GHG emission reduction. The capital investment in carbon capture facilities is high and the required purification and compression is energy intensive. Use of immature capture technology and requirement for extensive plant integration can be a significant operating and investment risk for industrial facilities. The North West Sturgeon Refinery (NWSR) project has been developed to take advantage of the rising supply of bitumen from the oil sands of northern Alberta and the need for refining conversion capacity to produce low carbon fuels with reduced GHG emissions. Since its inception the project has incorporated gasification technology to economically co-produce hydrogen for the refining process and pure $CO_2$ that will generate a modest revenue stream from sales into an EOR scheme. The fully integrated project will capture, use for EOR and geologically [store] over 1.2 million [metric tons] per year of 99 percent pure, dry $CO_2$, the equivalent to removing approximately 225,000 vehicles from the road. The $CO_2$ from the NWSR will also be the anchor supply for the Alberta Carbon Trunk Line (ACTL), an open access $CO_2$ pipeline being developed by Enhance Energy Inc. The ACTL has public funding which will support the development of a common $CO_2$ handling infrastructure for EOR in Alberta."

**"Moving CCS Forward in Europe."**

The following is from the Introduction of this document: "Back in 2007, the European Council agreed to pursue an aggressive effort to support the demonstration of CCS. The aim was to secure up to 12 commercial–scale projects by 2015, covering the range of technologies and geological storage options. Sitting alongside the European Union's (EU) wider ambitions on climate and energy policy, this intent firmly positioned Europe at the heart of expanding international efforts on CCS. But now, in mid-2013, the EU is still without any new commercial– scale CCS projects under construction. Two different funding mechanisms have failed to secure projects able to take positive final investment decisions. The previous momentum that [favored] CCS has been lost. But why has this happened, and what can be done about it? This paper looks at why CCS still matters for Europe, and how a more positive outlook can be encouraged. First, [the authors] review Europe's previous efforts on CCS, considering how policy measures have fared in the context of increasingly challenging economic and political conditions. This section, authored by E3G, then looks at how CCS could be reconsidered moving forward, with a focus on how a positive vision could be advanced to win back political support and inform policy choices. Second, with a number of potential policy options currently under consideration, [the authors] set out some initial ideas from the Bellona Foundation on how EU-wide and Member State policy incentives could work together to accelerate action on CCS over the coming years. Third, [the authors] consider the case of Norway—a country that is not a member of the EU, but which has also had leadership aspirations for CCS and now confronts similar challenges in bringing projects to reality. This section, authored by ZERO, also considers how Norway and the EU might be able to cooperate further in future."

**"Transport and storage economics of CCS networks in the Netherlands."**

The following is a summary of this document: "A team from the Rotterdam Climate Initiative, CATO-2 (the Dutch national R&D [program] on CCS) and the Clinton Climate Initiative, developed a financial model to assess the economics of alternative $CO_2$ transport and storage options in the North Sea, based on common user infrastructure. The purpose of the financial model that is available on the Global CCS Institute website is to introduce a simple planning tool relating to the transport and storage components of an integrated CCS project using readily available, non-confidential data. A steering group of major emitters with advanced plans for CCS projects in the Netherlands and Belgium guided the project. Although the report [focuses] on potential projects in the Netherlands (Rotterdam and Eemshaven) and Belgium (Antwerp) in the short to medium term, the analysis and lessons could be useful to other regions considering $CO_2$ network solutions."

# Legislative Activity

**"Liechtenstein Extends Carbon Dioxide Tax."**

The Liechtenstein Government adopted a bill revising the Principality's Carbon Dioxide Act ($CO_2$ Act) to align the legislation with Switzerland's revised $CO_2$ Act. The legislation calls for a $CO_2$ levy imposed on fossil fuel to be extended until 2020. The revised $CO_2$ Act maintains the incentive fee on fossil fuels ($CO_2$ levy) introduced in 2008 and increases the levy with interim targets. The revised act also introduces two measures aimed at transport and importers of petrol and diesel to compensate for a portion of emissions by investing in climate protection projects in Switzerland. From *Tax-News.com* on July 9, 2013.

**"State Lawmakers Push 1st-in-U.S. Carbon Tax."**

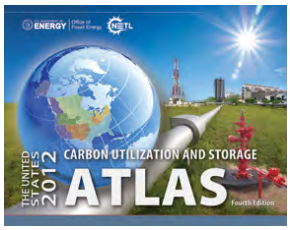
Massachusetts lawmakers are seeking to pass legislation that would tax carbon at $5 per metric ton. The legislation would increase taxes on gasoline as determined by the Department of Revenue and add new taxes to consumers of heating oil and firewood. The tax revenue under their proposal would be given back to taxpayers through a tax exemption and other measures. The bill would raise in the range of $350 million to $500 million, although tax breaks in the bill would cause the state government to retain $100 million to fund public transit and other programs. From *WBJournal.com* on July 18, 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:

NETL RSS Feed

NETL on Facebook

NETL on Twitter

NETL on LinkedIn

NETL on YouTube

## 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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