NETL the ENERGY lab

Carbon Storage Newsletter

February 2014

What's Inside?

Highlights

"Celebrating a Decade of Carbon Storage Research Through Partnership."

For the past decade, the U.S. Department of Energy (DOE) Office of Fossil Energy's (FE) National Energy Technology Laboratory (NETL) has managed a nationwide network of partnerships that team government, industry, academia, and nonprofit organizations to identify the best approaches for permanently storing carbon dioxide (CO_2) in deep geologic formations. Research performed by the seven Regional Carbon Sequestration Partnerships (RCSPs) helps validate the most suitable technologies and infrastructure needs for geologic carbon capture and storage (CCS). A number of lessons have been learned from this research, each leading to more effective ways to contain and monitor CO_2. The RCSPs are tailored to address the specific characteristics of their respective regions because the United States is a nation of varied emission sources, topography, and geology. Each RCSP evaluates potential storage sites in its geographic area and determines the optimal approach for CCS. Testing conducted at the sites prior to, during, and after injection provides insight regarding injectivity, capacity, and containment of CO_2 in the formations. Determining best practices for each region leads the RCSPs to identify regulatory and infrastructure requirements for future commercial deployment, making CCS easier and more effective. NETL and the RCSPs also make the results of their research available. To augment the information-sharing that occurs through avenues such as research papers, scientific conferences, and technical reports, DOE will post online a short series of lessons learned from the RCSPs' carbon storage projects over the next several weeks. These blog posts will include such topics as site characterization; industry partnerships; public outreach and education; and monitoring, verification, and accounting. More information on the RCSPs is available via the NETL website.

"Department of Energy Releases $8 Billion Solicitation for Advanced Fossil Energy Projects."

DOE published a solicitation in December 2013, making up to $8 billion in loan guarantee authority available to support innovative advanced fossil energy projects that avoid, reduce, or store greenhouse gases (GHGs). The loan guarantees under this new solicitation will help provide financing to support new or significantly improved advanced fossil energy projects, such as advanced resource development, carbon capture, low-carbon power systems, and efficiency improvements, which reduce emissions of CO_2, methane (CH_4), and other GHGs. DOE published a draft solicitation on July 9, 2013, which opened a 60-day comment period. During this time, DOE listened to potential applicants and other stakeholders and incorporated their feedback into the solicitation, which includes new provisions intended to facilitate applications, ensure quick review, and foster successful public-private partnerships. Currently, DOE's Loan Programs Office (LPO) supports a portfolio of more than $30 billion for more than 30 closed and committed projects. With the publication of the Advanced Fossil Energy Projects solicitation, the Department is accepting applications through the LPO web portal at apply.loanprograms.energy.gov, and expects to receive the initial applications by the end of February 2014. A copy of the solicitation, which includes application deadlines and eligibility requirements, and a fact sheet can be found at lpo.energy.gov. The solicitation is part of the Climate Action Plan. The loan guarantees are authorized by Title XVII of the Energy Policy Act of 2005. From *U.S. Department of Energy News Release* on December 12, 2013.

Announcements

NETL Funding Opportunity Announcement.

NETL released Funding Opportunity Announcement (FOA) DE-FOA-0001037, titled, "Research for Safe and Permanent Geologic Storage of CO_2." The application due date is March 24, 2014, and application forms and/or instructions are available online. Projects selected under this FOA will develop characterization tools, technologies, and/or methodologies that improve the ability to predict geologic storage capacity within 30 percent, improve the utilization of the reservoir by understanding how faults and fractures in a reservoir affect the flow of CO_2, and ensure storage permanence.

Sequestration Training and Education Program (STEP) and World Resources Institute (WRI) Workshop.

STEP is working with WRI to offer a Financial Assurances Workshop on March 13, 2014, in Washington, D.C., USA. The workshop will provide an overview of financial assurance with a focus on the regulations underpinning the Underground Injection Control (UIC) Class VI well operator. The workshop includes: financial assurance terms and concepts; discussion of the current financial assurance framework for Class VI wells; and discussion of financial assurance requirements by geologic storage phases. Contact Kathy Atchley (katchley@illinois.edu) for registration materials.

International Workshop on Public Education, Training, and Community Outreach for Carbon Capture and Storage.

This workshop is scheduled for July 30-31, 2014, at the National Sequestration Education Center (NSEC) in Decatur, Illinois, USA. The technical program features tools and techniques for public education, training, and community outreach on CCS. Workshop attendees will tour the commercial-scale CCS project at the Archer Daniels Midland facility. The workshop also includes a full day of programing for K-12 teachers with interactive lesson plans related to CCS and Science, Technology, and Mathematics (STEM). To present a paper, submit an abstract to dlarrick@richland.edu on the following topics: (1) Ongoing Programs in CCS Education and Training; (2) Project Developer/Industry Experience in Public Communications; (3) Sharing Knowledge/Lessons Learned for Effective CCS Outreach; or (4) Advancing CCS Education, Training, and Outreach Programs, Key Messages, and FAQs. Abstracts are due March 31, 2014.

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).

Draft of the Climate Registry's General Verification Protocol Version 2.1.

The Climate Registry released a draft of General Verification Protocol (GVP) Version 2.1 for public comment in January. The proposed updates to GVP v. 2.1 included a new option for verifications to be conducted to a limited level of assurance (existing policy requires a reasonable level of assurance). The proposed updates provide members with the flexibility to choose the level of assurance that best meets their needs and objectives. The Climate Registry has also proposed that only inventories verified to a reasonable level of assurance are eligible for Climate Registered™ Silver, Gold, or Platinum, or to serve as a base-year report through The Registry.

Course at the Wyoming Carbon Capture and Storage Technology Institute (WCTI).

This WCTI course, titled, "Well Construction, Operation, Monitoring and Testing," is intended to introduce CCS professionals to the construction and operating requirements of Class VI wells. In addition, a variety of techniques for monitoring the injected CO_2 plume in the subsurface and for detecting any potential releases from the well or reservoir will be discussed. The course syllabus is available via the link.

Carbon Storage in the News

"Demonstration Test for Capturing CO_2 In the Flue Gas from a Coal-Fired Power Generation Plant Completes Initial Demonstration Phase."

A demonstration test conducted by Mitsubishi Heavy Industries, Ltd. (MHI) and Southern Company Services, Inc. (SCS) has completed an initial demonstration phase. The demonstration test involved capturing and storing CO_2 emissions at an SCS affiliate's coal-fired power plant in Alabama. The demonstration test, which began in June 2011, focused on recovering 500 metric tons of CO_2 per day. After verifying the technology for recovering CO_2 from the coal-fired plant flue gas, integrated capture and storage demonstration testing began in August 2012. The CO_2 capture demonstration plant that supplied the CO_2 under this project was built by MHI and SCS. The plant consists of a flue-gas scrubber, flue-gas CO_2 capture/re-generation system, CO_2 compression machinery, and electrical components. The plant has the capacity to recover 150,000 metric tons of CO_2 per year with recovery efficiency exceeding 90 percent. With the initial demonstration phase completed, SCS and

Carbon Storage in the News (Continued)

MHI are considering additional demonstration phases and activities utilizing the plant. From *MHI News Release* on January 14, 2014.

"University of Calgary Receives $500k Grant."

The Natural Sciences and Engineering Research Council (NSERC) of Canada issued a grant to the Energy and Environment Research Group at the University of Calgary to support CO_2 capture research. The three-year grant, worth $583,082, will be used to develop a novel, integrated approach to energy production and gasification. This specific approach combines gasification technology with solid absorbent materials to capture CO_2. From *Carbon Capture Journal* on January 12, 2014.

"CO_2 Pipeline Proposed for Catron, Socorro Counties."

The United States Bureau of Land Management (BLM) is seeking public input for the proposed Kinder Morgan, Inc. Lobos CO_2 Pipeline. The 213-mile pipeline will transport CO_2 being produced at the St. Johns field in Arizona to the existing Kinder Morgan Cortez CO_2 pipeline in Torrance County. Kinder Morgan's 30-inch, 502-mile Cortez line delivers CO_2 from southwest Colorado to the Denver Hub oil fields in west Texas. The company will need 100-foot easements to build the pipeline (approximately 2,134 acres on private land, 773 on BLM land, 345 on state land, and 177 on tribal lands), according to a previous public meeting. The pipeline will be buried in the range of 3 to 36 feet deep, and up to 40 feet deep under the Rio Puerco and Rio Grande. Kinder Morgan is giving special consideration to reduce the pipeline's impact on farmers, protect topsoil during excavation, and minimize impacts on irrigation systems in the Rio Grande Valley. After construction, Kinder Morgan plans to retain an easement for maintenance and will install markers instead of fences. Landowners will be able to use the land as they did before the project. Public scoping meetings were held in December 2013 at Quemado, Socorro, Roswell, Mountainair, and Belen. The pipeline is scheduled for completion in 2015. From *El Defensor Chieftain* on January 16, 2014.

"Alberta Unveils State-of-the-Art Greenhouse Gas Emissions Monitoring."

Alberta is utilizing an advanced air monitoring system that was designed and constructed at Utah State University's Space Dynamics Lab. The device fires an infrared laser beam at targets such as oil sands sites, tailings ponds, and coal-fired power plants to measure the GHG emission volume(s). According to an official, the air-light detection and ranging system fills an air monitoring gap, because satellite systems cannot determine how much an individual industry emits and other units cannot measure large areas. The laser on the roof of the unit can fire an infrared beam 360 degrees around the trailer to detect particles as far away as 15 kilometers and GHGs from a distance of 2 kilometers. The system detects the absorption of light by CH_4 or CO_2 and calculates the volume in the atmosphere. The unit is operated by a two-member team and will be tested for several more months before use at other emission sites. An official said that the system could be an important tool to monitor compliance as Alberta works to reduce its GHG emissions. From *The Calgary Herald* on January 20, 2014.

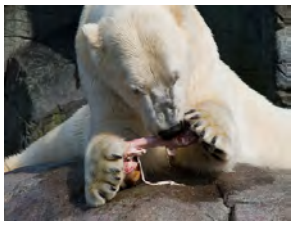
"Adnoc to Boost Oil Output by Injecting CO_2 into Reservoirs."

As part of its plans to boost oil production and replace the use of hydrogen gas in fields, Abu Dhabi National Oil Company (Adnoc) will inject CO_2 into some reservoirs beginning in 2016. Adnoc and Masdar have agreed on a joint venture for carbon capture, usage, and storage projects that will utilize CO_2 emitted from Emirates Steel. From *The National* on January 21, 2014.

"Maersk and Masdar Sign Carbon Capture MOU."

Maersk, a Danish shipping and energy conglomerate, and Masdar, the renewable energy company based in Abu Dhabi, signed a Memorandum of Understanding (MOU) to collaborate on carbon capture. Under the MOU, Maersk Oil will bring its TriGen technology to the emirate as it evaluates partners who could help it to boost its production capacity from 3 million barrels per day (bpd) to 3.5 million bpd. By building seven units with the TriGen technology, which generate CO_2 for injection into oil reservoirs, water, and power, Abu Dhabi would have the potential to boost production by 50,000 bpd through CO_2 injection, thus meeting its renewables target. The units have yet to be tested at commercial scale, but could be capable of producing 200 megawatts of power, in addition to producing distilled water that could be used for industrial or agricultural purposes. From *The National* on January 22, 2014.

Science



"Polar Bears Hunt on Land as Ice Shrinks."

According to researchers, polar bears in the western Hudson Bay area have shifted to a diet that is more land-based due to melting sea ice. Polar bears rely mainly on marine animals, such as seals, for food – especially in late spring. According to the research, higher temperatures are causing a reduction in Arctic sea ice extent, meaning that polar bears are coming ashore and eating a larger variety of foods, such as mushrooms and berries, as well as land-based animals, such as snow geese. The U.S. Endangered Species Act lists the polar bear as a threatened species and the International Union for Conservation of Nature lists them as vulnerable. From *Discovery News* on January 24, 2014.

"Large Old Trees Grow Fastest, Storing More Carbon."

U.S. Geological Survey (USGS) researchers believe that on an individual basis, large, old trees are better at absorbing atmospheric CO_2 than smaller, younger trees. According to the research, while trees age, their growth rate continues to accelerate, as does their ability to store CO_2. Published in the journal "Nature," the research

Science (Continued)

contradicts the previously accepted premise that tree growth rate declines in accordance with age. In the study, growth measurements of 673,046 trees belonging to 403 tree species from tropical, subtropical, and temperate regions across six continents were collected. The mass growth rates were calculated for each species and then analyzed for trends. The data showed that in most cases, mass growth rate increased continuously with tree size; in some cases, large trees appeared to be adding the carbon mass equivalent of an entire smaller tree each year. From *USGS News Release* on January 15, 2014.

"An alternative mechanism for accelerated carbon [storage] in concrete."

The following is the Abstract of this article: "The increased rate of [CO_2 storage] (carbonation) is desired in many primary and secondary life applications of concrete in order to make the life cycle of concrete structures more carbon neutral. Most carbonation rate studies have focused on concrete exposed to air under various conditions. An alternative mechanism for accelerated carbon [storage] in concrete was investigated in this research based on the pH change of waters in contact with pervious concrete which have been submerged in carbonate laden waters. This may be pertinent for applications of concrete reuse in marine or other aqueous applications such as jetties and riprap. The results indicate that the concrete exposed to high levels of carbonate species in water may carbonate faster than when exposed to ambient air, and that the rate is higher with higher concentrations. Validation of increased [CO_2 storage] was also performed via thermogravimetric analysis (TGA). It is theorized that the proposed alternative mechanism reduces a limiting rate effect of [CO_2] dissolution in water in the micro pores of the concrete." **Liv M. Haselbach and Jonathan N. Thomle,** *Sustainable Cities and Society.* (Subscription may be required.)

Policy

"EU to Cut Carbon Emissions by 40 [Percent] by 2030."

According to a recently reached deal, the European Union (EU) will cut its GHG emissions by 40 percent compared with 1990 levels by 2030. In addition, 27 percent of the EU's energy will be produced by renewable sources within the same timeframe. As part of the 2030 energy and climate package, Europe's emissions trading system will also be reformed, with a more flexible mechanism allowing the surplus of carbon permits to be curbed. Member states participating in the emissions trading system will have a non-legally binding target of improving energy efficiency by 24 percent by 2030. Before they can be fully accepted, the new measures will be debated by member state governments and the European parliament; the European council will discuss the proposals in March 2014. From *The Guardian* on January 22, 2014.

"A strategic decision-making model considering the social costs of carbon dioxide emissions for sustainable supply chain management."

The following is the Abstract of this article: "Incorporating sustainability into supply chain management has become a critical issue driven by pressures from governments, customers, and various stakeholder groups over the past decade. This study proposes a strategic decision-making model considering both the operational costs and social costs caused by the [CO_2] emissions from operating such a supply chain network for sustainable supply chain management. This model was used to evaluate [CO_2] emissions and operational costs under different scenarios in an apparel manufacturing supply chain network. The results showed that the higher the social cost rate of [CO_2] emissions, the lower the amount of the emission of [CO_2]. The results also suggested that a legislation that forces the enterprises to bear the social costs of [CO_2] emissions resulting from their economic activities is an effective approach to reducing [CO_2] emissions." **Shih-Chang Tseng and Shiu-Wan Hung**, *Journal of Environmental Management*. (Subscription may be required.)

"Energy related CO_2 emissions and the progress on CCS projects: A review."

The following is the Abstract of this article: "This review paper discusses the perspectives for development of CCS technologies in the global fight against climate change, such as low-carbon technology which is a vital component to reduce future carbon emissions. The information on the level and growth of CO_2 emissions, their source and geographic distribution, will be essential to lay the foundation for a global agreement; considering only for energy-related CO_2, and not for any other [GHGs]. [The authors] analyzed the distribution of the CO_2 emission intensity related to them. Besides, in order to predict possible future situations of energy consumption, CO_2 emissions intensity and the CCS role like the largest emission reduction potential, IEA has developed a number of scenarios; the baseline scenarios and comparative scenarios. [The authors] used the approach of the Blue Map Scenarios, bringing the 2005s emissions to a level of 50 [percent] by 2050 for a non-catastrophic human intervention in the climate system. Moreover, this paper shows the barriers, strategies for accelerating and the stages in the technology deployment. [The authors] also analyzed the CCS projects status; Challenges, SWOT analysis, and the currently Global CCS Technology Activity. For this, [the authors] consider the Large Scale Integrated Projects (LSIP), and the asset life-cycle model was used to categorize the status of a project according to its development stage. Alongside, the analysis involves: Total LSIPs by geographic region, by Industry and CO_2 Capture Technology. In addition, [the authors] also made a scope on some of the most relevant international actions in order to stimulate the fulfillment of the CO_2 intensity target." **Ruth Nataly Echevarria Huaman and Tian Xiu Jun**, *Renewable and Sustainable Energy Reviews*. (Subscription may be required.)

Geology

"Environmental concerns of underground coal gasification."

The following is the Abstract of this article: "Underground Coal Gasification is the conversion of solid Coal to gas in-situ by heating the coal and injecting oxidants air/oxygen to cause the gasification by partial combustion instead of complete combustion of coal. UCG is the promising technology having a lot of health, safety and environmental advantages over the conventional mining

Geology (Continued)

techniques; the major motivational aspects of UCG involves increased worker health and safety by using no man underground, no surface disposal of ash and coal tailings, low dust and noise pollution, low water consumption, larger coal reserves exploitation, and low volatile organic components, methane and [GHGs] emission to atmosphere. UCG is an inherently clean coal technology as it reduces deadly sulfur and nitrogen oxide emissions to very low levels. Total solid waste from UCG is typically half the volume generated by conventional coal plants and water use is substantially lower as well." **Muhammad Imran, Dileep Kumar, Naresh Kumar, Abdul Qayyum, Ahmed Saeed, and Muhammad Shamim Bhatti**, *Renewable and Sustainable Energy Reviews*. (Subscription may be required.)

Technology

"A simplified method for the evaluation of the performance of coal fired power plant with carbon capture."

The following is the Abstract of this article: "This paper presents a study of carbon capture systems based on chemical absorption and stripping with amines in pulverized coal fired power plants. The technical feasibility is shown for a 90 [percent] CO_2 removal on 100 [percent] of the exhaust gas flow rate. A simplified method to calculate the performance penalty in comparison with the original power plant is presented including the effect of coal ultimate analysis. The method is verified with data from an existing 75 MW coal fired power plant. The economic analysis is presented in terms of cost of electricity and cost of carbon capture and the results are that the cost of electricity nearly doubles in comparison with the reference plant, whereas the cost of captured CO_2 is considerably higher than the actual cost of CO_2 in the carbon trading markets." **Umberto Desiden and Marco Antonelli,** *Applied Thermal Engineering*. (Subscription may be required.)

"Targeting for carbon [storage] retrofit planning in the power generation sector for multi-period problems."

The following is the Abstract of this article: "Carbon constrained energy planning (CCEP) is useful to ensure that the CO_2 emissions limit for a region is met through deployment of low-carbon technologies. The increased demand in energy consumption due to economic growth requires additional energy supply and generation which would subsequently increase the carbon emissions. Nevertheless, most countries are now committed to reduce carbon emission to achieve long term sustainability goals. However, the development of alternative energy sources or CCS initiatives for power plants entails major capital investments. This paper demonstrates how these issues may be handled using CCEP with insight- and [optimization]-based targeting techniques for multi-period scenarios. Both approaches were developed recently for CCEP problems, but previous techniques were limited to single-period planning. The extensions to multi-period scenarios are demonstrated in this work with hypothetical illustrative examples, as well as a Malaysian case study." **Raymond E.H. Ooi, Dominic C.Y. Foo, and Raymond R. Tan,** *Applied Energy*. (Subscription may be required.)

"Power generation plants with carbon capture and storage: A techno-economic comparison between coal combustion and gasification technologies."

The following is the Abstract of this article: "Worldwide energy production requirements could not be fully satisfied by nuclear and renewables sources. Therefore a sustainable use of fossil fuels (coal in particular) will be required for several decades. In this scenario, CCS represents a key solution to control the global warming reducing [CO_2] emissions. The integration between CCS technologies and power generation plants currently needs a demonstration at commercial scale to reduce both technological risks and high capital and operating cost. This paper compares, from the technical and economic points of view, the performance of three coal-fired power generation technologies: (i) ultra-supercritical (USC) plant equipped with a conventional flue gas treatment (CGT) process, (ii) USC plant equipped with SNOX technology for a combined removal of sulphur and nitrogen oxides and (iii) integrated gasification combined cycle (IGCC) plant based on a slurry-feed entrained-flow gasifier. Each technology was [analyzed] in its configurations without and with CO_2 capture, referring to a commercial-scale of 1000 MW_{th}. Technical assessment was carried out by using simulation models implemented through Aspen Plus and Gate-Cycle tools, whereas economic assessment was performed through a properly developed simulation model. USC equipped with CGT systems shows an overall efficiency (43.7 [percent]) comparable to IGCC (43.9 [percent]), whereas introduction of SNOX technology increases USC efficiency up to 44.8 [percent]. Being the CCS energy penalties significantly higher for USC (about 10.5 [percent] points vs. about 8.5 for IGCC), the IGCC with CCS is more efficient (35.3 [percent]) than the corresponding CO_2-free USC (34.2 [percent] for the SNOX-based configuration). Whereas, for the case study, USC is most profitable than IGCC (with a net present value, NPV, of 190 M€ vs. 54 M€) for a conventional configuration, CO_2-free IGCC shows a higher NPV (−673 M€) than USC (−711 M€). In any cases, the NPV of all the CO_2-free configurations is strongly negative: this means that, with the current market conditions, the introduction of a CCS system cannot be economically justified without a significant incentive." **Vittorio Tola and Alberto Pettinau**, *Applied Energy.* (Subscription may be required.)

Terrestrial

"Carbon dioxide emissions from horizontal sub-surface constructed wetlands in the Mediterranean Basin."

The following is the Abstract of this article: "Constructed wetlands (CWs) are widely used natural-like systems for wastewater treatment where organic matter is removed through CO_2 emissions. Several studies have been conducted regarding emissions and the [storage] of CO_2 in CWs in the Northern Hemisphere; however, to the best of [the authors'] knowledge, no studies have been performed in the Mediterranean Basin. This work quantified daily and cumulative CO_2 emissions from a full-scale CW horizontal subsurface flow (HSSF) bed during semiarid Mediterranean spring climate conditions. The average daily CO_2-C that was released in the atmosphere during the first 50 days ranged from approximately 17.5 [percent] to 32.6 [percent] of the C that was removed from wastewater. Considering both the Phragmites australis aerial part dry matter production

Terrestrial (Continued)

(0.83 kg m^{-2}) and the average CO_2-C emissions, after 50 days of vegetative regrowth, the HSSF bed was demonstrated to act as a CO_2 sink. The cumulative CO_2 efflux was 452.15 ± 50.40 CO_2 g m^{-2} and 276.02 ± 12.07 CO_2 g m^{-2} for vegetated and unvegetated sites, respectively." **Antonio C. Barbera, Maurizio Borin, Antonio Ioppolo, Guiseppe L. Cirelli, and Carmelo Maucieri**, *Ecological Engineering*. (Subscription may be required.)

"The Arctic Ocean carbon sink."

The following is the Abstract of this article: "[The authors] present observation based estimates of the transport of dissolved inorganic carbon (DIC) across the four main Arctic Ocean gateways (Davis Strait, Fram Strait, Barents Sea Opening and Bering Straight). Combining a recently derived velocity field at these boundaries with measurements of DIC, [the authors] calculated a net summertime pan-Arctic export of 231 ± 49 *Tg C* yr^{-1}. On an annual basis, [the authors] estimate that at least 166 ± 60 *Tg C* yr^{-1} of this is due to uptake of CO_2 from the atmosphere, although time-dependent changes in carbon storage are not quantified. To further understand the region's role as a carbon sink, [the authors] calculated the volume-conserved net DIC transport from beneath a prescribed mixed layer depth of 50 m, referred to as 'interior transport', revealing an export of 61 ± 23 *Tg C* yr^{-1}. Applying a carbon framework to infer the sources of interior transport implied that this export is primarily due to the sinking and [remineralization] of organic matter, highlighting the importance of the biological pump. Furthermore, [the authors] qualitatively show that the present day Arctic Ocean is accumulating anthropogenic carbon beneath the mixed layer, imported in Atlantic Wate." **G.A. MacGilchrist, A. Naveira Garabato, T. Tsubouchi, S. Bacon, S. Torres-Valdés, and K. Azetsu-Scott**, *Deep Sea Research Part I: Oceanographic Research Papers*. (Subscription may be required.)

Trading

"KRX to Launch Carbon Trading Market in 2015."

Korea's stock market operator, the Korean Exchange (KRX), announced it was designated as the sole operator of the country's carbon trading market, set to begin in 2015. KRX will adopt systems for emissions trading that are similar to current stock market trading schemes. Under the cap-and-trade scheme, local Korean companies would be allowed to either buy rights to emit more carbon, or, if they can successfully reduce their GHG emissions, sell their emissions rights on the trading platform. Free permits will be allotted to companies by the Korean government through 2017; however, the portion of paid permits will be raised to three percent from 2018 to 2020, and to more than 10 percent from 2021 to 2025. Companies that emit at least 125,000 tons of GHGs per year will be affected by the regulations, as will individual plants that emit at least 25,000 tons of GHGs per year. KRX expects approximately 500 companies to join the carbon trading market. From *Global Post* on January 15, 2014.

"Climate game analyses for CO_2 emission trading among various world organizations."

The following is the Abstract of this article: "This paper simulates the saving in terms of the total abatement cost of CO_2 emission reductions for different trading games reflecting the potential cooperation among organizations including the EU, the Asia-Pacific Economic Cooperation (APEC) countries, the Union of South American Nations (USAN), and the Indian Ocean Rim Association for Regional Cooperation (IOR-ARC). A game approach is conducted to determine if the cooperation will come into existence among the organizations stated above. A similar idea is applied to the four largest emission countries, China, the United States, Russia, and India, as four individual players in the trading game. Joining the market is the strictly dominant strategy for any organization from the results. The Nash equilibrium shows that, regardless of the organizations that have already existed in the market, joining the market is always the best policy for the remaining organizations which are currently not in the market. Similarly, India likes the organization to which it belongs, i.e. IOR-ARC, to trade with the EU and APEC, and the [United States] wants the organization to which it belongs, i.e., APEC, to cooperate with the organizations USAN and IOR-ARC. However, China and Russia prefer trading with other countries within their own organizations." **Pei-Ing Wu, Chai Tzu Chen, Pei-Ching Cheng, and Je-Liang Liou**, *Economic Modelling*. (Subscription may be required.)

"The European Union Emission Trading System and technological change: The case of the Italian pulp and paper industry."

The following is the Abstract of this article: "[The authors] evaluate the contribution of technological change in reducing CO_2 emissions in the Italian pulp and paper industry during the first and second phases of application of the European Union Emission Trading System (EU-ETS). [The authors] decompose the variation in emission and emission intensity into three different types of effects: a composition effect, a technique effect and a scale effect. The composition effect measures the change in emissions and emissions intensity due to a shift in production towards products that cause less emissions. The technique effect measures the change per each type of product, thereby accounting for technology improvements in the production of each type of good produced. The scale effect singles out the reduction in total emission due to an overall reduction in output. [The authors] show that the first phase of the application of EU-ETS has led to a reduction in both emissions and emission intensity due to the composition effect. The technological change has had a limited negative impact on emissions in the first phase, while in the second phase there has been limited technology improvement in the industry. However, the figures of the scale effect show that the larger reduction in emission is due to the overall decrease in output." **Fulvio Fontini and Giulia Pavan**, *Energy Policy*. (Subscription may be required.)

"Enforcement and price controls in emissions trading."

The following is the Abstract of this article: "This paper examines how enforcement affects the structure and performance of emissions trading programs with price controls under uncertainty about firms' abatement costs. The analysis highlights how an enforcement strategy can cause abatement-cost risk to be transmitted to enforcement

Trading (Continued)

costs via the price of permits. When this occurs, accommodating the effect of abatement-cost risk with an optimal policy results in higher expected emissions and lower expected permit price than their second-best optimal values. However, it is possible to design an enforcement strategy that shields enforcement costs from abatement-cost risk by tying sanctions directly to permit prices. This enforcement strategy stabilizes enforcement effort, the optimal permit supply and price controls are independent of enforcement costs, and the policy produces the second-best optimal outcome." **John K. Stranlund and L. Joe Moffitt**, *Journal of Environmental Economics and Management*. (Subscription may be required.)

Recent Publications

"Integration of Capture Plant and Power Plant ROAD Special Report for the Global Carbon Capture and Storage Institute."

The following is a summary of this document: "This report focuses on the integration of the existing coal-fired [1,070] MW Unit 3 of Maasvlakte Power Plant (MPP3) with the proposed new 250 MW scale carbon capture plant of the Rotterdam Opslag en Afvang Demonstratieproject (ROAD). Carbon capture technology has been the subject of considerable research to reduce the costs of CCS, and the subject of many publications. However, the integration with the main power plant also has important impacts on the efficiency and operability of the CCS chain, and is a significant project cost in its own right."

"CO_2 Pipeline Infrastructure."

The following is from the "Background to the Study": "The aim of this study is to collate information from the public domain on existing CO_2 pipelines into a comprehensive reference document. Other objectives are to discuss the similarities and differences between CO_2 and other, specifically natural gas, pipelines and to provide an overview. The overall lessons learned from this study should support project developers, decision makers, regulators and governmental bodies who do not deal with engineering calculations and cost estimates on a regular basis." The CO_2 pipeline database is accessible online.

"A UK Vision for Carbon Capture and Storage."

The following is from the Executive Summary of this document: "The UK's CCS industry is at a crossroads. Urgent Government action is needed to ensure that this new technology-based industry develops in a timely manner, delivering significant economic growth and employment benefits and contributing towards the UK's carbon reduction targets. Delivering the optimum UK energy mix over the next 20 years involves multiple challenges: (1) a significant rise in demand for electricity, driven by economic growth and greater use of electricity at home and in industry and transport; (2) replacing a fifth of older power plant by 2020; and (3) delivering legally binding CO_2 emissions reductions of 60 percent by 2030, with the near-complete decarbonization of electricity supply sector, and significant reductions in industry. A balanced and effective energy strategy will be critical to ensuring that electricity and heat remain on tap and affordable to both industry and domestic consumers alike. Through a series of energy market reforms the government's Energy Bill is tasked with delivering the framework for £110bn [approximately $181 billion] of secure, low carbon and affordable energy investment by 2020. Investing in 'green growth' within the UK economy will provide jobs, tax revenues, inward investment and export potential. CCS technology can deliver on all these counts – providing least cost, secure energy in association with green growth…" A summary of the report, titled, "The Economic Benefits of CCS in the UK," is also available.

Legislative Activity

"[CO_2 Capture Wholesale Energy Price]."

DOE officials told the House Energy and Commerce Oversight and Investigations Subcommittee the first generation of CCS technologies have a CO_2 captured cost of $70 to $90 per ton for wholesale electricity production and a second generation of technologies could reduce the cost to $40 to $50 per ton. Officials also said that projects highlighting the second generation of CCS technologies are likely to emerge in the coming years and the overall impact on electric prices would depend on the size and type of power plant installing the technology. Officials stated that each of the three aspects of CCS (carbon capture, carbon compression and transportation, and carbon injection and storage) have been shown and individually demonstrated and industrial applications of CCS are in use throughout the United States. To view the testimony and watch a video of the hearing, visit the Energy & Commerce Committee website.

From *Bloomberg News* on February 12, 2014.

"Michigan Weighs Lower Tax for Carbon Dioxide-Injected Oil Wells."

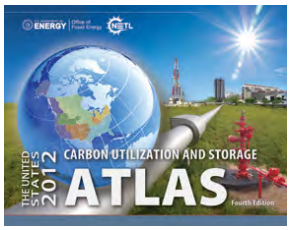
In January, Michigan lawmakers discussed bills that would reduce the severance tax from 6.6 percent to 4 percent for oil (EOR) and from 5 percent to 4 percent for gas (EGR) extracted (some smaller oil wells currently pay a 4 percent tax); allow CO_2 pipelines; and specify that eminent domain could be used to site pipelines in the same manner as oil and natural gas lines. The tax rate would decline for certain projects and may spur additional oil production, but it is unclear to lawmakers how the change could impact state revenues, according to a Michigan House Fiscal Agency analysis. The oil and gas severance tax currently generates approximately $60 million each year. From *MLive.com* on January 28, 2014.

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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