Carbon Storage Newsletter

NOVEMBER 2015

WHAT'S INSIDE?

HIGHLIGHTS

"Secretary Moniz Announces New CO_2 Storage Network at Multinational Carbon Sequestration Forum."

The U.S. Department of Energy (DOE) announced the formation of an international initiative to facilitate collaborative testing of advanced carbon capture and storage (CCS) technologies in a real-world, saline storage environment. The Carbon Sequestration Leadership Forum's (CSLF) Large-Scale Saline Storage Project Network will form a global network of large-scale carbon dioxide (CO_2) injection sites that can share best practices, operational experience, and key lessons to advance the deployment of CCS. The collaboration builds on the CO_2 Capture Test Center Network, which has been chaired by Norway since 2013; the United States will chair the capture center in 2016. From *energy.gov* on November 4, 2015.

"Underground CO_2 Storage, Natural Gas Recovery Targeted by Virginia Tech/NETL Researchers."

Researchers from DOE's National Energy Technology Laboratory (NETL) and Virginia Polytechnic Institute and State University (Virginia Tech) are investigating the feasibility of permanently and safely storing CO_2 underground while simultaneously recovering natural gas. The research is testing the use of CO_2 captured from power plants and industrial facilities to force natural gas out of the pores of organic-rich sedimentary rocks where the natural gas becomes trapped over time. In the process, the injected CO_2 would remain safely and permanently stored. Virginia Tech's Virginia Center for Coal and Energy Research (VCCER) initiated the injection of up to 20,000 tons of CO_2 into a coalbed methane field in Buchanan County, Virginia, USA, in July 2015. Researchers will use a state-of-the-art monitoring, verification, and accounting (MVA) program to monitor and collect data as the CO_2 is injected into the coal seams. The NETL-VCCER project was initiated in 2011 and builds upon earlier carbon storage tests conducted by the Southeast Regional Carbon Sequestration Partnership (SECARB), one of DOE's Regional Carbon Sequestration Partnerships (RCSPs). From *energy.gov* on October 20, 2015.

ANNOUNCEMENTS

NETL's 2015 Carbon Storage Atlas Shows Increase in U.S. CO_2 Storage Potential.

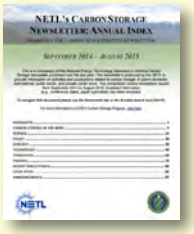
DOE/NETL released the fifth edition of the Carbon Storage Atlas (Atlas V), which shows prospective CO_2 storage resources of at least 2,600 billion metric tons – an increase over the findings of the 2012 Atlas. Atlas V highlights potential CO_2 storage resources in saline formations, oil and natural gas reservoirs, and unmineable coal seams. This edition also presents a detailed look at the RCSP Initiative's large-scale field projects, which are uniquely tailored to address technical and non-technical challenges within their respective regions.

DOE Selects Five Projects to Produce Fresh Water from CO_2 Storage Sites.

DOE/NETL selected five projects to develop and validate strategies to manage pressure and the flow of CO_2 in saline

Announcements (Continued)

formations through a Brine Extraction Storage Test (BEST). The projects will be managed under the Carbon Storage Program and will support the clean energy and climate goals announced by the U.S. and Chinese governments in November 2014.



Carbon Storage Newsletter Annual Index 2015 Available.

This document is a compilation of NETL's Carbon Storage Newsletter published over the September 2014 to August 2015 timeframe. Outdated information (e.g., conference dates, paper submittals, etc.) has been removed.

ION Engineering Successfully Completes Pilot-Scale Testing of Carbon Capture Technology.

ION Engineering announced the successful completion of the first pilot-scale testing of its solvent and process technology for the removal of CO_2 from large stationary sources. The project involved 1,200 hours of continuous testing at the 0.6-MWe Pilot Solvent Test Unit (PSTU), located at the National Carbon Capture Center (NCCC) in Wilsonville, Alabama, USA. More than 99 percent of the CO_2 was captured from the facility's flue gas.

Cambridge Draft Climate Change Strategy Open for Consultation.

Cambridge City Council (in the United Kingdom) produced a draft "Climate Change Strategy 2016 to 2021," providing a framework for addressing potential climate change from April 2016 through March 2021. Public consultation on the draft strategy is being accepted, via survey, through January 12, 2016.

Carbon Storage in the News

"Southern Company Subsidiary and Korea Electric Power Corporation Sign MOU to Jointly Evaluate Clean Coal Technology Deployment Worldwide."

Southern Company Services, a subsidiary of Southern Company, and Korea Electric Power Corporation (KEPCO) will jointly explore the deployment of clean coal power generation and CCS technologies through a recently signed Memorandum of Understanding (MOU). Through the agreement, the companies will explore CCS and other technologies in the United States and the Republic of Korea, as well as other developing nations. In addition, the agreement provides for the testing of KEPCO's carbon capture technologies at NCCC in Alabama, USA. Operated by Southern Company Services and aligned with U.S. and Korean efforts to cost-effectively reduce greenhouse gas (GHG) emissions, NCCC conducts research and development (R&D) to evaluate and advance emerging carbon capture technologies through integration with a coal-fired power plant and pilot gasification facility. From *Southern Company News Release* on October 15, 2015.

"GroundMetrics, Inc. Awarded Contract for CO_2 EOR Flood Monitoring."

Electromagnetic survey company GroundMetrics, Inc. was awarded a contract for a CO_2 enhanced oil recovery (EOR) flood monitoring survey in the Frio Sands Formation. The time-lapse electromagnetic survey of CO_2 will take place in an oil reservoir with sensors at the surface. With the depth greater than 5,000 feet, acquiring data from the surface allows for the entire field to be surveyed. From *GlobeNewswire* on October 12, 2015.

"Shell's Quest $1.35 Billion Carbon-Capture Project Near Edmonton on Target for Completion."

More than 100,000 metric tons of compressed CO_2 have been stored during startup testing of Shell Canada's Quest CCS project. The oil sands CCS project is expected to reduce CO_2 emissions from the bitumen upgrader at Scotford by up to 35 percent (approximately 1 million metric tons per year). Construction was initiated in 2012, and was finished in March 2015; after the commissioning phase was completed in August 2015, testing began. The original plan called for approximately 25 to 28 million metric tons of CO_2 to be stored over the life of the project. However, according to officials, test results indicate the potential capacity of more than 30 million metric tons. From *Edmonton Journal* on October 20, 2015.

"Norway Renews Carbon Capture, Storage Pact with SA."

The Norwegian and South African (SA) governments have renewed their long-term partnership on CCS research. According to the South African Center for Carbon Capture and Storage, the SA government carries out its CCS research in four phases. The first phase (completed in 2004) looked into CCS potential in SA, while the second (completed in 2010) was to identify potential sites for long-term storage in an atlas, with applications filed for permits. The currently underway third phase will build a pilot plant (10,000 metric tons of CO_2 per year) at Bongwana near Harding in KwaZulu-Natal. The fourth phase will be to scale that plant to 100,000 metric tons of CO_2 per year, and then to 1 million metric tons of CO_2 per year. From *Business Day Live* on October 20, 2015.

"$500 Million Oil Recovery Project Wraps Up First Phase in Hobbs."

Occidental Petroleum Corporation (Oxy Permian) completed the first

Carbon Storage in the News (Continued)

phase of its $500 million CO_2 EOR project in an oil field in South Hobbs, New Mexico, USA. According to the company, oil production has doubled since operations began more than a decade ago. The South Hobbs project replaces water-only recovery with CO_2 flooding, which is considered by Oxy Permian to be a third-stage oil recovery method. From *Albuquerque Business First* on October 21, 2015.

"JRI, MHI, and INPEX Enter Contract… for Feasibility Study on CCS-EOR Projects in Southern Mexico."

A feasibility study consortium entered a contract in response to a public offer, titled "Feasibility Study on CCS-EOR projects in Southern Mexico – FY2015 Global Warming Mitigation Technology Promotion Project." The consortium, comprising of the Japan Research Institute, Limited (JRI); Mitsubishi Heavy Industries, Ltd. (MHI); and INPEX CORPORATION, would carry out the commissioned work from October 2015 to March 2016. The consortium would study the capability of CCS-EOR in Southern Mexico by implementing the evaluation of CO_2 sources at petrochemical plants and refineries, investigating the EOR targeted fields, estimating the overall business profitability, and conducting other studies as necessary. From *Mitsubishi Heavy Industries, Ltd. News Release* on October 23, 2015.

Science

"Game-Changing Process Mitigates CO_2 Emissions Using Renewable Energy."

DOE/NETL researchers conceived and developed a new process involving gold nanoparticles that can convert CO_2 into usable chemicals and fuels. The process, which has the potential to lead to an industrial-scale way to reduce CO_2 emissions, is a "carbon neutral" energy cycle, using renewable energy sources to recycle waste CO_2 into chemicals and fuels without generating new CO_2 emissions. In addition to limiting atmospheric CO_2 emissions, the process will also offer an environmentally friendly supplement to traditional energy sources and enable the sustainable use of current fossil fuel resources. The process was detailed in a peer-reviewed paper published in the American Chemical Society (ACS) "ACS Applied Materials & Interfaces" journal. Data from the study is also being used to inform critical performance estimates needed to move the carbon-neutral energy cycle into industrially relevant applications. The Abstract of the paper, titled "Efficient Electrochemical CO_2 Conversion Powered by Renewable Energy," is available in the "Technology" section of this newsletter. From *energy.gov* on October 21, 2015.

"New Crystal Captures Carbon from Humid Gas."

Scientists have created a new material with micropores that is capable of more efficiently capturing CO_2 in the presence of water than previously known materials. The result of international cooperation between scientists from Stockholm University and Sogang University in Korea, the new material, a copper silicate crystal, is stable and recyclable, with the micropores within having different adsorption sites for CO_2 and water. Scientists believe the material, called SGU-29, could be used for capturing atmospheric CO_2. The research was published in a report titled "CO_2 capture from humid flue gases and humid atmosphere using a microporous coppersilicate," the Abstract of which is available in the "Technology" section of this newsletter. From *Stockholm University* on October 15, 2015.

Policy

"Expanding U.S.-Indonesia Cooperation for Energy Development and Energy Security."

Building on the U.S.-Indonesia Comprehensive Partnership, the United States and Indonesia will further expand their partnership by promoting clean energy technologies and policies to help Indonesia's energy demands, improve energy access, and reduce energy-sector GHG emissions. Expanded cooperation includes support through the U.S. Agency for International Development (USAID) for clean energy development and to build Indonesian capacity to reduce carbon in land use and energy. For more information, view the "Joint Statement by the United States of America and the Republic of Indonesia," which includes a section on Energy Cooperation. From *The White House Fact Sheet* on October 26, 2015.

"*In silico* science for climate policy: How policy-makers process and use carbon storage simulation data."

The following is the Abstract of this article: "Knowledge gained from computer simulations in new earth-related technologies is not limited to the scientific community itself but impacts other domains of society such as politics, business and industry, and the public at large. In general business and industry in the oil and gas business are using computer simulations on a daily basis. In this case it is using computer simulations to gain understanding of the risk of a new technology which would affect the subsurface on a large scale and hence in Europe a substantial amount of people. So far, research did not consider in depth patterns of in silico science for policy. This paper analyses how policy-makers process and use simulation data based on a case-study of geo-scientific [CO_2] capture modeling. The empirical results are based on 19 qualitative interviews with decision-makers from politics, business and industry, and society. The empirical results reveal a great variety of co-existing perception, evaluation and use patterns of how decision-makers deal with simulations. The field work reveals that the current state-of-the-art in research literature which emphasizes an overall misperception, misunderstanding and misuse of simulation data by policy-makers is, in general, not backed by the case-study results. However, scientific simulations do leave considerable room for misunderstandings for experts not disposing on specific geo-scientific and simulation expertise." **Dirk Scheer**, *Environmental Science & Policy.* (Subscription may be required.)

Geology

"Opportunities and obstacles for CO_2 mineralization: CO_2 mineralization specific frames in the interviews of Finnish carbon capture and storage (CCS) experts."

The following is from the Abstract of this article: "CCS is expected to significantly reduce CO_2 emissions for climate change mitigation purposes. Currently, the EU CCS Directive contains only geological storage as the storage option for CO_2 – excluding CO_2 mineralization as a storage option. Since all CCS technologies are currently in a relatively early stage of development, this exclusion seems unreasonable. Opportunities for the use of CO_2 mineralization and the main uncertainties that can potentially prevent the use of these opportunities are investigated in this paper. The analysis is done by means of framing methodology that enables the extraction of CCS experts' mental models concerning CO_2 mineralization from the interview data." **Laura Kainiemi, Sanni Eloneva, Arho Toikka, Jarkko Levänen, and Mika Järvinen**, *Journal of Cleaner Production*. (Subscription may be required.)

Technology

"Efficient Electrochemical CO_2 Conversion Powered by Renewable Energy."

The following is the Abstract of this article: "The catalytic conversion of CO_2 into industrially relevant chemicals is one strategy for mitigating [GHG] emissions. Along these lines, electrochemical CO_2 conversion technologies are attractive because they can operate with high reaction rates at ambient conditions. However, electrochemical systems require electricity, and CO_2 conversion processes must integrate with carbon-free, renewable-energy sources to be viable on larger scales. [The authors] utilize Au_{25} nanoclusters as renewably powered CO_2 conversion electrocatalysts with $CO_2 \rightarrow CO$ reaction rates between 400 and 800 L of CO_2 per gram of catalytic metal per hour and product selectivities between 80 and 95 [percent]. These performance metrics correspond to conversion rates approaching 0.8–1.6 kg of CO_2 per gram of catalytic metal per hour. [The authors] also present data showing CO_2 conversion rates and product selectivity strongly depend on catalyst loading. Optimized systems demonstrate stable operation and reaction turnover numbers (TONs) approaching 6×10^6 mol_{CO_2} $mol_{catalyst}^{-1}$ during a multiday (36 h total hours) CO_2 electrolysis experiment containing multiple start/stop cycles. TONs between 1×10^6 and 4×10^6 mol_{CO_2} $mol_{catalyst}^{-1}$ were obtained when [the authors'] system was powered by consumer-grade renewable-energy sources. Daytime photovoltaic-powered CO_2 conversion was demonstrated for 12 h and [the authors] mimicked low-light or nighttime operation for 24 h with a solar-rechargeable battery. This proof-of-principle study provides some of the initial performance data necessary for assessing the scalability and technical viability of electrochemical CO_2 conversion technologies. Specifically, [the authors] show the following: (1) all electrochemical CO_2 conversion systems will produce a net increase in CO_2 emissions if they do not integrate with renewable-energy sources, (2) catalyst loading vs activity trends can be used to tune process rates and product distributions, and (3) state-of-the-art renewable-energy technologies are sufficient to power larger-scale, [metric ton] per day CO_2 conversion systems." **Douglas R. Kauffman, Jay Thakkar, Rajan Siva, Christopher Matranga, Paul R. Ohodnicki, Chenjie Zeng, and Rongchao Jin**, *ACS Appl. Mater. Interfaces*. (Subscription may be required.)

"CO_2 capture from humid flue gases and humid atmosphere using a microporous coppersilicate."

The following is the Abstract of this article: "Capturing CO_2 from humid flue gases and atmosphere with porous materials remains costly because prior dehydration of the gases is required. A large number of microporous materials with physical adsorption capacity have been developed as CO_2-capturing materials. However, most of them suffer from CO_2 sorption capacity reduction or structure decomposition that is caused by co-adsorbed H_2O when exposed to humid flue gases and atmosphere. [The authors] report a highly stable microporous coppersilicate. It has H_2O-specific and CO_2-specific adsorption sites but does not have H_2O/CO_2-sharing sites. Therefore, it readily adsorbs both H_2O and CO_2 from the humid flue gases and atmosphere, but the adsorbing H_2O does not interfere with the adsorption of CO_2. It is also highly stable after adsorption of H_2O and CO_2 because it was synthesized hydrothermally." **Shuvo Jit Datta, Chutharat Khumnoon, Zhen Hao Lee, Won Kyung Moon, Son Docao, Thanh Huu Nguyen, In Chul Hwang, Dohyun Moon, Peter Oleynikov, Osamu Terasaki, and Kyung Byung Yoon**, *Science*. (Subscription may be required.)

"A meta-analysis of carbon capture and storage technology assessments: Understanding the driving factors of variability in cost estimates."

The following is the Abstract of this article: "The estimated cost of reducing carbon emissions through the deployment of CCS in power systems vary by a factor of five or more across studies published over the past [eight] years. The objective of this paper is to understand the contribution of techno-economic variables and modeling assumptions to explain the large variability in the published international literature on cost of avoided CO_2 ($CACO_2$) using statistical methods. [The authors] carry out a meta-analysis of the variations in reported $CACO_2$ for coal and natural gas power plants with CCS. [The authors] use regression and correlation analysis to explain the variation in reported $CACO_2$. The regression models built in [the authors'] analysis have strong predictive power ($R^2 > 0.90$) for all power plant types. [The authors] find that the parameters that have high variability and large influence on the value of $CACO_2$ estimated are levelized cost of electricity (LCOE) penalty, capital cost of CCS, and efficiency penalty. In addition, the selection of baseline technologies and more attention and transparency around the calculation of capital costs will reduce the variability across studies to better reflect technology uncertainty and improve comparability across studies." **Oguz Akbilgic, Ganesh Doluweera, Maryam Mahmoudkhani, and Joule Bergerson**, *Applied Energy*. (Subscription may be required.)

Terrestrial

"The dynamic soil organic carbon mitigation potential of European cropland."

The following is the Abstract of this article: "Changes in soil organic

Terrestrial (Continued)

carbon stocks depend on the management regime and a variety of environmental factors including climatic conditions and soil properties. So far, the dynamics of soil organic carbon have not been explicitly represented in global economic land use optimization models. Here, [the authors] apply an approach to represent soil organic carbon dynamics explicitly in a global bottom-up recursive dynamic partial equilibrium model using carbon response functions simulated with a biophysical process-based model. [The authors] project soil organic carbon emissions from European cropland to decrease by 40 [percent] from 64 $MtCO_2$ in 2010 to about 39 $MtCO_2$ in 2050 mainly due to saturation effect when soils converge toward their equilibrium after management, crop rotation, or land use change. Moreover, [the authors] estimate a soil organic carbon mitigation potential for European cropland between 9 and 38 $MtCO_2$ per year until 2050 for carbon prices between 10 and 100 USD/tCO_2. The total European mitigation potential including co-benefits from the crop and livestock sector due to the carbon price is even higher with 60 $MtCO_2$ equivalents (eq) per year. Thus carbon [storage] in soils could compensate 7 [percent] of total emissions from agriculture within the EU, 10 [percent] when including co-benefits from the crop and livestock sector. However, as production is reallocated outside Europe with increasing carbon prices, emissions decrease in Europe but increase in the rest of the world (20 $MtCO_2$ eq). Preventing GHG emission [release] to the rest of the world would decrease the European soil organic carbon mitigation potential by around 9 [percent] and the total European mitigation potential including co-benefits by 16 [percent]. Nevertheless, the net global mitigation potential would still increase. [The authors] conclude that no significant contributions to emission reduction targets should be expected from the European cropland carbon [storage] options considered in this study." **Stefan Frank, Erwin Schmid, Petr Havlík, Uwe A. Schneider, Hannes Böttcher, Juraj Balkovič, and Michael Obersteiner,** *Global Environmental Change*. (Subscription may be required.)

"Evolution and variation of atmospheric carbon dioxide concentration over terrestrial ecosystems as derived from eddy covariance measurements."

The following is the Abstract of this article: "Carbon dioxide (CO_2) is the most important anthropogenic [GHG] contributing to global climate change. Understanding the temporal and spatial variations of CO_2 concentration over terrestrial ecosystems provides additional insight into global atmospheric variability of CO_2 concentration. Using 355 site-years of CO_2 concentration observations at 104 eddy-covariance flux tower sites in Northern Hemisphere, [the authors] presented a comprehensive analysis of evolution and variation of atmospheric CO_2 concentration over terrestrial ecosystem (ACTE) for the period of 1997–2006. [The authors'] results showed that ACTE exhibited a strong seasonal variations, with an average [seasonal] amplitude (peak-trough difference) of 14.8 ppm, which was approximately threefold that global mean CO_2 observed in Mauna Loa in the United States (MLO). The seasonal variation of CO_2 were mostly dominant by terrestrial carbon fluxes, i.e., net ecosystem procution (NEP) and gross primary production (GPP), with correlation coefficient(r) were −0.55 and −0.60 for NEP and GPP, respectively. However, the influence of carbon fluxes on CO_2 were not significant at interannual scale, which implied that the inter-annual changing trends of atmospheric CO_2 in Northern Hemisphere were likely to depend more on anthropogenic CO_2 emissions sources than on ecosystem change. It was estimated, by fitting a harmonic model to monthly-mean ACTE, that both annual mean and seasonal amplitude of ACTE increased over the 10-year period at rates of 2.04 and 0.60 ppm yr^{-1}, respectively. The uptrend of annual ACTE could be attributed to the dramatic global increase of CO_2 emissions during the study period, whereas the increasing amplitude could be related to the increases in Northern Hemisphere biospheric activity. This study also found that the annual CO_2 concentration showed large variation among ecosystems, with the high value appeared in deciduous broadleaf forest, evergreen broadleaf forest and cropland. [The authors] attribute these discrepancies to both differential local anthropogenic impacts and carbon [storage] abilities across ecosystem types." **Min Liu, Jiabing Wu, Xudong Zhu, Honglin He, Wenxiao Jia, and Weining Xiang**, *Atmospheric Environment*. (Subscription may be required.)

Trading

"Government to Raise $22 Billion from Carbon Pricing in 2015: Report."

According to a new report from the Climate Markets and Investment Association (CMIA), carbon pricing schemes, such as taxes and emissions trading systems (ETSs), will generate approximately $22 billion for their governments. The figure is up 46 percent from the estimated $15 billion raised in 2014, according to CMIA. The report, titled "Carbon Pricing Revenues," is available on the CMIA website. From *Reuters* on October 28, 2015.

"[Vietnam] Approves Plan for $3.6M Carbon Market."

Vietnam has approved a project to create a carbon market. Funded by the World Bank and Vietnamese government, the project would help to set up a database of GHG emissions throughout the country; issue policies and state management tools related to the carbon market; implement the Nationally Appropriate Mitigation Action (NAMA) to create carbon credits; and assist Vietnam in building a roadmap to participate in the global carbon market. From *Vietnam News* on October 28, 2015.

"Carbon emissions and stock returns: Evidence from the EU Emissions Trading Scheme."

The following is the Abstract of this article: "This paper provides an empirical investigation of the effect of the European Union's Emissions Trading Scheme on German stock returns. [The authors] find that, during the first few years of the scheme, firms that received free carbon emission allowances on average significantly outperformed firms that did not. This suggests the presence of a large and statistically significant 'carbon premium,' which is mainly explained by the higher cash flows due to the free allocation of carbon emission allowances. A carbon risk factor can also explain part of the cross-sectional variation of stock returns as firms with high carbon emissions have higher exposure to carbon risk and exhibit higher expected returns." **A. Marcel Oestreich and Ilias Tsiakas**, *Journal of Banking & Finance*. (Subscription may be required.)

Recent Publications

"Assessing the Social Costs and Benefits of Regulating Carbon Emissions."

The following is the Executive Summary of this document: "U.S. government agencies are required to quantify the costs and benefits of regulations they propose. In the context of regulations pertaining to carbon emissions, the various agencies had been using differing (often implicit) estimates of the net social cost of carbon. In response, an Interagency Working Group was created in order to establish a consistent and objective 'social cost of carbon' (SCC). Although wide, the range of estimates of the social cost of carbon produced by the Interagency Working Group is both too narrow and almost certainly biased upwards. This is a consequence of using only three rather simplistic models, all of which use estimates of climate sensitivity that are likely too high and two of which likely overestimate the economic impact of climate change. Taking into account a wider range of climate models, impact evaluations, economic forecasts and discount rates, as well as the most recent evidence on climate sensitivity, this study finds that the range of social cost of carbon should be revised downwards. At the low end, carbon emissions may have a net beneficial effect (i.e. carbon should be priced negatively), while even at the high end carbon emissions are very unlikely to be catastrophic. Given this range of possible 'damage functions,' combined with significant uncertainty concerning the costs of limiting emissions of [CO_2] and other [GHGs]—costs which may, among other things, slow down the rate at which poor countries develop, thereby making the inhabitants of those countries more susceptible to climate and other changes—the social cost of carbon should be set at zero."

"Global CCS Institute CSS Legal and Regulatory Indicator."

The following is from the Executive Summary of this document: "The development of law and regulation to support the deployment of CCS has proven an important aspect of a national policy response to the technology. National regulators and regional legislatures in a number of jurisdictions globally have, in recent years, amended legislation or enacted legal and regulatory frameworks to address the technology. The Institute's CCS Legal and Regulatory Indicator ('the Indicator') offers a more detailed examination and assessment of national legal and regulatory frameworks, by considering a broad range of legal and regulatory factors, which are likely critical in the regulation of the technology. A broad spectrum of administrative and permitting arrangements across the project lifecycle, including issues related to environmental assessments, public consultation and long-term liability, have been considered. The resulting Indicator therefore represents a detailed assessment of each individual jurisdiction's legal and regulatory frameworks for the technology, as well as offering a comprehensive model for tracking progress and opportunities for the development of legal frameworks worldwide."

"Carbon Capture and Storage: The Lacq pilot – Project and injection period 2006-2013."

The following is from the Introduction of this document: "This book presents the results of a pilot project implementing for the first time the complete CCS chain in an industrial environment. This pilot was designed, built and operated by Total for more than three years. The CCS pilot project entailed the conversion of an existing air-gas combustion boiler into an oxygen-gas combustion boiler, using oxygen delivered by an air separation unit (ASU) to obtain a more CO_2 concentrated (and easier to capture) flue gas stream. The 30 MWth oxy-boiler was able to deliver up to 38 t/h of steam to the high pressure (HP) steam network of the Lacq sour gas production and treatment plant. After quenching of the flue gas stream, the CO_2 stream was compressed (to 27 barg), dried and transported in a gaseous phase via existing pipelines to the Rousse depleted gas field, 29 kilometers away, where it was injected. Over the injection period of 39 months, 51,340 metric tons of CO_2 were injected. Total's main objectives in this experiment were: [1] To demonstrate the technical feasibility and reliability of an integrated chain comprising CO_2 capture, transportation and injection into a depleted gas reservoir; [2] To acquire operating experience and data to upscale the oxy-combustion technology from pilot (30 MWth) to industrial scale (200 MWth) while downscaling the 'oxy-combustion' capture cost compared to classical post capture technologies; [3] To develop and apply geological storage qualification methodologies, monitoring methodologies and technologies on site to serve in future onshore storage monitoring programs that will be larger in scale, longer in time and economically and technically viable; [4] To promote CCS knowledge sharing among a range of stakeholders, from governments, public institutions, industry, academia, non-governmental organizations, to the local communities and the broader public, through an outreach and communication program of activities including face-to-face meetings, workshops and technical meetings, site visits, informative videos, open days with site tours and press releases. This book shares the project's scientific results as well as the major achievements and lessons learnt."

"Prospects for CO_2-EOR in the UKCS."

The following is from the Executive Summary of this document: "The UK's oil and gas industry has made a significant contribution to UK GDP over the last fifty years. However, the North Sea basin is mature and is expected to see major decommissioning over the next 10-15 years. Recovery of remaining oil reserves could be significantly improved by greater use of [EOR] techniques. One option involves injecting CO_2 into the oil reservoirs to [mobilize] the remaining oil (CO_2-EOR). It is a mature technology that has been used onshore in the USA for 40 years, where it has benefited from large natural sources of CO_2. It has the additional benefit of providing low-cost storage space for CO_2 emissions. An un-risked screening of technical EOR potential across the oil fields in the UK Continental Shelf (UKCS) identified a resource of up to 6 billion barrels of additional oil, with storage for [more than 1 billion metric tons] of CO_2. However, CO_2-EOR is untested at scale offshore, as yet, and therefore faces technical, commercial and economic risks. Less than a tenth of the un-risked potential is likely to be

Recent Publications (Continued)

[realizable] when economic, commercial and operational risks are taken into account. Developing CO_2-EOR could extend the life of the oil fields for up to 15 years, delaying of decommissioning and sustaining the wider UK oil industry. By providing secure, low-cost CO_2 storage, CO_2-EOR will benefit the development of CCS, which, in turn, will reduce the cost of achieving the UK's energy and carbon targets. Furthermore, developing the CO_2 transport infrastructure in the North Sea to supply CO_2-EOR could help open up the best and largest CO_2 storage assets in Europe. A new industry could be developed in the UK North Sea storing CO_2 and providing opportunities to manage emissions from [neighboring] EU member states."

"Methodology for Greenhouse Gas Emission Reductions from Carbon Capture and Storage Projects."

The following is the Background and Applicability section of this document: "CCS is the separation and capture of CO_2 from the atmospheric emissions of industrial processes or the direct air capture (DAC) of atmospheric CO_2 and the transport and safe, permanent storage of the CO_2 in deep underground geologic formations. In CCS, CO_2 that would otherwise have been emitted into the atmosphere or that currently resides in the atmosphere is captured and disposed of underground. By preventing CO_2 from large-scale industrial facilities from entering the atmosphere or by removing the CO_2 that currently resides in the atmosphere, CCS is a powerful tool for addressing potential climate change. Geologic storage is defined as the placement of CO_2 into a subsurface formation so that it will remain safely and permanently stored. Examples of subsurface formations include deep saline [formations] and oil and gas producing reservoirs. The CO_2 for geologic storage comes either from industrial facilities that emit large amounts of CO_2, particularly those that burn coal, oil, or natural gas; or potentially directly from the atmosphere via large-scale chemical DAC facilities. Industrial facilities include power plants, petroleum refineries, oil and gas production facilities, iron and steel mills, cement plants, and various chemical plants. This methodology outlines the requirements and process for CCS Project Proponents that store CO_2 in oil and gas reservoirs to qualify their projects for carbon credits under the American Carbon Registry® (ACR) program. The methodology is based on the accounting framework developed by the Center for Climate and Energy Solutions (formerly the Pew Center on Global Climate Change)."

Legislative Activity

"South Africa Consults On Carbon Tax Legislation."

South Africa's National Treasury has published draft carbon tax legislation for public comment. The South African government has committed to reduce its GHG emissions below current levels by 34 percent by 2020, and by 42 percent by 2025. The carbon offsets are expected to enable firms to cost-effectively lower their carbon tax liability while incentivizing investment in GHG emission-reduction projects. From *Tax-News* on November 5, 2015.

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 **National Energy Technology Laboratory's CCS Database** includes active, proposed, and terminated CCS projects worldwide. The information is taken from publically available sources to provide convenient access to information regarding efforts by various industries, public groups, and governments towards development and eventual deployment of CCS technology. NETL's CCS Database is available as a Microsoft Excel spreadsheet and also as a customizable layer in Google Earth.

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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NETL on Facebook

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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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