NETL the ENERGY lab

OCTOBER 2015

Carbon Storage Newsletter

What's Inside?

Highlights

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

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) released the fifth edition of the Carbon Storage Atlas (Atlas V), which shows prospective carbon dioxide (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 Regional Carbon Sequestration Partnership (RCSP) Initiative's large-scale field projects, which are uniquely tailored to address technical and non-technical challenges within their respective regions. For each large-scale field project, Atlas V provides a summary of approaches taken, technologies validated, and lessons learned in carrying out key aspects of a carbon capture and storage (CCS) project: site characterization; risk assessment; simulation and modeling; monitoring, verification, accounting, and assessment; site operations; and public outreach. These efforts collectively contribute to the development of regional carbon management plans, aid in regulatory development, and help determine appropriate infrastructure for CCS commercialization in each region. From *NETL News Release* on September 28, 2015.

"Energy Department Selects Five Projects in First Step 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 formations through a Brine Extraction Storage Test (BEST). The projects will be managed by DOE/NETL under the Carbon Storage Program. In addition, the selected projects will also support the clean energy and climate goals announced by the U.S. and Chinese governments in November 2014. Following the feasibility and design phase, one of the recipients will be selected for a pilot project to validate brine/water injection and treatment technology. From *energy.gov* on September 16, 2015.

Announcements

DOE/NETL Funding Announcement.

DOE/NETL's Carbon Storage Program will fund nine projects to research new CO_2 storage technologies devoted to intelligent monitoring systems and advanced well integrity and mitigation approaches. The selected projects focus on the following three research priorities: (1) CCS-specific intelligent systems for monitoring, controlling, and optimizing CO_2 injection operations; (2) diagnostic tools and methods capable of characterizing borehole release pathways or fluid flow in existing wells; and (3) next-generation materials and methods for mitigating wellbore release.

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.

Announcements (Continued)

Quest CCS Project Set to Launch.

Shell announced that its Quest CCS project, which is expected to store approximately 1 million metric tons of CO_2 per year from the Scotford Upgrader, will officially launch in November 2015. The Quest project will capture and compress the CO_2 produced by the Upgrader, then transport it via underground pipeline to three injection wells. Quest's underground CO_2 storage will be monitored through a measurement, monitoring, and verification program.

Carbon Storage in the News

"BHP Billiton and SaskPower Partner to Accelerate Development of Carbon Capture & Storage."

SaskPower will share data, information, and lessons learned from its Boundary Dam facility with BHP Billiton in a new partnership to accelerate the global development of CCS technology. Under the Memorandum of Understanding (MOU), BHP Billiton would contribute to the establishment of a global knowledge center focused on promoting research and reducing potential costs and risks associated with new CCS projects. From *BHP Billiton News Release* on September 10, 2015.

"Devon to Dedicate \$100M CO_2 Oil Recovery Project."

Devon Energy will invest approximately \$100 million into a CO_2 injection facility to serve the Big Sand Draw in the Wind River Basin near Riverton, Wyoming, USA. The investment will be used for enhanced oil recovery (EOR). According to Devon officials, the company is currently producing 2,500 barrels of CO_2 per day at Big Sand Draw; the company expects production to peak beyond 5,000 barrels per day in the near future as more wells come online. From *Wyoming Business Report* on September 18, 2015.

"UK Government Awards [Approximately \$2.6 Million] to CCS Projects."

The United Kingdom (UK) government's Energy Entrepreneurs Fund awarded funding to three projects for the development and demonstration of CCS technologies to support cost reductions and innovation. In one project, Carbon Clean Solutions, Ltd., will compare the performance of different solvents to remove CO_2 from flue gases. In another project, C-Capture, Ltd., will investigate amine-free solvents for suitability and scaling-up for industry use. In the final project, FET Engineering, Ltd., will aim to make their PureStream technology available for commercial deployment by 2017. From *Carbon Capture Journal* on October 2, 2015.

"British Study Finds New Potential for Carbon Storage."

According to a case study on CCS in the North Sea, CO_2 storage in geologic formations could be optimized by injecting the CO_2 into two points simultaneously. The British Geological Survey (BGS) case study found that using the "dual-injection" method allowed for storing more CO_2 in less area. The BGS case study was conducted in the Captain Sandstone in the North Sea, which lies more than one mile beneath the sea surface off the northeast coast of Scotland. More information on the study is available via a Scottish Carbon Capture and Storage (SCCS) press release. From *UPI.com* on September 10, 2015.

"North Sea Carbon Storage Scheme Gets Support."

The UK government announced plans to support a Royal Dutch Shell CCS program in the North Sea. With assistance from a UK energy company, Royal Dutch Shell is proposing to capture CO_2 released from an Aberdeen power station and store it in the Goldeneye reservoir in the North Sea. According to a study conducted by BGS, Royal Dutch Shell's Peterhead CCS project has the potential to store up to 20 million tons of CO_2. From *UPI.com* on September 14, 2015.

Science

"Protected Areas Save Mangroves, Reduce Carbon Emissions."

According to a study published in the journal "Ecological Economics," protected areas that keep Indonesia's mangrove habitats intact also prevent the release of CO_2 emissions. Mangroves are dense forests of trees and shrubs that grow in low-lying coastal areas. Using a detailed, country-wide dataset, the analysis states that keeping the mangroves "avoided release of approximately 13 million metric tons of CO_2 into the atmosphere." The Abstract of this study, titled "Do protected areas reduce blue carbon emissions? A quasi-experimental evaluation of mangroves in Indonesia," is available in the "Terrestrial" section of this newsletter. From *EurekAlert!* on September 14, 2015.

"Gas 'Fingerprinting' Could Help Energy Industry Manage Carbon Dioxide Storage."

A new technique for monitoring CO_2, discovered by scientists from the Scottish Universities Environmental Research Center (SUERC), has the potential to contribute to the energy industry's efforts to reduce future greenhouse gas (GHG) emissions, a recently published study claims. Using gas samples collected from wells at the Cranfield CO_2-EOR field in Mississippi, USA, from 2009 and 2012, SUERC researchers used the unique signature from traces of noble gases (in this case, helium, neon, and argon) to monitor the fate of CO_2 stored underground. The study, titled "Tracing injected CO_2 in the Cranfield enhanced oil recovery field (MS, USA) using He, Ne and Ar isotopes," was published in the "International Journal of Greenhouse Gas Control." From *University of Glasgow* on October 5, 2015.

Science (Continued)

"BYU Technology Tackles Climate Change by Freezing Carbon."

A scientist from Brigham Young University (BYU) has developed a system that prevents the release of CO_2 into the atmosphere by freezing it and capturing up to 99 percent of it in the process. The system freezes the CO_2 with -130 degrees Celsius (-202 degrees Fahrenheit) temperatures, separates the dry ice from the gas, and then heats everything back up. The CO_2 is then pressurized into liquid form for uses such as EOR. An overview of the technology was published in the "International Journal of Greenhouse Control." The Abstract of the paper, titled "Prediction and validation of external cooling loop cryogenic carbon capture (CCC-ECL) for full-scale coal-fired power plant retrofit," is available in the "Technology" section of this newsletter. From *BYU News Release* on September 28, 2015.

Policy

"Québec Sets New Greenhouse Gas Reduction Targets."

The province of Québec, Canada, at the recommendation of its consultation committee on potential climate change, announced plans to cut its GHG emissions to 37.5 percent below 1990 levels by 2030. The Québec government will present its plans at the 21st Conference of the Parties (COP-21) to the United Nations Framework Convention on Climate Change (UNFCCC), scheduled to be held in Paris, France, in December 2015. More information is available in the Minister of Sustainable Development, Environment and the Fight Against Climate Change Press Release. From *CBC News* on September 17, 2015.

Washington to Set Carbon Emission Limits.

The Washington Department of Ecology is drafting a rule that would require a portion of the state of Washington's CO_2 emitters to reduce their GHGs. Businesses and organizations responsible for producing 100,000 metric tons or more of GHGs could potentially be covered under the rule. Over the next year, public meetings and hearings will be held to gather input from stakeholders. More information is available on the Washington State Department of Ecology website. From *Washington State Department of Ecology News Release* on September 21, 2015.

"Economic evaluation on CO_2-EOR of onshore oil fields in China."

The following is the Abstract of this article: "Carbon dioxide enhanced oil recovery (CO_2-EOR) and [storage] in depleted oil reservoirs is a plausible option for utilizing anthropogenic CO_2 to increase oil production while storing CO_2 underground. Evaluation of the storage resources and cost of potential CO_2-EOR projects is an essential step before the commencement of large-scale deployment of such activities. In this paper, a hybrid techno-economic evaluation method, including a performance model and cost model for onshore CO_2-EOR projects, has been developed based on previous studies. Total 296 onshore oil fields, accounting for about 70 [percent] of total mature onshore oil fields in China, were evaluated by the techno-economic method. The key findings of this study are summarized as follows: (1) deterministic analysis shows there are approximately 1.1 billion tons (7.7 billion barrels) of incremental crude oil and 2.2 billion tons CO_2 storage resource for onshore CO_2-EOR at net positive revenue within the Chinese oil fields reviewed under the given operating strategy and economic assumptions. (2) Sensitivity study highlights that the cumulative oil production and cumulative CO_2 storage resource are very sensitive to crude oil price, CO_2 cost, project lifetime, discount rate and tax policy. High oil price, short project lifetime, low discount rate, low CO_2 cost, and low tax policy can greatly increase the net income of the oil enterprise, incremental oil recovery and CO_2 storage resource. (3) From this techno-economic evaluation, the major barriers to large-scale deployment of CO_2-EOR include complex geological conditions, low API of crude oil, high tax policy, and lack of incentives for the CO_2-EOR project." **Ning Wei, Xiaochun Li, Robert T. Dahowski, Casie L. Davidson, Shengnan Liu, and Yongjin Zha**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

Geology

"Capillarity and wetting of carbon dioxide and brine during drainage in Berea sandstone at reservoir conditions."

The following is the Abstract of this article: "The wettability of CO_2-brine-rock systems will have a major impact on the management of carbon [storage] in subsurface geological formations. Recent contact angle measurement studies have reported sensitivity in wetting behavior of this system to pressure, temperature, and brine salinity. [The authors] report observations of the impact of reservoir conditions on the capillary pressure characteristic curve and relative permeability of a single Berea sandstone during drainage—CO_2 displacing brine—through effects on the wetting state. Eight reservoir condition drainage capillary pressure characteristic curves were measured using CO_2 and brine in a single fired Berea sandstone at pressures (5–20 MPa), temperatures (25–50°C), and ionic strengths (0–5 mol kg^{-1} NaCl). A ninth measurement using a N_2-water system provided a benchmark for capillarity with a strongly water wet system. The capillary pressure curves from each of the tests were found to be similar to the N_2-water curve when scaled by the interfacial tension. Reservoir conditions were not found to have a significant impact on the capillary strength of the CO_2-brine system during drainage through a variation in the wetting state. Two steady-state relative permeability measurements with CO_2 and brine and one with N_2 and brine similarly show little variation between conditions, consistent with the observation that the CO_2-brine-sandstone system is water wetting and multiphase flow properties invariant across a wide range of reservoir conditions." **Ali Al-Menhali, Ben Niu, and Samuel Krevor**, *Water Resources Research*. (Subscription may be required.)

"CO_2-induced mechanical [behavior] of Hawkesbury sandstone in the Gosford basin: An experimental study."

The following is the Abstract of this article: "CO_2 [stored] in saline [formations] undergoes a variety of chemically-coupled mechanical effects, which may cause CO_2-induced mechanical changes and time-dependent reservoir deformation. This paper investigates the mineralogical and microstructural changes that occur in reservoir rocks following injection of CO_2 in deep saline [formations] and the manner in which these changes influence the mechanical properties of the

Geology (Continued)

reservoir rocks. In this study, cylindrical sandstone specimens, 38 mm in diameter and 76 mm high, obtained from the Gosford basin, were used to perform a series of unconfined compressive strength (UCS) tests. Different saturation conditions: dry, water- and brine-saturated sandstone samples with and without $scCO_2$ (super-critical carbon dioxide) injection, were considered in the study to obtain a comprehensive understanding of the impact of $scCO_2$ injection during the CO_2 [storage] process on saline [formation] mechanical properties. An acoustic emission (AE) system was employed to identify the stress threshold values of crack closure, crack initiation and crack damage for each testing condition during the whole deformation process of the specimens. Finally, scanning electron microscopy (SEM), X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses were performed to evaluate the chemical and mineralogical changes that occur in reservoir rocks during CO_2 injection. From the test results, it is clear that the CO_2-saturated samples possessed a lower peak strength compared to non-CO_2 saturated samples. According to SEM, XRD and XRF analyses, considerable quartz mineral corrosion and dissolution of calcite and siderite were observed during the interactions of the CO_2/water/rock and CO_2/brine/rock systems, which implies that mineralogical and geochemical rock alterations affect rock mechanical properties by accelerating the collapse mechanisms of the pore matrix. AE results also reveal the weakening effect of rock pore structure with CO_2 injection, which suggests a significant effect of CO_2 on failure mechanisms of the reservoir rock, with CO_2 saturation showing a significant influence on crack initiation and crack damage stages." **T.D. Rathnaweera, P.G. Ranjith, M.S.A. Perera, A. Haque, A. Lashin, N. Al Arifi, D Chandrasekharam, SQ Yang, T Xu, SH Wang, and E Yasar,** *Materials Science and Engineering A*. (Subscription may be required.)

Technology

"Reducing uncertainty associated with CO_2 injection and brine production in heterogeneous formations."

The following is the Abstract of this article: "Spatial heterogeneity and variability across many orders of magnitude are two properties of formation permeability that are challenging to effectively capture in subsurface flow models. With regard to geological CO_2 storage, heterogeneity affects storage capacity, plume migration, pressure build-up around injection wells and, if utilized, the possibility of early breakthrough at brine extraction wells. Faced with under-characterized heterogeneity and an information-poor environment, the challenge is to make as much use as possible of the available data in reducing uncertainty associated with model prediction of a CO_2 injection operation. The two types of data used here to inform models are point permeability measurements from each well and interference tests between wells; these are both obtained from a synthetic permeability distribution approximating a hypothetical CO_2 storage formation. These data are used to reduce uncertainty in predictions of CO_2 injection, brine and CO_2 production rates, and CO_2 breakthrough times obtained from simulations of five-spot CO_2 injection/brine production performed on >600 conditional permeability realizations. First, assuming the underlying permeability field exhibits long-range correlation and a log-normal permeability distribution, a Bayesian analysis was undertaken using the point permeability measurements to reduce the likely magnitude of permeability heterogeneity. Comparison of realizations drawn from the prior and posterior indicate that the data were sufficient to exclude extreme scenarios with very rapid or very slow CO_2 transport and breakthrough at brine production wells. Thirty-year prediction envelopes for net CO_2 retention, brine and CO_2 production were reduced by 40, 45 and 72 [percent], respectively. In the second stage, simulated interference tests for each of the posterior realizations were compared against interference tests simulated for the synthetic 'true' permeability field. Weighting functions derived from these comparisons are used to further refine predictions, providing additional reductions of uncertainty by 38 and 69 [percent] for brine and CO_2 production rates, respectively. Predictions of CO_2 breakthrough are especially sensitive to analysis of interference tests, with a good estimate of the correct time obtained in three out of four cases." **David Dempsey, Daniel O'Malley, and Rajesh Pawar**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

"Assessing the usefulness of the isotopic composition of CO_2 for [release] monitoring at CO_2 storage sites: A review."

The following is the Abstract of this article: "[Geologic] storage of injected CO_2 is a promising technology to reduce CO_2 emissions into the atmosphere. Tracer methods are an essential tool to monitor CO_2 plume distribution in the target formation and to enable tracking potential [release] of CO_2 outside the storage reservoir. Here, [the authors] demonstrate that the isotopic composition of CO_2 can serve as a suitable tracer at large CO_2 injection sites provided that the injected CO_2 is isotopically distinct from background CO_2 sources that are usually composed of dissolved inorganic carbon, bedrock-derived carbon, and soil CO_2. Very [favorable] conditions for this tracer approach exist if δ13C values of injected CO_2 are more than 10‰ different from those of baseline CO_2 and other dissolved inorganic carbon species at the CCS site. In this case, changes in δ13C values accompanied with increasing concentrations of CO_2 or DIC in samples obtained regularly at monitoring sites within or above the storage reservoir indicate arrival of injected CO_2. The proportion of injected CO_2 contributing to the obtained samples can be quantified when carbon isotope fractionation effects are either negligible or thoroughly known. [The authors] point out several areas where additional detailed information on carbon isotope effects during phase change, transport and geochemical reactions is desirable to refine this tracer approach for temperature, pressure and salinity conditions relevant for CO_2 storage sites. Oxygen isotope ratios of injected CO_2 were not found to be a conservative tracer due to oxygen isotope exchange between CO_2 and water on time scales of hours to a few days. δ18O measurements on CO_2 and H_2O have, however, revealed pore space saturation with CO_2 and hence indicate the presence of injected CO_2 within CO_2 storage reservoirs. [The authors] suggest that the stable isotopic composition of injected CO_2 is a suitable tracer for assessing the movement and fate of injected CO_2 in the target reservoir and for [release] detection at CO_2 storage sites, provided that the injected CO_2 is isotopically distinct from background CO_2 sources. A key advantage is that this tracer approach does not depend on the co-injection of additional tracers and hence can be continuously used in large-scale commercial storage projects with CO_2 injection rates exceeding 1 million [metric

Technology (Continued)

tons] per year at reasonable cost." **B. Mayer, P. Humez, V. Becker, C. Dalkhaa, L. Rock, A. Myrttinen, and J.A.C. Barth**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

"Prediction and validation of external cooling loop cryogenic carbon capture (CCC-ECL) for full-scale coal-fired power plant retrofit."

The following is the Abstract of this article: "Bench-scale experiments and Aspen Plus™ simulations document full-scale, steady-state performance of the external cooling loop cryogenic carbon capture (CCC-ECL) process for a 550 MWe coal-fired power plant. The baseline CCC-ECL process achieves 90 [percent] CO_2 capture, and has the potential to capture 99+ [percent] of CO_2, SO_2, PM, NO_2, Hg, and most other noxious species. The CCC-ECL process cools power plant flue gas to 175 K, at which point solid CO_2 particles desublimate as the flue gas further cools to 154 K. Desublimating flue gas cools in a staged column in direct contact with a cryogenic liquid and produces a CO_2-lean flue gas that warms against the incoming flue gas before venting. The CO_2/contacting liquid slurry separates through a filter to produce a CO_2 stream that warms to 233 K and partially flashes to provide a CO_2-rich product. The CO_2–rich product (99.2 [percent]) liquefies under pressure to form a product for EOR or [storage]. All contacting liquid streams cool and cycle back to the staged column. An internal CF4 refrigeration cycle transfers heat from melting CO_2 to desublimating CO_2 by cooling contact liquid. An external cooling loop of natural gas or other refrigerant provides the additional heat duty to operate the cryogenic process. The nominal parasitic power loss of operating CCC-ECL is 82.6 MWe or about 15 [percent] of the coal-fired power plant's rated capacity. In different units, the energy penalty of CCC-ECL is 0.74 MJe/kg CO_2 captured and the resulting net power output is decreased to 467 MWe. Lab- and skid-scale measurements validate the basic operation of the process along with the thermodynamics of CO_2 solids formation." **Mark J. Jensen, Christopher S. Russell, David Bergeson, Christopher D. Hoeger, David J. Frankman, Christopher S. Bence, and Larry L. Baxter**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

Terrestrail

"Do protected areas reduce blue carbon emissions? A quasi-experimental evaluation of mangroves in Indonesia."

The following is the Abstract of this article: "Mangroves provide multiple ecosystem services such as blue carbon [storage], storm protection, and unique habitat for species. Despite these services, mangroves are being lost at rapid rates around the world. Using the best available biophysical and socio-economic data, [the authors] present the first rigorous large-scale evaluation of the effectiveness of protected areas (PAs) at conserving mangroves and reducing blue carbon emissions. [The authors] focus on Indonesia as it has the largest absolute area of mangroves (about 22.6 [percent] of the world's mangroves), is one of the most diverse in terms of mangrove species and has been losing its mangroves at a very fast rate. Specifically, [the authors] apply quasi-experimental techniques (combining propensity score and covariate matching, differences-in-differences, and post-matching bias adjustments) to assess whether PAs prevented mangrove loss between 2000 and 2010. [The authors'] results show that marine protected areas reduced mangrove loss by about 14,000 ha and avoided blue carbon emissions of approximately 13 million metric tons (CO_2 equivalent). However, [the authors] find no evidence that species management PAs stalled the loss of mangroves. [The authors] conclude by providing illustrative estimates of the blue carbon benefits of establishing PAs, which can be cost-effective policies for mitigating climate change and biodiversity loss." **Daniela A. Miteva, Brian C. Murray, and Subhrendu K. Pattanayak**, *Ecological Economics*. (Subscription may be required.)

Trading

"CO_2 Allowances Sold for \$6.02 in 29th RGGI Auction."

The states participating in the Regional Greenhouse Gas Initiative (RGGI) announced that 25,374,294 CO_2 allowances sold in their 29th auction of CO_2 allowances were sold at a clearing price of $6.02. The total allowances sold included both the initial offering of 15,374,294 CO_2 allowances, as well as the 10 million additional Cost Containment Reserve (CCR) allowances. The CCR is a fixed supply of 10 million allowances only available for sale if CO_2 allowance prices exceed certain price levels; there are no more CCR allowances available for 2015 (the CCR will be replenished in 2016). In addition, the Auction Notice and application materials for the 30th quarterly auction, to be held on December 2, 2015, were released. The Auction Notice for CO_2 Allowance Auction 30 provides the information needed to submit a Qualification Application and indicate intent to bid. The RGGI states will offer 15,374,274 CO_2 allowances for sale using a reserve price of $2.05. This will be the last quarterly auction in which states will offer CO_2 allowances for purchase to meet CO_2 interim compliance obligations for the 2015 interim control period, which began on January 1, 2015. To date, RGGI CO_2 allowance auctions have generated a total of more than $2.2 billion for reinvestment in strategic programs, such as GHG abatement and renewable energy programs. From *RGGI* on September 11, 2015, and October 5, 2015.

Recent Publications

"An Executable Plan for enabling CCS in Europe."

The following is from the Executive Summary of this document: "Emitting CO_2 to the atmosphere is currently much cheaper than storing it safely underground. Emitters can pay an 'ETS wergild' and are divorced from all the consequences of their actions, yet if they try to [store] CO_2

they risk taking on liability for decades under the CO_2 Storage Directive. Those factors serve, along with the lack of a near-term business case, to prolong the current inertia on CCS in the [European Union (EU)]. Urgent action is now required to deliver CO_2 storage projects and enabling infrastructure in preparation for commercial deployment. This requires an Executable Plan, owned by the European Commission. This note sketches the contours of such a plan, describing how the Commission can effectively and rapidly aid wide uptake of CCS in Europe; delivering additional CCS projects in power and industry; progressing the development of CCS hubs in Europe; and supporting the appraisal of storage capacity required for commercial CCS deployment. The Executable Plan has been prepared in response to discussion of the 5 Point Action Plan (ANNEX 1) for CCS […] It draws solely on existing policies and public financing opportunities, with the aim to enable their most efficient and effective use. It is designed to feed into the SET Plan preparation and next steps on the Energy Union Strategy. The proposed plan builds on [Zero Emissions Platform's (ZEP's)] insights into the principles for development of CCS in Europe, in particular the need to: decouple the capture of CO_2 from transport and storage (T&S); develop CCS in phases through (expanding) infrastructure hubs; optimize available funding and create mechanisms to [commercialize] CCS; and engage [Member State (MS)] though 2050 decarbonisation plans to enable the development of T&S infrastructure."

"[Optimizing] CO_2 storage in geological formations; a case study offshore Scotland."

The following is from the Executive Summary of this document: "CCS is considered a key technology to provide a secure, low-carbon energy supply and reduce the [GHG] emissions that contribute to the adverse effects of climatic change. [Commercialization] projects for the permanent storage of CO_2 captured at power plants are currently in the design stage for the Peterhead, White Rose, Caledonia Clean Energy and Don Valley projects. Storage of the CO_2 captured by these projects is planned in strata deep beneath the North Sea in depleted hydrocarbon fields or regionally extensive sandstones containing brine (saline [formation] sandstones). The vast majority of the UK and Scotland's potential storage resource, which is of European significance, is within brine-saturated sandstone formations. The sandstone formations are each hundreds to thousands of square [kilometers] in extent and underlie all sectors of the North Sea. The immense potential to store CO_2 in these rocks can only be fully achieved by the operation of more than one injection site within each formation. Government, university and research institutes, industry, and stakeholder [organizations] have anticipated the need to inform a second phase of CCS developments following on from a [commercialization] project in Scotland. The CO_2 MultiStore study, led by SCCS, investigates the operation of more than one injection site within a storage formation using a North Sea case study. The Captain Sandstone, within the mature oil and gas province offshore Scotland, contains the Goldeneye Field, which is the planned storage site for the Peterhead CCS project. Previous research was augmented by data from offshore hydrocarbon exploration and detailed investigation of the Goldeneye Field for CO_2 storage…"

"CarbonNet storage site selection and certification: challenges and successes."

The following is from the Abstract of this document: "The CarbonNet Project is seeking CO_2 storage sites in the nearshore area of the Gippsland Basin that provide permanent and safe storage for 25 to 125 Mt of CO_2. The process used by CarbonNet for site selection follows international best practice, aligned to DNV GL Recommended Practice (DNV-RP-J203) to provide decision makers and stakeholders with independent expert assurance of environmentally safe, long-term [geologic] storage. The DNV-RP-J203 requires a systematic approach, based on understanding and minimizing storage risks and analysis of diverse geoscience and environmental factors. The main areas of investigation include: [selection and qualification of storage sites; documentation of site [characterization] and site development plans; risk management throughout the life cycle of CO_2 [geologic] storage projects; monitoring and storage performance verification; well assessment and management planning; and planning for site closure and subsequent stewardship]. The CarbonNet Project reviewed more than twenty five storage concepts at fourteen locations, within 25km of the coastline. These were quantified for prospective storage volume and risk for capacity, containment, and injectivity. A portfolio of three sites was shortlisted. CarbonNet has had its storage site selection process endorsed by an Independent Scientific Peer Review and the site selection process was assessed by DNV GL and a Statement of Feasibility issued for the portfolio in January 2013. Detailed site-specific risk analyses and data gap analyses of key elements were prepared for each site. As a result, a [prioritized] site was selected for further analysis and the development of a site appraisal plan…"

"Pathways to Deep Decarbonization in Canada."

The following is from the Executive Summary of this document: "In this second Deep Decarbonization Pathways Project (DDPP) Canada report [the authors] look outside of Canada's borders to identify global decarbonization trends that will affect Canada and [its] ability to achieve deep decarbonization. [The authors] focus on identifying resilient pathways that policy can target regardless of eventual ambition, whether it is tentative, short-term steps or longer-term shifts towards deeper reductions. Complementing this domestic focus is [the authors'] interactions with the 16 other project teams in the DDPP. Through a series of meetings and working groups, [the authors] have collectively begun to coalesce around deep decarbonization pathways that are resilient across countries but also mitigation ambition. [The authors] observe that in virtually every country there are clean energy policies and technology drivers that are pushing global decarbonization trends, notably decarbonization of electricity production and energy-efficiency improvements in buildings and transport. Despite global trends towards progress in reducing the emission intensity of electricity production, buildings and transport, however, significant gaps in global technology exist that pose a challenge for Canadian deep decarbonization efforts, especially in primary extraction but also for emission intensive heavy industries.

Recent Publications (Continued)

It is these twin themes that Canadian climate policy must now address: how to deepen and broaden current Canadian policy signals and technology deployment, and where policy attention will be required to push next generation decarbonisation technologies forward, particularly in liquid fossil fuels and industrial processes. [The authors'] analysis identifies six decarbonization pathways under three main themes that emerge from [their] analysis and modelling…"

Legislative Activity

"[Senators] Offer Pathway to a Cleaner Energy Future and Economy."

A group of Senators released a national energy bill, the American Energy Innovation Act of 2015, that addresses the creation of new jobs, updated infrastructure, and technological innovation through programs in the energy sector that modernize infrastructure, reduce CO_2 emissions, invest in clean energy, and support research and development (R&D). Specifically, the bill includes provisions such as: reducing GHG emissions and securing CO_2 reduction targets from other countries; investing in energy storage; implementing recommendations from DOE's Quadrennial Energy Review; and investing in clean energy technologies. For more information, view the bill text and the bill summary. From *U.S. Senate Committee on Energy & Natural Resources* on September 22, 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:

NETL RSS Feed

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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

The National Energy Technology Laboratory (NETL), part of DOE's national laboratory system, is owned and operated by the U.S. Department of Energy (DOE). NETL supports DOE's mission to advance the national, economic, and energy security of the United States.

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