CSN CARBON STORAGE NEWSLETTER

AUGUST 2020

This newsletter is compiled by the National Energy Technology Laboratory to provide information on recent activities and publications related to carbon storage. It covers domestic, international, public sector, and private sector news in the following areas:

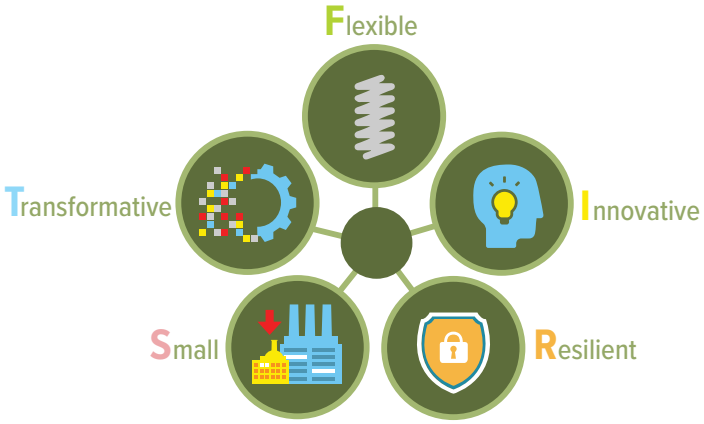
CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

NATIONAL ENERGY TECHNOLOGY LABORATORY

DOE/NETL HIGHLIGHTS

DOE Invests in Coal FIRST Initiative.

The U.S. Department of Energy (DOE) announced federal funding to support the Coal FIRST (Flexible, Innovative, Resilient, Small, Transformative) Initiative. Seven projects will receive funding under the Funding Opportunity Announcement (FOA), "*Critical Components for Coal FIRST Power Plants of the Future*," for cost-shared research and development. In addition, DOE is releasing a new FOA, "*Design Development and System Integration Design Studies for Coal FIRST Concepts*," in which projects must incorporate carbon capture and storage (CCS) or carbon capture, utilization, and storage (CCUS) technologies. From *energy.gov*. July 2020.



DOE Announces Funding for FLECCS Program.

DOE announced funding for 12 projects under Phase I of the *Advanced Research Projects Agency-Energy's (ARPA-E)* FLExible Carbon Capture and Storage (FLECCS) Program. FLECCS Phase I project teams will design, model, and optimize CCS processes that enable flexibility on a high-variable renewable energy grid. At the conclusion of Phase I, teams will be downselected to Phase II to receive additional funding to further develop their technologies. The list of FLECCS projects is *available online*. From *energy.gov*. July 2020.

arpa·e CHANGING WHAT'S POSSIBLE

ANNOUNCEMENTS

NETL-Led NRAP Expanding Toolset, Collaborations.

Led by the National Energy Technology Laboratory (NETL), the National Risk Assessment Partnership (NRAP) has worked to accelerate the commercial deployment of large-scale carbon storage for the past 10 years. Now into Phase II, NRAP is expanding its *award-winning toolset* and creating new collaborations to continue improving the ability to address risk management for carbon storage sites. NRAP researchers are engaging with new partners such as DOE's Regional Initiatives, industry, state and federal regulators, and academia.

NRAP team members at their annual meeting in 2019

ANNOUNCEMENTS *(cont.)*

CO_2 Storage Resource Catalogue Launched.

The Oil and Gas Climate Initiative, Global CCS Institute, and Pale Blue Dot Energy launched a worldwide evaluation of geologic carbon dioxide (CO_2) storage resource assessments. The *CO_2 Storage Resource Catalogue*, to be updated annually, aims to become a global repository for all future storage resource assessments.

CCS Project Reaches Milestone.

Shell's Quest CCS project has captured and stored 5 million metric tons of CO_2 since its startup in November 2015. Originally designed to capture and store approximately 1 million metric tons of CO_2 per year, the Quest CCS facility exceeded the target at a cost approximately 35% lower than that forecasted in 2015.

CCS Collaboration Renewed.

ExxonMobil and Princeton University's (USA) Andlinger Center for Energy and the Environment renewed their collaboration to better understand underground storage capacity for future CO_2 storage projects.

Fact Sheet on Pilot Test at NCCC.

The CO_2 Capture Project *released a fact sheet* detailing the results of pilot testing conducted at the DOE-sponsored National Carbon Capture Center (NCCC) in Wilsonville, Alabama (USA). The pilot tested piperazine with advanced stripper technology for capturing CO_2 from low-CO_2 flue gas (representative of flue gas from natural gas combined cycle power plants).

Companies Invest in CCUS Projects.

Carbon Clean Solutions Limited (CCSL) finalized an investment to deliver its CO_2 capture technology for CCUS projects across the steel, cement, waste management, and refining and petrochemicals sectors. Additional information on the investment is available on the *CCSL website*.

ZEP, European Commission Discuss CCS.

A meeting between the Zero Emissions Platform (ZEP) and the European Commission focused on the role of CCS projects, CO_2 infrastructure, and clean hydrogen in Europe. ZEP presented a *set of recommendations* for how the European Union (EU) can use CCS.

15 Years of CCS Research at SCCS.

Scottish Carbon Capture and Storage (SCCS) is celebrating its 15th year researching CCS technologies. Since inception in 2005, the SCCS team broadened its reach to a range of international projects exploring, developing, and defining the use of CCS technology across sectors, from industrial processes and power generation to hydrogen production, waste-to-energy, and refineries.

Report Studies Need for CCS.

A new study examines the importance of CCS in achieving carbon neutrality in the EU. Eurogas' study, "*A Pathway to a Carbon Neutral 2050: The Role of Gas*," investigates different scenarios to help the EU reach its goals.

PROJECT and BUSINESS DEVELOPMENTS

Offshore CO_2 Storage Consortium Formed.

A CO_2 storage consortium, comprised of Maersk Drilling, INEOS Oil & Gas Denmark, and Wintershall Dea, will target the development of CO_2 storage capacity offshore Denmark based on reusing discontinued offshore oil and gas fields for CO_2 storage. The first phase of the CCS project will be a feasibility study to validate reservoir compatibility, followed by a CO_2 injection pilot test. The long-term goal of the project is to develop the capacity to store approximately 3.5 million tons of CO_2 per year by 2030. From *Maersk Drilling Press Release*. June 2020.

Research Project Commenced at Otway.

A team of engineers began a research project at the Otway National Research Facility (located in south-western Victoria, Australia) that focuses on reducing the long-term cost of CO_2 storage monitoring. A water tracer technology team from Deakin University will seek to develop new ways to track variations in water quality in groundwater above rock that acts as a natural barrier to saline formations and stored CO_2. The *Otway National Research Facility* was established in 2008 to demonstrate that CO_2 could be safely captured, transported, and injected and stored in different geologic formations. From *Carbon Capture Journal*. July 2020.

Project Uses CCS to Produce Hydrogen from Natural Gas.

A project to produce hydrogen from natural gas in combination with CCS is being developed in the United Kingdom (UK). The initial phase of the Hydrogen to Humber Saltend (H2H Saltend) project comprises a 600-megawatt auto thermal reformer with CO_2 capture to convert natural gas to hydrogen. Later phases can serve other industrial users, enabling a large-scale network for transporting and storing captured CO_2 emissions. The H2H Saltend project supports the UK government's aim to establish at least one low-carbon industrial cluster by 2030 and a net-zero cluster by 2040. From *Equinor News Release*. July 2020.

CCS Systems Used at Cement Plant.

Carbon8 Systems signed a commercial agreement to deploy its CCUS systems at a cement plant in France. Carbon8's CO_2ntainer system will be integrated into the existing industrial processes onsite at the cement plant and will capture CO_2 from the plant's flue gas emissions. The CO_2 will then be used to convert cement bypass dust into construction aggregates. The aggregates can then be repurposed in various commercial applications, such as lightweight concrete blocks. From *Carbon Capture Journal*. July 2020.

PROJECT and BUSINESS DEVELOPMENTS *(cont.)*

CCS Project Receives Grant.

The North Dakota Industrial Commission awarded a grant to Midwest AgEnergy Group to advance the development of a potential CCS system at the Blue Flint facility located near Underwood, North Dakota (USA). The research will include drilling a stratigraphic well to examine the geology of the surrounding area and collecting core samples that will be analyzed for suitability to store CO_2 in saline formations. If the project is successful, the Blue Flint facility anticipates storing approximately 200,000 tons per year. From *Ethanol Producer Magazine*. June 2020.

Collaboration to Use CCS to Transport Liquefied CO_2.

Preem signed a collaborative agreement with industry and government stakeholders to create a joint infrastructure for transporting liquefied CO_2 extracted using CCS technology. The CinfraCap project will identify an industry-scale logistics system required to support CCS, eventually presenting proposals for an optimized infrastructure that links to other CCS projects. From *Preem Press Release*. June 2020.

Full-Scale Demo Project Approved by Norwegian State Agency for CCS.

Gassnova, the Norwegian state agency for CCS projects, is supporting a full-scale carbon capture demonstration project at a waste-to-energy plant in Oslo, Norway. The project, which tested Shell's CANSOLV CO_2 carbon capture technology at Fortum Oslo Varme's Waste-to-Energy plant at Klemetsrud in Oslo, is expected to contribute to Norway's emission goals. A pilot initiated at Klemetsrud in 2018 captured more than 90% of all flue gas; according to officials, going full-scale with CCS will improve the plant's environmental performance by helping it achieve net-negative emissions. From *DNV GL Media Release*. July 2020.

LEGISLATION and POLICY

Examining Impact of Legal Framework on CCS.

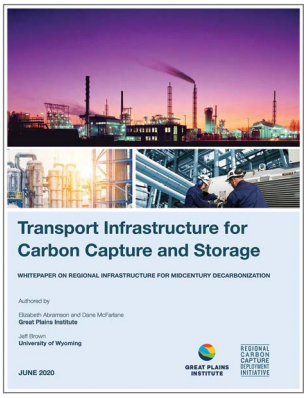
Research examining the impact of legal framework for CCS projects in Canada and Mexico was *published in the U.K.'s Environmental Liability: Law, Policy, and Practice*. The paper was prompted by an agreement between Mexico and the University of Calgary's Global Research Initiative to share expertise. From *Haskayne School of Business News*. June 2020.

Consortium to Advise UK Government on CCS.

The UK Department for Business, Energy, and Industrial Strategy appointed a consortium to provide engineering and technical advice for advancing CCUS development in the UK. The consortium will support the design of a CCUS work program to enable the deployment of various projects during the 2020s and advise on the engineering and technical implications for CCUS business models, associated policy development, and CCUS cluster engagement. The consortium is part of the UK government's goal to have the option to deploy CCUS at scale during the 2030s. From *New Civil Engineer*. July 2020.

White Paper Identifies Near-Term CCS Opportunities.

The Great Plains Institute and the University of Wyoming (USA) *released a white paper* presenting the results of modeling efforts to identify regional-scale CO_2 transport infrastructure that would serve existing facilities and enable participation by new capture projects and facilities in the near future. The white paper identifies near-term CCS opportunities, designing and planning the regional transport infrastructure required to maximize CO_2 reductions while minimizing cost and land use impacts throughout the Midwest, Rockies, Plains, Gulf Coast, and Texas. From *Enhanced Oil Recovery Institute*. July 2020.



EMISSIONS TRADING

Virginia to Join RGGI.

The state of Virginia (USA) *finalized its regulation* to establish a market-based program to reduce greenhouse gases (GHGs) and will join the Regional Greenhouse Gas Initiative (RGGI) as a participant. Beginning on January 1, 2021, Virginia will be able to take part in the quarterly CO_2 auctions and will be a part of the RGGI program review process. From *RGGI Press Release*. July 2020.

RGGI States Initiate Auction Process for Auction 49.

The states currently participating in RGGI initiated the auction process for their 49th quarterly CO_2 auction scheduled for September 2, 2020. Auction 49 will offer 16,192,785 CO_2 allowances for sale at a minimum reserve price of $2.32. An 11.8 million CO_2 allowance cost containment reserve (CCR) will also be made available (the CCR will be accessed if the interim clearing price exceeds the CCR trigger price of $10.77). From *RGGI*. July 2020.

RGGI Inc.

SCIENCE NEWS

DOE Lab Demonstrates Novel, Affordable CO_2 Removal Method.

Researchers from DOE's Oak Ridge National Laboratory conducted a study to expand technology options for reducing industrial CO_2 emissions. Results of the study, *published in the journal Chem*, expand the limited library of options for carbon capture membranes. The research was supported by *DOE's Office of Science*. The researchers will next investigate the mechanisms by which fluorinated membranes absorb and transport CO_2. From *Oak Ridge National Laboratory News*. July 2020.

Study Identifies Optimal BECCS Facility in UK.

Researchers studied six potential locations for bioenergy with carbon capture and storage (BECCS) power plants across the UK, finding the Drax power station in North Yorkshire (UK) to be an optimal site. Led by the University of Southampton, the study assessed each site based on several criteria, including proximity to CO_2 storage sites, costs of transportation, potential for geologic storage, and flood mitigation. *A video explaining the study is available online*. From *University of Southampton News*. June 2020.

Researchers Convert CO_2 into Formic Acid.

Researchers at Oslo University (Norway) developed a process to convert waste CO_2 through artificial photosynthesis. The researchers show that under the right circumstances, FDH enzymes can "grab" a CO_2 molecule and convert it into formic acid, a substance used by industry in multiple forms. From *Carbon Capture Journal*. July 2020.

Researchers Study CO_2 Removal Ability of Rock Dust.

According to a study *published in the journal Nature*, spreading rock dust on farmland has the potential to remove approximately half of the atmospheric CO_2 produced by Europe. The "enhanced rock weathering" process involves layering crushed rock onto soil; when silicate or carbonate materials in the dust dissolve in rain water, CO_2 is drawn into the solution to form bicarbonate ions, which are eventually washed into the ocean where they form carbonate minerals, storing their CO_2 indefinitely. From *The Washington Post*. July 2020.

PUBLICATIONS

The US Section 45Q Tax Credit for Carbon Oxide Sequestration: An Update.

The following is from the Introduction of this Global CCS Institute brief: "This brief is intended for carbon capture and storage (CCS), climate and clean energy advocates, policymakers and projects developers globally and focuses on the latest developments with regards to the 45Q tax credit for carbon oxide sequestration in the US, including a summary of the guidance released so far. The US has a long history of providing energy tax credits to a variety of fuels and production methods. In the context of clean energy deployment, tax credits have become the preferred incentive structure by the federal government to spur the deployment of and unlock investment in clean energy. Examples include tax credits for energy efficiency investments, the federal Investment Tax Credit (ITC) for solar energy and the Production Tax Credit (PTC) for wind, all of which have delivered large amounts of renewable energy capacity. With the ability to claim tax credits depending on a clean energy developer's being profitable enough to owe taxes, a market for financing clean energy has developed through these tax credits. Such tax equity partnerships allow a developer who is unable to claim the credits to secure financing by partnering with an investor – a tax equity investor."

A New Era for CCUS Driven by Contrasted Policies and Business Models: US and European Approaches.

The following is a summary of this CEDIGAZ document: "[…] There are currently 20 new, large-scale, CCUS projects planned around the world, nine of them in Europe. While projects developed in the middle of the 2000s mainly targeted coal-fired power plants and stored the captured carbon, the focus of the new projects is different as they tend to concentrate on industrial and manufacturing processes and on carbon utilization rather than just storage. Several projects involve production of clean hydrogen from natural gas, a cheaper option than hydrolysis using renewable power. New business models aim at reducing costs by dis-integrating the CCUS value chain into its three components of capture, transport and storage, and by addressing clusters of industrial facilities to achieve economies of scale. The US is the most advanced globally in terms of CCUS supporting policies. In February 2018, the US Congress passed substantial tax credits to encourage private investment in the deployment of CCUS. In addition, in September 2018, California amended its Low Carbon Fuel Standard (LCFS) program with a CCS Protocol. While insufficient to incentivize CCUS in existing facilities (retrofitting) or in the largest US emitting sectors like power plants or cement and steel production, they should help deploy CCUS on the 'low hanging fruits' which could lead to cost reduction for further projects through the learning curve and the deployment of shared infrastructure. As Europe's new energy strategy aims at a carbon neutral economy by 2050, large-scale deployment of CCUS appears necessary. The EC is supporting CCUS through a range of policy initiatives and has pledged to invest €10 billion in CCUS and other low-carbon technologies. Nine projects are currently under development, making Europe the leader in the renewed global effort to promote CCUS. They focus on energy intensive industries and those with inherent process emissions of CO_2 (e.g. cement). Gas-fired power plants are also targeted and several [projects] involve clean hydrogen production from natural gas. The business model of European CCUS projects is to develop multi-user 'hub and cluster' facilities in industrial regions, tied-in to shared transport and storage infrastructure. With different policy approaches and different incentives, the US and Europe both look to achieve global leadership in CCUS technologies and both recognize the crucial role of carbon management and CCUS in the future."

PUBLICATIONS *(cont.)*

Assessment of CO_2 trapping mechanisms in partially depleted oil-bearing sands.

The following is from the abstract of this article: "The objective of this work is to evaluate various CO_2 sequestration mechanisms occurring in the Morrow B Sandstone in the Farnsworth Unit. A history-matched numerical simulation model was created using extensive geological, petrophysical, and operational data collected from the field. The numerical model is competent to investigate the impact of residual, structural-stratigraphic, solubility, and mineral trapping mechanisms on the fluid transportation dynamics and petrophysical property variations. The model forecasts the field response of 20 years of WAG injections. Afterward, all wells were shut-in, and the reservoir was allowed to evolve for 1000 years to investigate the fate of injected CO_2. In this paper, [the authors] assess the impacts of various trapping mechanisms on oil recovery and CO_2 storage efficacy. By analyzing the results reported from the numerical simulation model, the in-situ fluid composition and mineralogy changes are also investigated. More importantly, [the authors] seek to confirm the petrophysical property variations due to the CO_2 injection with observations from laboratory measurements. The experiences gained from this study provide valuable insights regarding physiochemical storage induced by the CO_2 injection activities and serve as a benchmark case for future CO_2 enhanced oil recovery (EOR) projects involving reactive solute transport." **Qian Sun, William Ampomah, Eusebius Junior Kutsienyo, Martin Appold, Benjamin Adu-Gyamfi, Zhenxue Dai, and Mohamed Reza Soltanian,** *Fuel.* (Subscription may be required.)

Mobilization of trace metals from caprock and formation rocks at the Illinois Basin – Decatur Project demonstration site under geological carbon dioxide sequestration conditions.

The following is from the abstract of this article: "One concern for geologic CO_2 sequestration is the potential leakage of CO_2 or CO_2-saturated brine containing trace metals into overlying aquifers, which poses the risk of adversely affecting underground sources of drinking water. In this work, rock and brine samples collected in the Illinois Basin – Decatur Project (IBDP), a large-scale geological CO_2 sequestration demonstration project in Decatur, Illinois, USA, as well as synthetic brine samples were used to understand the mobilization of trace metals as a result of CO_2–rock–brine interactions under IBDP-specific conditions (50°C and 20.6 MPa). Rock sample characterization indicated that, at the IBDP site, trace metal concentrations were greatest in cap rock samples from the Eau Claire Formation, compared with those from formations above and below this Formation. The natural brine samples collected from the Mt. Simon Sandstone reservoir were highly reducing and saline, with trace metal concentrations up to 680 times greater than the U.S. Environmental Protection Agency-prescribed drinking water standards. Batch leaching experiments indicated that both trace metal mobilization from rock and immobilization from the brine occurred when high-pressure CO_2 was introduced into the rock-brine system. The amounts of metals mobilized from the rock generally accounted for <5% of the total metals in the rock, but for some metals, including Ni, Pb, and Tl, up to 63% of the metals in the rock were mobilized to the brine. Leaching of trace metals into synthetic brines was different from that into the natural brine. The results of this study provided current information on the trace element sources and will help in risk simulations and experimental design to further evaluate potential impact of leakage on groundwater quality, which is important for future GCS projects to consider for monitoring and containment assurance purposes." **Hongbo Shao, Jared T. Freiburg, Peter M. Berger, Alexander H. Taylor, Hanna F. Cohen, and Randall A. Locke II,** *Chemical Geology.* (Subscription may be required.)

Can bioenergy carbon capture and storage aggravate global water crisis?

The following is from the abstract of this article: "Bioenergy carbon capture and storage (BECCS) is an effective option for mitigation of greenhouse gas (GHG) emissions. Nevertheless, there is barely serious debate about whether its implementation can possibly jeopardize the global water resources security. Here, [the authors] provided an assessment of biomass-based Substitute Natural Gas (BioSNG) production combined with CCS, a promising BECCS technology, in terms of global water resources security, with a focus on the growth of two typical second-generation bioenergy crops: *switchgrass* and *miscanthus*. A bottom-up analysis approach was applied in this paper to calculating water consumption for BECCS and estimating water quality deterioration caused by increasing fertilizer and pesticide application. The results indicated that water usage of BECCS was equal to adding 12.86%–16.64% (*switchgrass*) and 17.59%–26.06% (*miscanthus*) additional water stress on global available water resources at 2100. Additional N fertilizer application in 2100 would be equal to over 84%, 55% and 42% for both *switchgrass* and *miscanthus* under three CCS capture efficiency scenarios, respectively, comparing to such global scale in 2012. Additional phosphate fertilizer adding to global annual available water at 2100 were 0.004–0.008 mg L^{-1} (*switchgrass*) and 0.003–0.006 mg L^{-1} (*miscanthus*), respectively. The secondary environmental hazards, such as N_2O emission, would offset GHG emission mitigation by BECCS. Meanwhile, the enrichment and leaching of pesticide residues increased the risk of groundwater contamination. This study revealed water consumption and contamination issues caused by BECCS cannot be neglected. Thus, additional studies of accurate land-use models in global scale and advanced technology for biofuel extraction are needed in the future." **Bin Hu, Yilun Zhang, Yi Li, Yanguo Teng, and Weifeng Yue,** *Science of The Total Environment.* (Subscription may be required.)

Technical economic analysis of an intensified Integrated Gasification Combined Cycle (IGCC) power plant featuring a sequence of membrane reactors.

The following is from the abstract of this article: "In this work, a technical economic analysis (TEA) is carried-out for the design of an Integrated Gasification Combined Cycle (IGCC) power plant featuring a sequence of hydrogen-permeable ceramic membrane reactors (MRs). The proposed design features membrane reactors that generate hydrogen of higher purity than conventional reactor-separator systems used in IGCC plants, and enable over 90% carbon capture in the Dual-Stage Selexol unit. A multi-scale model is used to simulate the proposed MR sequence, and a commercial process flowsheet simulator is used to create the proposed intensified MR IGCC plant flowsheet, which is subsequently heat integrated. The TEA developed for the MR IGCC power plant allows for the economic characteristics of its design to be compared with those of a traditional IGCC plant equipped with carbon capture storage (CCS) technology." **Patricia A. Pichardo, Seçgin Karagöz, Theodore Tsotsis, Richard Ciora, and Vasilios I. Manousiouthakis,** *Journal of Membrane Science.* (Subscription may be required.)

PUBLICATIONS *(cont.)*

CO_2 storage and $CaCO_3$ production using seawater and an alkali industrial by-product.

The following is from the abstract of this article: "Indirect carbonation is one of the typical carbon capture, utilization, and storage technologies. It is well known, however, that the technology is very difficult to achieve economic feasibility because expensive chemical solvents used account for most of the cost. To overcome this limitation, [the authors] performed an experimental study to secure the economic feasibility of the technology by replacing such chemical solvents with nearly costless seawater. For the study, [the authors] used cement kiln dust (CKD), which is an alkali industrial by-product, together with seawater. In this paper, [the authors] attained CO_2 storage and $CaCO_3$ yield despite the use of seawater, which is comparable in both quantitative and qualitative respects to the existing studies using chemical reagents. The CO_2 storage and $CaCO_3$ yield were 185kg-CO_2/ton-CKD and 419kg-$CaCO_3$/ton-CKD, respectively. With the addition of Mg into the seawater, moreover, the amounts could significantly increase to reach 271kg-CO_2/ton-CKD and 615kg-$CaCO_3$/ton-CKD, respectively. Despite using CKD and seawater containing many impurities, the purity of $CaCO_3$ produced was as high as 99.4%. It was also found that Mg is one component, which can elute Ca from CKD, dissolved in seawater. The solid to liquid ratio was the most influential factor for the Ca elution efficiency, while the CO_2 flow rate and NaOH dosage had significant effects on the carbonation efficiency." **Junhyeok Jeon and Myoung-Jin Kim,** *Chemical Engineering Journal.* (Subscription may be required)

Carbon sequestration and soil restoration potential of grazing lands under exclosure management in a semi-arid environment of northern Ethiopia.

The following is from the abstract of this article: "Exclosures are used to regenerate native vegetation as a way to reduce soil erosion, increase rain water infiltration and provide fodder and woody biomass in degraded grazing lands. Therefore, this study assessed the impact of grazing exclosure on carbon sequestration and soil nutrients under 5 and 10 years of grazing exclosures and freely grazed areas in Tigray, northern Ethiopia. Carbon stocks and soil nutrients increased with increasing grazing exclusion. However, open grazing lands and 5 years of grazing exclosure did not differ in above- and belowground carbon stocks. Moreover, 10 years of grazing exclosure had a higher ($p < 0.01$) grass, herb and litter carbon stocks compared to 5 years exclosure and open grazing lands. The total carbon stock was higher for 10 years exclosure (75.65 t C ha^{-1}) than the 5 years exclosure (55.06 t C ha^{-1}) and in open grazing areas (51.98 t C ha^{-1}). Grazing lands closed for 10 years had a higher SOC, organic matter, total N, available P, and exchangeable K + and Na + compared to 5 year's exclosure and open grazing lands. Therefore, establishment of grazing exclosures had a positive effect in restoring degraded grazing lands, thus improving carbon sequestration potentials and soil nutrients." **Tsegay Gebregergs, Zewdu K. Tessema, Negasi Solomon, and Emiru Birhane,** *Ecology and Evolution.* (Subscription may be required.)

Geomechanical and petrographic assessment of a CO_2 storage site: Application to the Acorn CO_2 Storage Site, offshore United Kingdom.

The following is from the abstract of this article: "Extraction or injection of fluids within the subsurface causes fluctuations of fluid pressures and thus stress conditions. It is paramount to have knowledge of the geomechanical strength of a system's lithologies, and the factors that control it, in order to maintain optimal conditions during extraction/injection. If the yield strengths of the reservoir or caprock are overcome, particularly in the near-wellbore region where stress is amplified, these fluctuations could potentially compromise the system, through compactional or dilatational failure. Here [the authors] have used a novel combination of methods to determine the geomechanical and petrographic properties of the reservoir and caprock lithologies to assess suitability of the proposed Acorn CO_2 Storage Site, offshore north-east Scotland, for long-term injection and storage of CO_2. The Acorn CO_2 Storage Site has a highly porous and transmissible sandstone reservoir, with bulk mineralogy that will be stable under CO_2-rich conditions, making it ideal for receiving at least 152 MT CO_2 injected over ~20 years and storage of >1000 years post-injection, as part of the ACT-Acorn Development Plan. However, due to the high porosity and low cementation of the sandstone reservoir, it has low yield strength and is vulnerable to disaggregation and porosity-reduction if injection rates are too high and stress/pressure conditions exceed their yield strength. The results presented here provide quantitative constraints on the porosity reduction expected should yield occur and place limits on CO_2 injection rates. The shale caprock, with a high swelling clay content and very low permeability, present ideal Carbon Capture and Storage seal properties." **Michael J. Allen, Daniel R. Faulkner, Richard H. Worden, Elliot Rice-Birchall, Nikolaos Katirtsidis, and James E.P. Utley,** *International Journal of Greenhouse Gas Control.* (Subscription may be required.)

CO_2 mitigation policy for Indian thermal power sector: Potential gains from emission trading.

The following is from the abstract of this article: "This study shows potential cost savings by adoption of emission trading in India. At the Paris Agreement, India pledged to reduce CO_2 emissions intensity by about 30–35% by 2030 relative to 2005. Applying joint production function of electricity and CO_2 emissions, [the authors] find that India could have saved about US$ 5 to 8 billion, if she had constituted an emission trading system, with the provision of banking and borrowing over the study period of 5 years. To [the authors'] knowledge, this is the first study measuring foregone gains due to absence of a nationwide carbon emission-trading program in coal fired thermal power sector, using an ex-post analysis." **Surender Kumar, Shunsuke Managi, and Rakesh Kumar Jain,** *Energy Economics.* (Subscription may be required.)

ABOUT DOE'S CARBON STORAGE PROGRAM

The **Carbon Storage Program** at the National Energy Technology Laboratory (NETL) is focused on developing and advancing technologies to enable safe, cost-effective, permanent geologic storage of CO_2, both onshore and offshore, in different depositional environments. The technologies being developed will benefit both industrial and power sector facilities that will need to mitigate future CO_2 emissions. The program also serves to increase the understanding of the effectiveness of advanced technologies in different geologic reservoirs appropriate for CO_2 storage—including saline formations, oil reservoirs, natural gas reservoirs, unmineable coal, basalt formations, and organic-rich shale basins—and to improve the understanding of how CO_2 behaves in the subsurface. These objectives are key to increasing confidence in safe, effective, and permanent geologic CO_2 storage.

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

Newsletters, program fact sheets, best practices manuals, roadmaps, educational resources, presentations, and more information related to the Carbon Storage Program is available on *DOE's Energy Data eXchange (EDX) website*.

Rig drilling a site characterization well at the Craig Power Station in Colorado, USA. *Photo Source: Schlumberger Carbon Services*

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 (note that all links were active at the time of publication).

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1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

Program staff are also located in
Houston, Texas and **Anchorage, Alaska**.

CUSTOMER SERVICE: 1-800-553-7681

www.netl.doe.gov

Contact

Mark McKoy
304-285-4426
Mark.McKoy@netl.doe.gov

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