U.S. DEPARTMENT OF ENERGY | OFFICE OF FOSSIL ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

CSN CARBON STORAGE NEWSLETTER

JANUARY 2021

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:

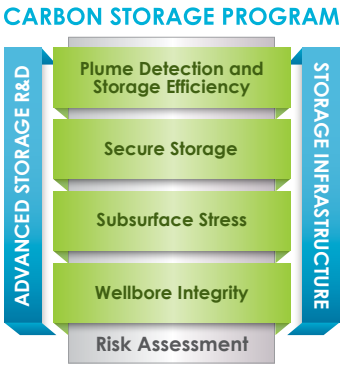
CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

NATIONAL ENERGY TECHNOLOGY LABORATORY

DOE/NETL HIGHLIGHTS

DOE Announces Funding for Carbon Storage Projects..

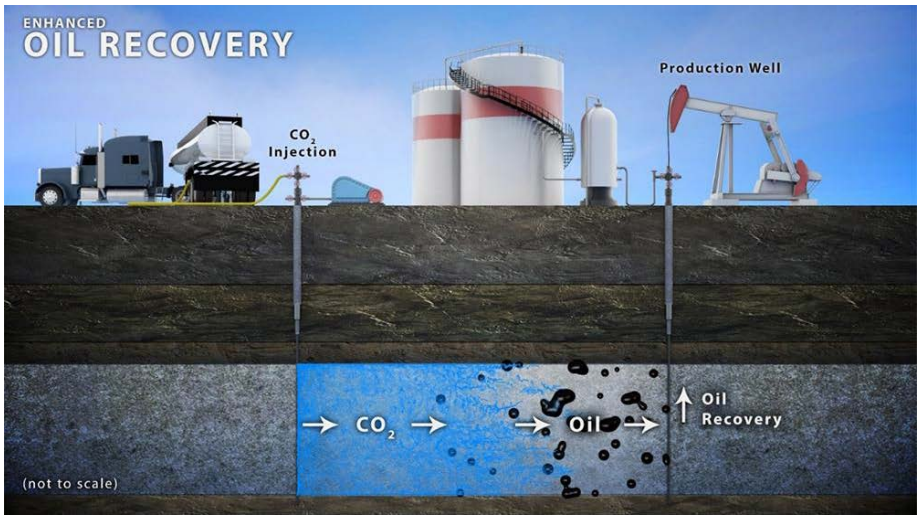
The U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) made available federal funding for cost-shared research and development (R&D) to develop tools and methods designed to optimize safe, secure, and verifiable carbon dioxide (CO_2) storage. The "Emerging CO_2 Storage Technologies: Optimizing Performance Through Minimization of Seismicity Risks and Monitoring Caprock Integrity" Funding Opportunity Announcement (FOA) supports the *Advanced Storage R&D* technology area of DOE's *Carbon Storage Program*. From *energy.gov*. December 2020.



ANNOUNCEMENTS

NETL Explores Expanded Use for CO_2-EOR.

A project utilizing National Energy Technology Laboratory (NETL) expertise in CO_2-enhanced oil recovery (EOR) is underway in southern Michigan (USA). *The project* aims to access significant resources in the Trenton/Black River play by injecting CO_2 in the subsurface to improve the flow of oil to production wells. The goals of the project are to help the United States maintain its energy independence and economically use captured CO_2 while reducing emissions and maximizing the lifetime utility of existing infrastructure and wells in mature fields.



NETL-Funded Project Supports Carbon Utilization Program.

More than 1,200 hours of field testing was completed at the *Wyoming Integrated Test Center*. The demonstration of a process to create concrete blocks using CO_2 from power plant flue gas support DOE's *Carbon Utilization Program*.

ANNOUNCEMENTS *(cont.)*

DOE Released Hydrogen Program Plan.

DOE released its *Hydrogen Program Plan* to provide a strategic framework for its hydrogen research, development, and demonstration activities. The plan involves participation from FE, as well as the DOE Offices of Energy Efficiency and Renewable Energy, Nuclear Energy, Electricity, Science, and the Advanced Research Projects Agency–Energy.

DOE Announces Selections for FOA.

DOE/FE selected 14 projects to receive federal funding for cost-shared R&D to help foster new uses for domestic coal resources. The projects will be managed by NETL and support the *Advanced Coal Processing Technologies Program*, which focuses on improving coal feedstock, producing high-value products from coal, and alternative technologies to produce high-performance carbon material from coal.

CCUS Stakeholder Workshops Held.

STRATEGY CCUS—a European Union funded project—conducted workshops to support the development and deployment of carbon capture, utilization, and storage (CCUS) in Southern and Eastern Europe. Participants included local and national government officials, community representatives, industry members, CCUS project developers and researchers, environmental groups, and support organizations.

Report on Global Status of CCS.

The *Global Status of CCS Report 2020* (purchase may be required) demonstrates the role carbon capture and storage (CCS) technologies can play in reducing emissions to net-zero by 2050. In addition, the Global CCS Institute report also documents the current status of CCS technology, as well as the milestones it has achieved in 2020.

PROJECT and BUSINESS DEVELOPMENTS

CO_2 Injection Begins at Otway Stage 3 Project.

Australian CCUS research organization CO2CRC announced the commencement of CO_2 injection operations at their *Otway Stage 3 project* in southwestern Victoria, Australia. The project aims to develop monitoring and verification technologies for field applications that have a lower surface environmental footprint, can be operated and monitored remotely, and are more cost-effective and reliable than traditional CO_2 monitoring methods. From *CO2CRC Media Release*. December 2020.

Project Certified for CO_2 Storage.

Carbon dioxide storage beneath the Danish North Sea as part of Project Greensand was confirmed to be feasible by independent certification. The project completed the first phase of validation with the certification of feasibility to DNV GL's (Det Norske Veritas Germanischer Lloyd) CCS certification regime and the international standard. DNV GL confirmed that the Nini West field in Denmark is conceptually suitable for injecting 0.45 million metric tons of CO_2 per year, per well, for a 10-year period. Project Greensand is aiming to have the first well from the Nini platform ready for injection in 2025, with the long-term goal of developing the capacity to store approximately 3.5 million metric tons of CO_2 per year before 2030. From *Oil and Gas Republic*. November 2020.

Construction Begins at Storage Plant.

Construction began at *Climeworks' Ocra plant* (Iceland), which combines direct air capture technology with CO_2 storage. The construction involves two phases—Phase I began in October 2020 and included the infrastructure and foundation; in Phase II, the plant and machinery will be installed. Once complete, Ocra is expected to remove more than 4,000 tons of CO_2 from the atmosphere per year. From *Carbon Capture Journal*. December 2020.

Feasibility Study to be Conducted for Large-Scale CCS Project.

Neptune Energy will conduct a feasibility study for a large-scale CCS project in the Dutch North Sea. The project could achieve more than 50% of the CO_2 reduction targeted by the Dutch industrial sector. From *Offshore Magazine*. December 2020.

Companies Collaborate on CCS Compression.

Aker Carbon Capture and MAN Energy Solutions signed a technology-cooperation agreement to develop more energy-efficient compression solutions for CCS applications with heat recovery. The agreement will form the basis for project deliveries to carbon capture plants. From *Carbon Capture Journal*. December 2020.

Australian and Japanese Companies to Study CCS.

Australian and Japanese companies are reviewing plans to capture CO_2 and store it under the ocean floor off the coast of Australia. The companies are working on proposals to ship industrial emissions across the Asia-Pacific region and store it under the seabed. From *Japan Times*. December 2020.

CCUS Pilot Project Underway.

Cambridge Carbon Capture (CCC) won the first phase of a United Kingdom (UK) Research and Innovation competition to pilot CO_2LOC—its carbon capture and utilization technology. *CCC's CO_2LOC technology* enables CO_2 storage through a two-stage mineralization process that stores CO_2 in rock form and that can be utilized across a range of industries. From *Cambridge Independent*. December 2020.

MOU Signed to Collaborate on CCUS in Italy.

Italian companies Eni and Saipem signed a Memorandum of Understanding (MOU) to cooperate on potential CCUS opportunities in Italian industrial districts. The objective of the MOU is to contribute toward the decarbonization process of entire production chains to help achieve CO_2 emissions reduction goals. From *Eni Press Release*. December 2020.

LEGISLATION and POLICY

CCUS Bills Introduced to Extend 45Q.

The Accelerating Carbon Capture and Extending Secure Storage Through 45Q (ACCESS 45Q) Act was introduced in the U.S. House of Representatives. The bill aims to extend the date for projects to begin construction to claim the 45Q tax credit for carbon oxide storage by 10 years and would also provide a direct pay elective for the full value of the tax credits. In addition, *the 45Q CCUS Tax Credits Amendment Act of 2020 was introduced in the U.S. Senate*. The bill looks to extend 45Q's start of construction date by five years to counter delays in finalizing regulator guidance. From *Biomass Magazine*. December 2020.

US Legislation Introduced to Support Natural Carbon Storage.

Two U.S. Senators introduced legislation to support the reduction of atmospheric CO_2 through the restoration and conservation of forests, grasslands, wetlands, and coastal habitats. The *Trillion Trees and Natural Carbon Storage Act* amends existing international conservation programs to include carbon storage among the list of approved technical assistance categories. From *U.S. Senator Mike Braun Press Release*. December 2020.

UK Government Plan Includes CCUS Commitment.

The UK government *outlined a 10-point plan* that includes a commitment to CCUS. The plan sets a target to capture 10 million metric tons of CO_2 by 2030 and includes new investment to spur CCUS technologies. From *Carbon Capture Journal*. November 2020.

EMISSIONS TRADING

Results of 50th RGGI Auction Released.

The states participating in the Regional Greenhouse Gas Initiative (RGGI) announced the results of their 50th auction of CO_2 allowances. A total of 16,237,495 CO_2 allowances were sold at a clearing price of $7.41, with bids ranging from $2.32 to $15.00 per allowance. In addition, none of the 11.8 million cost containment reserve (CCR) allowances made available were sold. (The CCR is a fixed additional supply of allowances made available if CO_2 allowance prices exceed certain price levels [$10.77 in 2020].) Auction 50 generated more than $120.3 million for states to reinvest in strategic programs, including energy efficiency and greenhouse gas (GHG) abatement programs. Additional details are available in the *Market Monitor Report for Auction 50*. From *RGGI News Release*. December 2020.

SCIENCE

Monitoring System for CCS Operations Launched.

Silixa launched a distributed acoustic sensing-based system for CCS monitoring. According to the company's news release, the fiber-optic monitoring system, referred to as Carina® CarbonSecure™, includes continuous and microseismic monitoring throughout the lifetime of a CO_2 storage facility to ensure safety over the stages of CCS. In addition, the company claims the system is a reservoir management tool that can be deployed to assess the viability of geologic formations for CO_2 storage during site characterization; monitor well and storage integrity, as well as microseismic activity, during CO_2 injection; and provide 4D monitoring of the CO_2 plume migration throughout the lifetime of the facility. From *Silixa News Release*. November 2020.

Researchers Study Red Sea Carbon Storage System.

A team of researchers from King Abdullah University of Science and Technology (Saudi Arabia) used an underwater robot to investigate the carbon storage potential of the Red Sea, factoring in water temperature and oxygen depletion. By studying the fate of organic carbon at different depths, the researchers hope to better predict how oceans absorb and store atmospheric CO_2 in the future. From *Phys.org*. December 2020.

Deep Tillage of Soil Can Improve Carbon Storage: Study.

Researchers conducted a meta-analysis of 43 separate studies to further understand the relationship between deep tillage and soil organic carbon (SOC). According to their results, *published in Renewable and Sustainable Energy Reviews*, deep tillage can enhance SOC and increase storage of CO_2 by approximately 8%. From *Concordia University*. December 2020.

Marine Scrubber Technology to Include CCS.

A Norwegian company developed an emissions capture system that helps promote compliance with regulations and is equipped with CCS capabilities. Developed by TECO 2030, "Future Funnel" could help the shipping industry reduce emissions and address the International Maritime Organization's GHG targets while permitting existing ships to operate. From *The Maritime Executive*. December 2020.

PUBLICATIONS

A Four-County Appraisal of the San Andres Residual Oil Zone (ROZ) "Fairway" of the Permian Basin.

The following is from the Introduction of this DOE/NETL report: "This report addresses the four-county San Andres Residual Oil Zone (ROZ) 'fairway' within the West Texas portion of the Permian Basin—Gaines, Yoakum, Terry, and Dawson counties. In this report, the term 'ROZ fairway' refers to the portion of the ROZ where there is no overlying oil field. The ROZ under a conventional oil field is not included in the assessment. This four-county San Andres ROZ fairway resource assessment has been undertaken to address five fundamental questions: [1.] What is the size and distribution of the in-place San Andres ROZ fairway oil resource favorable for CO_2-enhanced oil recovery (EOR)? [2.] How much of this in-place San Andres ROZ fairway oil resource can be mobilized and technically produced using CO_2 EOR? [3.] How much CO_2 can be stored by developing the San Andres ROZ fairway resource in this four-county area? [4.] What portion of the San Andres ROZ fairway resource can be economically developed while providing by-product storage of CO_2? [5.] What value could the uneconomic portion of the San Andres ROZ fairway resource provide?"

Start up and shutdown times of power carbon capture, usage and storage (CCUS) facilities.

Department for Business, Energy & Industrial Strategy

The following is from the Executive Summary of this UK Department for Business, Energy, and Industrial Strategy (BEIS) document: "The Department for Business, Energy and Industrial Strategy (BEIS) has commissioned AECOM to investigate potential improvements to the start-up and shut-down times of gas-fired power Carbon Capture, Utilisation and Storage (power CCUS) facilities. This report summarises the outputs of the study, including process modelling to demonstrate the performance of a range of configuration variants and inputs to the BEIS Dynamic Dispatch Model. A reference or 'standard' configuration case was identified to achieve 95% capture of normal carbon dioxide emissions from a modern H-Class Combined Cycle Gas Turbine power plant. The standard configuration was developed from open literature, project history and AECOM experience of carbon capture processes and is recorded in the Basis of Design, which is appended to this report. Results of the literature review are also provided in an appendix to this report. A concept design was developed for the power CCUS facility, using Thermoflow 29 for the power cycle and ProMax 5.0 for the carbon capture process. Results of the simulation work are presented in the report, including concept material balances and estimated electrical and heat consumption of a 95% post-combustion capture plant. 35% MEA (no other solvent) was the solvent chosen for this study as an open-art, technology-neutral solvent."

Could congressionally mandated incentives lead to deployment of large-scale CO_2 capture, facilities for enhanced oil recovery CO_2 markets and geologic CO_2 storage?

The following is from the abstract of this article: "In passing the Bipartisan Budget Act of 2018, Congress reformed and strengthened a section of the tax code, 45Q, which provides tax credits of up to \$35/ton CO_2 for the capture and utilization of CO_2 in qualifying applications such as enhanced oil recovery (EOR) and up to \$50/ton CO_2 for CO_2 that is captured and permanently stored in a geologic repository. Earlier versions of the tax credit with lower credit values generated limited interest. This change to the tax code could potentially alter U.S. energy systems. This paper examines the effect of the increased 45Q credits on CO_2 capture, utilization and storage (CCUS) deployment in the United States and on petroleum and power production. A range of potential outcomes is explored using five modeling tools. The paper goes on to explore the potential impact of possible modifications of the current tax credit including extension of its availability in time, the period over which 45Q tax credits can be utilized for any given asset and increases in the value of the credit as well as interactions with technology availability and carbon taxation. The paper concludes that 45Q tax credits could stimulate additional CCUS beyond that which is already underway." **James Edmonds, Christopher Nichols, Misha Adamantiades, John Bistline, Jonathan Huster, Gokul Iyer, Nils Johnson, Pralit Patel, Sharon Showalter, Nadja Victor, Stephanie Waldhoff, Marshall Wise, and Frances Wood,** *Energy Policy*. (Subscription may be required.)

Major role of particle fragmentation in regulating biological sequestration of CO_2 by the oceans.

The following is the abstract of this article: "A critical driver of the ocean carbon cycle is the downward flux of sinking organic particles, which acts to lower the atmospheric carbon dioxide concentration. This downward flux is reduced by more than 70% in the mesopelagic zone (100 to 1000 meters of depth), but this loss cannot be fully accounted for by current measurements. For decades, it has been hypothesized that the missing loss could be explained by the fragmentation of large aggregates into small particles, although data to test this hypothesis have been lacking. In this work, using robotic observations, [the authors] quantified total mesopelagic fragmentation during 34 high-flux events across multiple ocean regions and found that fragmentation accounted for 49 ± 22% of the observed flux loss. Therefore, fragmentation may be the primary process controlling the sequestration of sinking organic carbon." **Nathan Briggs, Giorgio Dall'Olmo, and Hervé Claustre,** *Science*. (Subscription may be required.)

The Value of Bioenergy with CO_2 Capture and Storage in an Electrified UK Heat Sector.

The following is from the abstract of this article: "The electrification of heat in the UK offers an alternative to a heating system dominated by natural gas, but poses significant challenges for the current energy supply, both in terms of meeting peak heat demand, and in decommissioning existing infrastructure. The UK's recent adoption of a net zero target by 2050 signals an increase in ambition in heat decarbonisation targets. On the other hand, negative emissions from the power sector, in the form of bioelectricity with carbon capture and storage (BECCS), could provide both low-carbon firm power and CO_2 removal, to assist in this transition. [The authors'] study explores the role of CO_2 removal in least cost electrification pathways to net zero, using a spatially explicit hourly unit operation and capacity expansion optimisation model of the UK heat and power sectors. [The authors] model the full biomass and CCS value chains to account for potential geo-physical, sustainability and financial constraints to BECCS deployment at the regional level. [The authors'] contribution introduces the methodology to derive the biomass supply curve and CO_2 storage capacity and injectivity cost curves for the UK." **Mathilde Fajardy, Vasileios Charitopoulos, and David Reiner,** *Computer Aided Chemical Engineering*. (Subscription may be required.)

PUBLICATIONS *(cont.)*

Amazon forest response to CO_2 fertilization dependent on plant phosphorus acquisition.

The following is from the abstract of this article: "Global terrestrial models currently predict that the Amazon rainforest will continue to act as a carbon sink in the future, primarily owing to the rising atmospheric carbon dioxide (CO_2) concentration. Soil phosphorus impoverishment in parts of the Amazon basin largely controls its functioning, but the role of phosphorus availability has not been considered in global model ensembles—for example, during the Fifth Climate Model Intercomparison Project. Here [the authors] simulate the planned free-air CO_2 enrichment experiment AmazonFACE with an ensemble of 14 terrestrial ecosystem models. [The authors] show that phosphorus availability reduces the projected CO_2-induced biomass carbon growth by about 50% to 79 ± 63 g C m^{-2} yr^{-1} over 15 years compared to estimates from carbon and carbon–nitrogen models. [The authors'] results suggest that the resilience of the region to climate change may be much less than previously assumed. Variation in the biomass carbon response among the phosphorus-enabled models is considerable, ranging from 5 to 140 g C m^{-2} yr^{-1}, owing to the contrasting plant phosphorus use and acquisition strategies considered among the models. The Amazon forest response thus depends on the interactions and relative contributions of the phosphorus acquisition and use strategies across individuals, and to what extent these processes can be upregulated under elevated CO_2." **Katrin Fleischer, Anja Rammig, Martin G. De Kauwe, Anthony P. Walker, Tomas F. Domingues, Lucia Fuchslueger, Sabrina Garcia, Daniel S. Goll, Adriana Grandis, Mingkai Jiang, Vanessa Haverd, Florian Hofhansl, Jennifer A. Holm, Bart Kruijt, Felix Leung, Belinda E. Medlyn, Lina M. Mercado, Richard J. Norby, Bernard Pak, Celso von Randow, Carlos A. Quesada, Karst J. Schaap, Oscar J. Valverde-Barrantes, Ying-Ping Wang, Xiaojuan Yang, Sönke Zaehle, Qing Zhu, and David M. Lapola,** *Nature Geoscience*. (Subscription may be required.)

The current status of high temperature electrochemistry-based CO_2 transport membranes and reactors for direct CO_2 capture and conversion.

The following is from the abstract of this article: "The concept of direct CO_2 capture and conversion has attracted significant interest from industries and academia in recent decades due to its potential to address the current grand challenge of global warming/climate change, rapid depletion of fossil fuels and realization of a future carbon neutral ecosystem. The incumbent benchmark technology for CO_2 capture is the post-combustion flue-gas 'amine washing', which is energy intensive and costly for large-scale commercial implementation. The CO_2 conversion technologies, on the other hand, are still at their infancy with many technical challenges to overcome, but primarily being explored in laboratory-scale, low-temperature, solution-based and high-temperature, solid-oxide-based electrochemical cells with renewable electricity perceived as the energy input. In this article, [the authors] provide a comprehensive overview on an emergent class of high-temperature electrochemical CO_2 transport membranes that can capture and convert CO_2 into valuable chemicals in single catalytic reactor fashion. The review starts with the chemistry and transport theory of three basic types of membranes purposely designed for different CO_2 feedstocks and downstream conversions. A range of key functional materials used in these membranes and their microstructural/electrochemical properties important to the CO_2 transport are then thoroughly discussed in conjunction with the effects of surface modifications and operating conditions. Several types of combined CO_2 capture and conversion catalytic reactors based on these membranes are also assessed with a focus on their working principles, system configurations and performance demonstrations. Finally, challenges and prospective of these electrochemical CO_2 transport membranes and their associated conversion reactors are candidly discussed for future development." **Peng Zhang, Jingjing Tong, Kevin Huangm Xuefeng Zhu, and Weishen Yang,** *Progress in Energy and Combustion Science*. (Subscription may be required.)

Post-combustion CO_2 capture from a natural gas combined cycle power plant using activated carbon adsorption.

The following is from the abstract of this article: "As fossil fuel power plants have emitted significant quantity of carbon dioxide (CO_2) into the atmosphere which aggravates climate change, capturing and storing such emissions is key to mitigate the issue. An adsorption system based on a physical adsorbent i.e. activated carbon is first assessed to capture CO_2 emissions from a natural gas combined cycle. Then a subcritical sequential supplementary firing combined cycle with CO_2 capture is used to analyse the effect of CO_2 concentration. Analyses are carried out in terms of power loss and thermal efficiency. To evaluate the advantages of post-combustion CO_2 capture using activated carbon, results are compared with systems using a commercial absorbent, i.e. monoethanolamine and a chemical adsorbent i.e. polyethyleneimine/silica. The net efficiency of natural gas combined cycle using activated carbon increases slightly from 50.8% to 51.1% due to the lower regeneration temperature at 358 K. The performance of the system using PEI/silica is almost the same as that using activated carbon at 368 K. Although the thermal energy required to regenerate the activated carbon is relatively high, a significant improvement of net efficiency is observed with increased partial pressure. Economic analysis indicates that the systems using activated carbon is a competitive alternative for CO_2 capture. It is concluded activated carbon is relatively more advantageous than monoethanolamine in terms of efficiency and cost, which could be further improved with enhanced heat and mass recovery." **L. Jiang, A. Gonzalez-Diaz, J. Ling-Chin, A.P. Roskilly, and A.J. Smallbone,** *Applied Energy*. (Subscription may be required.)

A comprehensive review of value-added CO_2 sequestration in subsurface saline aquifers.

The following is from the abstract of this article: "This paper comprehensively reviews CO_2 sequestration process in saline aquifers. The storage mechanisms including structural, residual, solubility, and mineral trappings are assessed along with a discussion of their relative contributions, and their key parameters and optimisations. In view of storage security and capacity, effects of rock and fluid properties and reservoir conditions together with injection strategies are discussed. Furthermore, CO_2 storage site selection is investigated followed by an evaluation of the different measurement, monitoring and verification methods to mitigate the risk of leakage. Field examples with key learnings are also presented to help engineers with sustainable development of storage projects." **Sunil Kumar, Jalal Foroozesh, Katriona Edlmann, Mohamed Gamal Rezk, and Chun Yan Lim,** *Journal of Natural Gas Science and Engineering*. (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

Contacts

If you have questions, feedback, or suggestions for NETL's Carbon Storage Newsletter, please contact:

Carbon Storage Newsletter Support
CSNFeedback@netl.doe.gov

Mark McKoy
Technology Manager
Carbon Storage
304-285-4426
Mark.McKoy@netl.doe.gov

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