

CSN

CARBON STORAGE
NEWSLETTER

DECEMBER 2019

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:

- ▷ DOE/NETL HIGHLIGHTS
- ▷ ANNOUNCEMENTS
- ▷ PROJECT and BUSINESS DEVELOPMENTS
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CARBON STORAGE PROGRAM
DOCUMENTS and
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- ▷ Carbon Storage Educational Resources
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NATIONAL
ENERGY
TECHNOLOGY
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DOE/NETL HIGHLIGHTS

DOE Announces Funding to Develop CCS Technology.

The U.S. Department of Energy's (DOE) *Advanced Research Projects Agency-Energy (ARPA-E)* announced funding to develop carbon capture and storage (CCS) technologies that enable power generators to respond to grid conditions in a high variable renewable energy (VRE) penetration environment. The FLExible Carbon Capture and Storage (FLECCS) Program, which seeks to develop technologies capable of addressing difficulties in decarbonization of electricity systems and focuses specifically on complications in CCS design, operations, and commercialization, will have two phases. Phase I will focus on designing and optimizing CCS processes that enable flexibility on a high-VRE grid. Phase II will focus on building components, unit operations, and small prototype systems to reduce the technical risks and costs associated with CCS systems. From *energy.gov* on November 14, 2019.



CHANGING WHAT'S POSSIBLE

ANNOUNCEMENTS

*US Senate Confirms New Secretary of Energy.*

The U.S. Senate confirmed former Deputy Secretary of Energy Dan Brouillette to be the 15th U.S. Secretary of Energy. The official swearing in will occur at a later date.

DOE Announces Funding to Collaborate Internationally and Accelerate CCUS.

DOE's Office of Fossil Energy (FE) announced federal funding for national laboratories to collaborate with international partners to accelerate and mature carbon capture, utilization, and storage (CCUS) projects. The collaboration will be on seven of *the 12 projects that were selected* as part of the *Accelerating Carbon Capture and Storage Technologies (ACT) Initiative*. The ACT Initiative is a consortium of 10 European countries (France, Germany, Greece, the Netherlands, Norway, Romania, Spain, Switzerland, Turkey, the United Kingdom) and the United States.

*DOE Ranked Global Leader in CCS Research.*

DOE was described as a global leader in CCS research in a *report* issued by the peer-reviewed journal *Science of the Total Environment*. DOE ranked first in number of publications and "h-index," which measures the productivity and citation impact of a scientist.

NETL-Developed Model Helps Evaluate CO₂ Storage Potential.

DOE/FE's National Energy Technology Laboratory (NETL) developed the CO₂ Prophet Model, which is an oil reservoir simulator that calculates carbon dioxide (CO₂) retention and oil production for enhanced oil recovery (EOR) projects. The CO₂ Prophet Model is available online, along with supporting documentation, and provides key input to the FE/NETL Onshore CO₂-EOR Cost Model (currently in beta-testing). Integrated, these models enable rapid evaluation of the economics and CO₂ storage potential of multiple oil field and residual oil zone units.

DOE Announces Funding for CCUS Projects.

DOE/FE announced approximately \$110 million in federal funding for cost-shared research and development (R&D) projects under three Funding Opportunity Announcements (FOAs). Approximately \$75 million is for awards selected under two FOAs announced in fiscal year 2019 (FY 2019), with \$35 million for a new FOA. The projects will build upon DOE's large-scale CCUS pilot and demonstration projects to test, mature, and prove CCUS technologies at commercial scale. Responses for the new FOA are due by January 15, 2020.

ANNOUNCEMENTS *(cont.)*

Conference Highlights CCUS.

The Carbon Capture and Storage Association hosted "CCUS 2019: Capturing the clean growth opportunities," which brought together stakeholders from the CCUS sector, including industry providers, potential customers, policymakers, investors, and researchers. Presentations from the conference are [available online](#).



CO₂ Utilization Summit to be Held in February.

Active Communication International's (ACI) 15th Carbon Dioxide Utilization Summit is scheduled for February 26–27, 2020, in Orlando, Florida, USA. Focusing on the reuse of greenhouse gases (GHGs) and their conversion into sustainable materials, the conference brings together senior experts from various industries to discuss the sustainable, technological, and commercial aspects of CO₂ utilization.

PROJECT and BUSINESS DEVELOPMENTS

Joint-Development Agreement May Lead to CO₂ Storage.

ExxonMobil and FuelCell Energy signed a joint-development agreement (JDA) for the purpose of capturing CO₂ from industrial sources. FuelCell Energy's proprietary technology uses carbonate fuel cells to efficiently capture and concentrate CO₂ streams from large, industrial sources. Combustion exhaust is directed to the fuel cell, which produces power while capturing and concentrating CO₂ for storage. The modular design enables the technology to be deployed at a wide range of locations. From *Carbon Capture Journal* on November 7, 2019.

CCS Facility Captures 3 Million Metric Tons of CO₂.

According to company officials, SaskPower's CCS facility near Estevan, Saskatchewan, Canada, has captured more than 3 million metric tons of CO₂. SaskPower has committed to reducing its GHG emissions by at least 40% below 2005 levels by 2030 through increased use of renewable energy, as well as by continuing to utilize CCS technology. From *Carbon Capture Journal* on November 8, 2019.

LEGISLATION and POLICY

EU Countries Increase Funding for Low-Carbon Investment.

Five European Union (EU) member states increased funding to the Modernization Fund, which is a pool of carbon allowances that will be auctioned after 2020 to finance low-carbon investments in Europe. According to the European Commission, the increase in funding is expected to amount to more than 350 additional EU carbon allowances, which will be sold on the common EU auctioning platform in equal shares for each year from 2021 to 2030. The Modernization Fund supports low-carbon investments in the energy systems of 10 EU member states (Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia). From *S&P Global* on November 11, 2019.

Report Highlights CCUS Potential in North Sea.

A new report claims the North Sea has the potential to become a leader in energy transition through the deployment of CCUS technology. The report, titled "*Turning the tide: The transformation of the North Sea*," is a collaboration between PricewaterhouseCoopers and Oil and Gas UK.

Program Looks at Experimental CO₂ Storage Methods.

A Canadian group was awarded a grant for an initiative to turn forest waste into biochar and store it in soil as a potential and experimental means of removing CO₂ through carbon storage.

Drilling Operations Begin for CO₂ Storage Project.

Drilling operations at a CO₂ storage project in southern Australia have begun. Easternwell will drill four wells for its project with CO₂CRC's Otway in Victoria, Australia, using their Rig 103, which is capable of drilling production and core extraction wells 2,400 meters deep. The objective of the project is to demonstrate the efficiency of implementing solutions for monitoring CO₂. From *Ferrovial Newsroom* on November 11, 2019.



Demonstration Plant Reaches CO₂ Injection Target.

Japan CCS (JCCS) achieved its target of 300,000 metric tons of CO₂ injection at the Tomakomai CCS Demonstration Project in Tomakomai City, Hokkaido Prefecture, Japan. JCCS was selected by the Ministry of Economy, Trade, and Industry of Japan to demonstrate CO₂ reduction technologies. The CCS demonstration project at Tomakomai commenced in FY 2012; in November 2019, the cumulative CO₂ injection reached the 300,000 metric ton target. A monitoring operation will be conducted at the project site. From *JCCS Media Release* on November 25, 2019.

New Program Promotes CO₂ Storage.

The U.S. Department of Agriculture's Natural Resources Conservation Service and the Nature Conservancy have partnered on a program to support sustainable forests and carbon market development in targeted areas in Virginia, Tennessee, and Kentucky (USA). The *Healthy Forest Reserve Program* will offer financial assistance for specific conservation actions on private forests and tribal lands. Landowners who develop a carbon forest project will also get assistance with carbon credit development. From *CBS19 News* on November 13, 2019.



EMISSIONS TRADING

RGGI States Release Reports.



The states participating in the Regional Greenhouse Gas Initiative (RGGI) released the 2017 Annual Electricity Monitoring Report. The “[CO₂ Emissions from Electricity Generation and Imports in the Regional Greenhouse Gas Initiative: 2017 Monitoring Report](#),” the ninth such annual monitoring report released by the RGGI states, summarizes data for electricity generation, electricity imports, and related CO₂ emissions for the RGGI states. In addition, the independent market monitor for RGGI released a report containing information on the secondary market for RGGI CO₂ allowances, including future prices, market activity, and allowance holdings. Potomac Economics’ “[Report on the Secondary Market for RGGI CO₂ Allowances: Third Quarter 2019](#)” addresses the period from July through September 2019. The report is part of Potomac’s ongoing monitoring of the RGGI auctions and the secondary markets in which CO₂ allowances are traded, and is based on data reported to the U.S. Commodity Futures Trading Commission and the Intercontinental Exchange, as well as other data. From *RGGI News Releases* on November 8 and 14, 2019.

“[CO₂ Emissions from Electricity Generation and Imports in the Regional Greenhouse Gas Initiative: 2017 Monitoring Report](#),” the ninth such annual monitoring report released by the RGGI states, summarizes data for electricity generation, electricity imports, and related CO₂ emissions for the RGGI states. In addition, the independent market monitor for RGGI released a report containing information on the secondary market for RGGI CO₂ allowances, including future prices, market activity, and allowance holdings. Potomac Economics’ “[Report on the Secondary Market for RGGI CO₂ Allowances: Third Quarter 2019](#)” addresses the period from July through September 2019. The report is part of Potomac’s ongoing monitoring of the RGGI auctions and the secondary markets in which CO₂ allowances are traded, and is based on data reported to the U.S. Commodity Futures Trading Commission and the Intercontinental Exchange, as well as other data. From *RGGI News Releases* on November 8 and 14, 2019.

Full Compliance Requirements Met for California Cap-and-Trade Program.



CALIFORNIA
AIR RESOURCES BOARD

The California (USA) Air Resources Board (CARB) announced that all businesses covered by the state’s cap-and-trade program have fully met their compliance obligations for 2018. In addition, CARB released data from the Mandatory Reporting Regulation (MRR), which shows that emissions remained below 1990 levels in 2018. The *MRR data* also indicates that California is on track to meet the GHG reduction target of 2020 under [Assembly Bill 32](#). From *California Air Resources Board News Release* on November 4, 2019.

SCIENCE NEWS

Engineers Develop New Way to Remove CO₂.

Researchers from the Massachusetts Institute of Technology (MIT) are researching a new way of removing CO₂ from the air that could potentially work at any concentration level. According to the researchers, the new method is also less energy-intensive and less expensive compared to other methods, which require higher concentrations of the gas. The technique is described in an article published in the journal *Energy and Environmental Science*. From *MIT News* on October 24, 2019.

Tool Estimates Carbon Storage Potential.

A new tool enables farmers in New Zealand to estimate how much CO₂ their tree blocks are capable of storing. The carbon stock tool adds to an existing GHG emissions analysis tool by using data from the Ministry for Primary Industries’ [Carbon Look-Up Tables](#) to estimate the carbon storage potential for existing and future tree blocks on farms (Carbon Look-Up Tables are a series of pre-calculated values of forest carbon stocks, by age, for a given forest type). From *New Zealand Herald* on November 2, 2019.

Researchers Study Business Potential of CCUS.

Researchers from UCLA, the University of Oxford, and five other institutions analyzed 10 different ways to use CO₂, focusing on the potential of turning the captured CO₂ into commercial products such as fuels or construction materials. [Published in the journal Nature](#), the research presents a comprehensive study of the potential future scale and cost of utilizing CO₂. From *UCLA Samueli School of Engineering* on November 6, 2019.

JOURNAL ARTICLES

Maturing global CO₂ storage resources on offshore continental margins to achieve 2DS emissions reductions.

The following is from the abstract of this article: “Most studies on CO₂ emissions reduction strategies that address the ‘two-degree scenario’ (2DS) recognize a significant role for CCS. For CCS to be effective, it must be deployed globally on both existing and emerging energy systems. For nations with large-scale emissions, offshore geologic CO₂ storage provides an attractive and efficient long-term strategy. While some nations are already developing CCS projects using offshore CO₂ storage resources, most geographic regions have yet to begin. This paper demonstrates the geologic significance of global continental

margins for providing broadly-equitable, geographically-relevant, and high-quality CO₂ storage resources. [The authors] then use principles of pore-space utilization and subsurface pressure constraints together with analogs of historic industry well deployment rates to demonstrate how the required storage capacity can be developed as a function of time and technical maturity to enable the global deployment of offshore storage for facilitating 2DS. [The authors’] analysis indicates that 10–14 thousand CO₂ injection wells will be needed globally by 2050 to achieve this goal.” **P. S. Ringrose and T. A. Meckel**, *Scientific Reports*. (Subscription may be required.)

JOURNAL ARTICLES (cont.)

Enhanced safety of geologic CO₂ storage with nanoparticles.

The following is from the abstract of this article: "Some methods have been developed to detect leakage of CO₂ from its desired storage domain, but that is not sufficient to prevent and mitigate a leak. Two techniques have been proposed to prevent the migration of buoyant CO₂ from the storage domain by expediting mixing of CO₂ with the brine and mitigate risk of its leakage risk. These two methods are injection of CO₂ pre-mixed with brine, and injection of CO₂ with nanoparticles (NPs). The former has been studied to some extent, however, understanding of the latter is very limited. Unlike the application of NPs in hydrocarbon recovery, its use to enhance safety of CO₂ storage is a fairly unexplored topic that can have important benefits for the safety of the storage process. Also, the use of NPs for subsurface application in general is compromised for its cost. [The authors] investigate how NPs produced from low-level nuclear waste can be added with injected CO₂ to enhance the mixing of CO₂ with brine, which can mitigate leakage risk of CO₂. [The authors] numerically investigate the effect of adding NPs from nuclear waste with the CO₂ and show that it enhances the mixing of CO₂ with in-situ brine in saline aquifers that mitigates the risk related to buoyancy and high mobility of CO₂. Additionally, [the authors] examine the effect of reservoir heterogeneity on mixing of CO₂ in reservoir brine when it is injected with NPs. The results show that: (i) addition of NPs to CO₂ leads to higher mixing, (ii) the discrete shape of CO₂ concentration in brine tends to diffuse and become smooth as the heterogeneity of the medium increases, and (iii) the impact of heterogeneity is more pronounced than the fraction of NPs on mixing." **Harpreet Singh and Akand Islam**, *International Journal of Heat and Mass Transfer*. (Subscription may be required.)

Green tax reforms with promotion of renewable energy sources and carbon capture and sequestration: Comparison of different alternatives.

The following is from the abstract of this article: "The need to decarbonize economic production processes is undeniable and has been considered by most countries worldwide. Renewable Energy Sources (RES) and Carbon Capture and Sequestration (CCS) technologies appear among the most promising routes to the decarbonization process. [The authors] propose an equilibrium model where final-goods production uses labor and energy, and energy is generated using non-polluting RES and polluting fossil fuels. The government implements a Green Tax Reform (GTR), where it imposes a tax on emissions and uses revenues to finance subsidies to RES and support to CCS technologies. [The authors] test how results change according to the priority given to RES or to CCS support. [The authors'] results show that prioritizing RES support achieves better economic results and potentially also better environmental results. Overall, [the authors'] empirical simulation demonstrates that resource substitution has a stronger benefit than decarbonizing fossil fuels." **Susana Silva, Isabel Soares, and Carlos Pinho**, *Energy Reports*. (Subscription may be required.)

Is it worth to invest? -An evaluation of CTL-CCS project in China based on real options.

The following is from the abstract of this article: "China's consumption of liquid fuels as well as the dependence on foreign oil has increased considerably in recent years. Alternative liquid fuel technologies such as coal to liquid (CTL) are attracting attentions. However, facing uncertainties of energy price and carbon price as well as policy fluctuations and potential CO₂ utilizations, evaluations of CTL project becomes a complex question. In this context, [the authors] develop a sequential investment real options decision model of a typical CTL-CCS project in China with the flexibility in investment timing and operation. As an application, the model is used to evaluate Shenhua direct coal liquefaction (DCL) project with CCS retrofits option. Four scenarios and sensitivities of key parameters are discussed. The results show that under current market and policy conditions the CTL project is economically infeasible but the option to delay is of huge value. A high level of carbon price or carbon tax is necessary to make the CCS retrofit economically feasible despite relatively lower capture costs, while the captured CO₂ could be better utilized for Enhanced Oil

Recovery (EOR). [The authors] suggest the government to exempt fuel tax for enhancing the economic viability of CTL companies, especially in the current condition of low oil price." **Xing Yao, Ying Fan, Yuan Xu, Xian Zhang, Lei Zhu, and Lianyong Feng**, *Energy*. (Subscription may be required.)

Reaction of pseudowollastonite with carbonate-bearing fluids: Implications for CO₂ mineral sequestration.

The following is from the abstract of this article: "The kinetics of silicate carbonation in aqueous solutions are typically sluggish, especially at neutral to alkaline conditions. This hampers the complete understanding of the mechanisms and parameters that control mineral carbonation during carbon capture and storage (CCS). Here [the authors] study the hydrothermal dissolution and carbonation of pseudowollastonite (psw; α -CaSiO₃), one of the most reactive silicates known, under a range of geochemical conditions ranging from acidic to strongly alkaline pH, presence/absence of different background alkali metal ions and carbonate sources (K₂CO₃ and Na₂CO₃, pH ~13, or NaHCO₃ and KHCO₃, pH ~9). [The authors] show that in addition to amorphous silica precipitation, the formation of secondary Na+Ca- or K+Ca-silicates in the presence of Na⁺ and K⁺ background ions, respectively, fosters the progress of psw carbonation. However, the formation of Ca-containing secondary crystalline silicates and Ca-containing amorphous silica is shown to be a strong handicap for a fully effective carbonation. In all cases a higher conversion into CaCO₃ (up to ~70 mol%) is achieved when using bicarbonate salts (i.e., lower initial pH). By using a reactor with a pressurized CO₂-solution, with and without Na⁺ or K⁺ background ions, rapid and nearly complete conversion of psw with a CaCO₃ yield ~92 mol% is achieved because, in addition to the initial low pH (~3.7) that favored α -CaSiO₃ dissolution, abundant Ca-free non-passivating amorphous silica formed along with calcite. These results imply that the presence (e.g., use of sea water during CO₂ injection or mixing with saline formation solutions) or the release of different alkali metal ions (e.g., after feldspar and/or basaltic glass dissolution) in combination with a reaction-induced pH increase during in situ CCS scenarios may strongly limit carbonation due to the capture of alkaline-earth metals in secondary silicates and a reduction in reaction rates. In turn, [the authors'] results show that the high conversion achieved in pure CO₂-aqueous systems, while relevant for ex situ CCS, may not reflect the actual conversion in multicomponent natural systems following reactive transport during in situ CCS. Moreover, the precipitation of secondary silicate and calcium carbonate phases have a direct cementing effect, which could be detrimental for in situ CCS, as it would likely reduce host rock permeability, but would be relevant and beneficial for the setting of novel CaSiO₃-based non-hydraulic cements with reduced CO₂ footprint." **Luis Monasterio-Guillot, Fulvio Di Lorenzo, Encarnacion Ruiz-Agudo, and Carlos Rodriguez-Navarro**, *Chemical Geology*. (Subscription may be required.)

Offshore power generation with carbon capture and storage to decarbonise mainland electricity and offshore oil and gas installations: A techno-economic analysis.

The following is from the abstract of this article: "This study investigates the techno-economic potential of offshore power generation from natural gas with carbon capture and storage to reduce the climate impact of mainland electricity and the offshore oil and gas industry. This potential is assessed through techno-economic assessments over two relevant cases ('floating' and 'shallow water' cases) including comparison with relevant reference concepts. In the base case evaluation, the offshore power plant concept toward decarbonising mainland electricity results in high costs (178 and 258 \$/MWh respectively for the floating and shallow water cases) compared to a reference onshore power plant with carbon capture and storage (around 95 \$/MWh). However, a stronger potential is identified for the concept toward decarbonising offshore oil and gas platforms as the concept results in costs more comparable with the reference electrification concept (137 compared to 133 \$/MWh in the floating case and 207 compared to 166 \$/MWh in the shallow water case). Although the base cases show a limited potential for the offshore concept, the results show that with technological improvements (advanced capture technology, reuse of infrastructure...) and more suited case characteristics (development

JOURNAL ARTICLES *(cont.)*

based on associated gas...), the offshore concept offers a significant potential for cost-efficiently decarbonising the offshore oil and gas industry, while a more moderate potential is foreseen for the decarbonisation of mainland electricity.” **S. Roussanaly, A. Aasen, R. Anantharaman, B. Danielsen, J. Jakobsen, L. Heme-De-Lacotte, G. Neji, A. Sødal, P.E. Wahl, T.K. Vrana, and R. Dreux,** *Applied Energy*. (Subscription may be required.)

Pressure management via brine extraction in geological CO₂ storage: Adaptive optimization strategies under poorly characterized reservoir conditions.

The following is from the abstract of this article: “Industrial-scale injection of CO₂ into the subsurface increases the fluid pressure in the reservoir, which if not properly controlled can potentially lead to geomechanical damage (i.e., fracturing of the caprock or reactivation of faults) and subsequent CO₂ leakage. Brine extraction is one approach for managing formation pressure, effective stress, and plume movement in response to CO₂ injection. The management of the extracted brine can be expensive (i.e., due to transportation, treatment, disposal, or re-injection), with added cost to the carbon capture and sequestration (CCS); thus, minimizing the volume of extraction brine is of great importance to ensure that the economics of CCS are favorable. The main objective of this study is to demonstrate the use of adaptive optimization methods in the planning of brine extraction and to investigate how the quality of initial site characterization data and the use of newly acquired monitoring data (e.g. pressure at observation wells) impact the optimization performance. [The authors] apply an adaptive management approach that integrates monitoring, calibration, and optimization of brine extraction rates to achieve pre-defined pressure constraints. [The authors’] results show that reservoir pressure management can be extremely benefited by early and high frequency pressure monitoring during early injection times, especially for poor initial reservoir characterization. Low frequencies of model calibration and optimization with monitoring data may lead to optimization problems because either pressure buildup constraints are violated or excessively high extraction rates are proposed. The adaptive pressure management approach may constitute an effective tool to manage pressure buildup under uncertain reservoir conditions by minimizing the volumes of extracted brine while controlling pressure buildup.” **Ana González-Nicolás, Abdullah Cihan, Robin Petrusak, Quanlin Zhou, Robert Trautz, David Riestenberg, Michael Godec, and Jens T. Birkholzer,** *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

Modeling oil saturation evolution in residual oil zones: Implications for CO₂ EOR and sequestration.

The following is from the abstract of this article: “Residual oil zones (ROZs) are extensively developed in carbonate formations in the Permian Basin, West Texas. These ROZs have the potential both for economically-viable CO₂ enhanced oil recovery (CO₂-EOR) and for significant volumes of associated CO₂ sequestration. The accepted model for ROZ formation is based on the hydrodynamic effects of tectonically-controlled increased water flow in aquifers at the base of oil fields. The nature of this process is modelled using a commercial reservoir simulator in this work. These simulations explore the effects of strength of aquifer flow, flow direction, and capillary pressure on the nature and distribution of oil saturations in ROZs. A special emphasis was on understanding the impact of heterogeneity of capillary pressures in ROZ reservoirs. These factors determine the thickness of ROZs, the magnitude of oil saturation, and the slope of water-oil contacts. Understanding the magnitude of oil saturation and how it varies within ROZs is important in determining reserves, and evaluating both EOR and sequestration potential. The geometry of ROZs are established slowly, especially for small regional water fluxes, however oil saturations achieve almost steady states in relatively short time scales. The simulated oil saturation profiles found in this study are in reasonable agreement with the measured profile published for the San Andres Seminole Unit’s ROZ. The results support the plausibility of the hydrodynamic model, but do not rule out other models for the origin of ROZs.” **Bo Ren and Ian Duncan,** *Journal of Petroleum Science and Engineering*. (Subscription may be required.)

Achieving carbon-neutral iron and steelmaking in Europe through the deployment of bioenergy with carbon capture and storage.

The following is from the abstract of this article: “The 30 integrated steel plants operating in the European Union (EU) are among the largest single-point CO₂ emitters in the region. The deployment of bioenergy with carbon capture and storage (bio-CCS) could significantly reduce their emission intensities. In detail, the results demonstrate that CO₂ emission reduction targets of up to 20% can be met entirely by biomass deployment. A slow CCS technology introduction on top of biomass deployment is expected, as the requirement for emission reduction increases further. Bio-CCS could then be a key technology, particularly in terms of meeting targets above 50%, with CO₂ avoidance costs ranging between €60 and €100 t_{CO2}⁻¹ at full-scale deployment. The future of bio-CCS and its utilisation on a larger scale would therefore only be viable if such CO₂ avoidance cost were to become economically appealing. Small and medium plants in particular, would economically benefit from sharing CO₂ pipeline networks. CO₂ transport, however, makes a relatively small contribution to the total CO₂ avoidance cost. In the future, the role of bio-CCS in the European iron and steelmaking industry will also be influenced by non-economic conditions, such as regulations, public acceptance, realistic CO₂ storage capacity, and the progress of other mitigation technologies.” **Hana Mandova, Piera Patrizio, Sylvain Leduc, Jan Kjærstad, Chuan Wang, Elisabeth Wetterlund, Florian Kraxner, and William Gale,** *Journal of Cleaner Production*. (Subscription may be required.)

Comparing carbon accumulation in restored and natural wetland soils of coastal Louisiana.

The following is from the abstract of this article: “Louisiana’s chronic wetland deterioration has resulted in massive soil organic matter loss and subsequent carbon release through oxidation. To combat these losses, and reestablish ecosystem function, goods, and services, many restoration projects have been constructed or planned throughout coastal Louisiana. There are significant data gaps and conflicting results regarding wetland contributions [...] especially related to carbon sequestration in restored wetlands. An exceptionally large data set was used to derive carbon accumulation rates from key soil characteristics and processes. Assessments and comparisons of bulk density, organic matter, total carbon, vertical accretion (short- and longer-term), and carbon accumulation rates were made across time (chronosequence) and space (i.e., coastwide, watershed basins, and vegetation zones). Carbon accumulation rates in the Louisiana coastal zone were generally correlated to hydrogeomorphology, with higher rates occurring in zones of high river connectivity or in swamp or higher salinity tolerant marsh. On average, naturally occurring wetlands had higher carbon accumulation rates than restoration sites. Although some restoration measures were higher, and most showed increasing carbon accumulation rates over time [...]” **Glenn M. Suir, Charles E. Sasser, Ronald D. DeLaune, and Elizabeth O. Murray,** *International Journal of Sediment Research*. (Subscription may be required.)

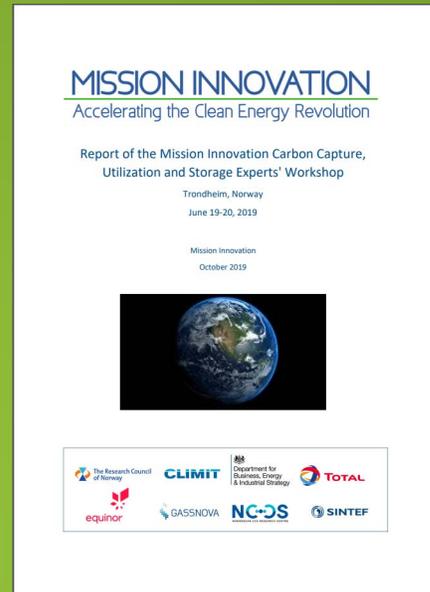
REPORTS and OTHER PUBLICATIONS

Carbon Capture Innovation Challenge: Report of the Carbon Capture, Utilization and Storage Experts' Workshop.

The following is from the Preface of this Mission Innovation Report: "... The Mission Innovation Carbon Capture Challenge aims to provide a platform for advancing broad international collaboration in CCUS research and development that could significantly reduce CO₂ emissions. This report presents the outcome of the Mission Innovation CCUS Experts workshop held in Trondheim, Norway in June 2019, in which attendees worked to identify research gaps, opportunities, and priorities in CCUS. The workshop addressed six different topics, and the report presents summaries and recommendations for all six topics, in short-, medium-, and long-term perspectives."

Scaling Up Action: Aiming for net zero emissions.

The following is from the Foreword of this Oil and Gas Climate Initiative (OGCI) report: "A key focus for OGCI this year has been carbon capture, use and storage (CCUS). [OGCI is] delighted to be launching CCUS KickStarter, a major new initiative designed to facilitate large-scale commercial investment in CCUS, by enabling multiple low-carbon industrial hubs. These hubs capture carbon dioxide from several industrial companies and bring economies of scale by sharing transport and storage infrastructure. [OGCI aims] to work with governments and other industries to facilitate the necessary market conditions for investment in CCUS hubs and projects by OGCI member companies, OGCI Climate Investments, governments and other investors. To this end [OGCI has] developed a strategic cooperation with the Clean Energy Ministerial CCUS Initiative to facilitate the market conditions for commercial scale investment in CCUS around the world."



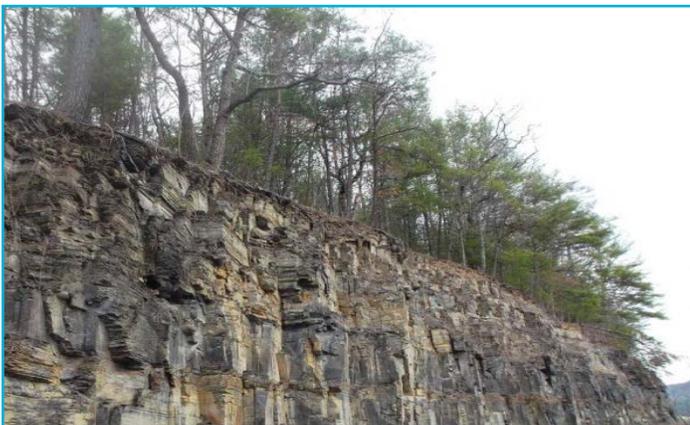
ABOUT DOE'S CARBON STORAGE PROGRAM

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 CO₂, 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 CO₂ emissions. The program also serves to increase the understanding of the effectiveness of advanced technologies in different geologic reservoirs appropriate for CO₂ 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 CO₂ behaves in the subsurface. These objectives are key to increasing confidence in safe, effective, and permanent geologic CO₂ 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](#).



Parallel, vertical, orthogonal natural fracture faces (joint sets) in an outcrop of organic-rich Millboro Shale (Marcellus equivalent), Clover Creek, VA. Photo by Dan Soeder, 2014.

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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