CSN CARBON STORAGE NEWSLETTER

MARCH 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:

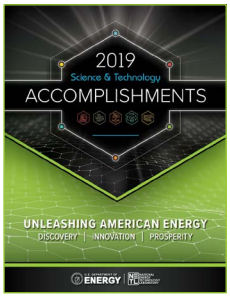
CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

NATIONAL ENERGY TECHNOLOGY LABORATORY

DOE/NETL HIGHLIGHTS

NETL Celebrates 2019 Achievements.

The National Energy Technology Laboratory (NETL) welcomed congressional guests and university partners to the *Science and Technology (S&T) Accomplishments Session*, celebrating more than 30 notable 2019 S&T accomplishments that focused on key research priorities that promote safe, reliable, and affordable energy nationwide. The interactive poster session, held at NETL's Pittsburgh, Pennsylvania (USA) site, featured a broad range of NETL researchers sharing work that showcased NETL's facilities and core science and engineering capabilities. From *NETL Press Release* on February 20, 2020.



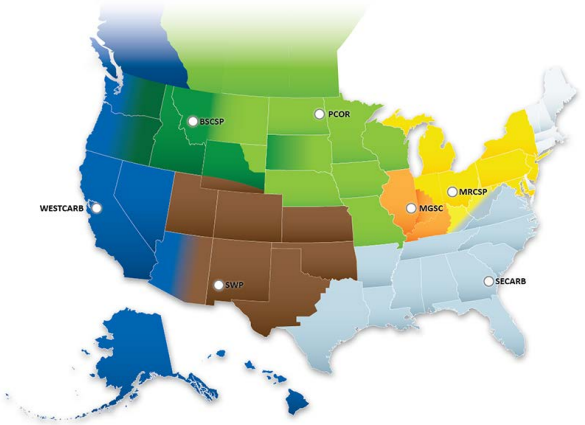
FY 2021 Congressional Budget Request Released.

The President's FY 2021 Congressional Budget Request seeks $930.7 million to fund the U.S. Department of Energy's (DOE) Office of Fossil Energy (FE). The Budget Request includes funding for the Fossil Energy Research and Development (R&D) Program, which includes R&D programs in carbon capture, utilization, and storage (CCUS). The FY 2021 Budget Request focuses on early-stage R&D and reflects an increased reliance on the private sector to fund later-stage research, development, and commercialization of energy technologies. From *energy.gov* on February 11, 2020.

ANNOUNCEMENTS

NETL Project Validates CO_2 Storage.

The Plains CO_2 Reduction (PCOR) Partnership, one of DOE's seven *Regional Carbon Sequestration Partnerships (RCSPs)*, completed work across the Great Plains and into portions of Canada that demonstrates the ability to reduce carbon dioxide (CO_2) emissions and enhance the efficiency of oil production. Supported by NETL, RCSP activities have included assessments of geologic and terrestrial storage potential in each region, followed by small-scale validation projects and six large-scale (greater than 1 million metric tons of CO_2) geologic storage projects.



Podcast Features NETL, Carbon Storage.

DOE/NETL was featured on a recent edition of the Energy Cast podcast, in which the focus was carbon storage. The episode covered the 45Q tax credit, enhanced oil recovery (EOR), and the RCSPs, among other topics.

ANNOUNCEMENTS *(cont.)*

DOE Announces Funding for Components of Coal FIRST Power Plants.

DOE/NETL announced federal funding for cost-shared R&D projects under the Funding Opportunity Announcement (FOA) "*Critical Components for Coal FIRST Power Plants of the Future*." DOE's Coal FIRST (Flexible, Innovative, Resilient, Small, Transformative) Initiative seeks to develop the coal plant of the future needed to provide secure and reliable power to the U.S. grid. DOE anticipates selecting up to 14 cost-shared projects focused on developing the critical components required by Coal FIRST and transformational coal-fired systems. Responses are due March 30, 2020.

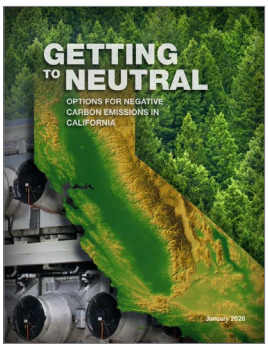
Report: US Energy-Related CO_2 Emissions Reduced in 2019.

An *International Energy Agency (IEA) report* claims that energy-related CO_2 emissions in the United States fell 2.9% in 2019. According to the report, U.S. emissions have decreased nearly 1 metric gigaton since 2000.

Saudi Arabia Hosts International Conference on CCUS.

More than 800 participants attended the International Carbon Capture, Utilization, and Storage Conference (*iCCUS 2020*) in Riyadh, Saudi Arabia. Organized by the National Oil and Gas Authority, the conference focused on the role of CCUS technologies in empowering the global carbon economy.

LLNL Develops Program for a Carbon-Neutral California.



The Lawrence Livermore National Laboratory (LLNL) released a report outlining ways to make California (USA) carbon neutral by 2045. "*Getting to Neutral: Options for Negative Carbon Emissions in California*" offers a three-pronged strategy for removing CO_2 emissions across the state, leading to the potential storage of 125 million metric tons of CO_2 underground each year.

Reforestation Initiative Reaches Milestone.

The Hawaiian Legacy Reforestation Initiative planted its 500,000th tree in Hawaii (USA), increasing carbon storage on the island. To date, more than 1,200 acres of former pastureland on Oahu and Hawaii Island have been reclaimed and returned to native forest.

PROJECT and BUSINESS DEVELOPMENTS

Study to Map UK Offshore CO_2 Storage Potential.

A study conducted by Heriot-Watt University (Edinburgh, Scotland) will produce a roadmap for CO_2 storage in the United Kingdom (UK) by identifying sites with CO_2 storage potential. Funded by the Oil and Gas Technology Centre and supported by the UK regulator Oil and Gas Authority, the study will focus on mapping the geological features of the gas fields of the southern North Sea. The sites with the most CO_2 storage potential, as well as those with any potential release points, will be identified, and the overburden will be mapped to develop mitigation strategies and warning systems for any possible CO_2 release. From *Carbon Capture Journal* on February 5, 2020.

ExxonMobil to Expand Carbon Capture Facility, EOR Operations.

ExxonMobil filed a permit application to expand its carbon capture facility in LaBarge, Wyoming (USA) and construct a pipeline and CO_2 injection well. In addition, ExxonMobil plans to add compressors to capture approximately 50% more CO_2 from natural gas streams than existing infrastructure allows; the CO_2 will then likely be used for EOR. The company plans to begin construction later this year and complete the project by 2020. From *Billings Gazette* on February 10, 2020.

Monitoring Work Completed for North Sea CCS Project.

Ashtead Technology completed subsea installation monitoring work to support the Northern Lights carbon capture and storage (CCS) project in the North Sea. Ashtead Technology monitored the installation of an Integrated Satellite Structure with their Deflection Monitoring System and equipment, which monitored and analyzed parameters in real-time, reducing the risk of structural damage by enabling any potential issues to be acted upon quickly. Developed by Equinor in partnership with Shell and Total, the Northern Lights CCS project seeks to capture and transport CO_2 from onshore sources and store it under the seabed. From *Oilfield Technology* on February 13, 2020.

Pre-FEED Carbon Capture Study Commissioned.

Chevron Technology Ventures commissioned a pre-front end engineering design (FEED) study to explore the potential for testing technology by Svante Inc. (formerly Inventys Inc.). The pre-FEED study will evaluate the feasibility and design of a CO_2 capture unit in one of Chevron's California (USA) facilities and is expected to be complete in the first half of 2020. From *Hydrocarbon Engineering* on February 12, 2020.

Drax Announces New CCUS Projects.

Drax Group announced new partnerships with cleantech company Econic Technologies and Deep Branch Biotechnology that may lead to projects using CCUS technology. In addition, Drax is working with multiple businesses to deliver *a zero-carbon industrial cluster* by 2040, in which CO_2 from industry across the region (North of England) could be captured, transported, and stored under the North Sea. From *Drax Press Release* on January 30, 2020.

Partnership Receives Grant to Incorporate Carbon Storage.

A partnership consisting of towns and non-profit organizations in Massachusetts (USA) received a grant from the state that may be used to incorporate carbon storage practices. The Mohawk Trail Woodlands Partnership plans to utilize the grant to conduct a regional feasibility study to explore forestry management practices that incorporate carbon storage. The Mohawk Trail Woodlands Partnership works to increase natural resource-based economic development, support forest conservation on private land and use of sustainable forestry practices, and improve the fiscal sustainability of towns and cities. From *Greenfield Recorder* on February 12, 2020.

LEGISLATION and POLICY

CCUS Legislation Proposed.

Legislation that promotes R&D for carbon capture technology and researches solutions for CO_2 utilization was introduced in the U.S. House of Representatives. The *New Energy Frontiers Through Carbon Innovation Act* directs existing DOE funds for research, development, and deployment of carbon capture technology for natural gas-generated power, and also establishes a "Carbon Innovation Hub" that will examine solutions to CO_2 utilization. From *U.S. Congressman Dan Crenshaw Press Release* on February 12, 2020.

US Representative Introduces Legislation Incentivizing Carbon Storage.

Legislation that incentivizes the use of wood products as carbon storage devices by planting 1 trillion trees globally by 2050 was introduced in the U.S. House of Representatives. The *Trillion Trees Act* is based on a 2019 Swiss report featured by the American Academy for the Advancement of Science that concluded planting 1 trillion trees throughout the world could store 205 gigatonnes of CO_2. The act has three parts: (1) plant more trees in urban areas, (2) grow more wood in existing forests, and (3) store more CO_2 by incentivizing innovative building practices. From *U.S. Congressman Bruce Westerman Press Release* on February 12, 2020.

Bill Seeks Net-Zero CO_2 Emissions in US by 2050.

A group of U.S. senators introduced a bill that would require the United States to become "net-zero" by 2050. *The Clean Economy Act* would require the U.S. Environmental Protection Agency (EPA) to develop a plan to reduce greenhouse gas (GHG) emissions by 2025, 2030, and 2040, before reaching net-zero emissions by 2050. From *The Hill* on February 11, 2020.

Legislation Looks to Expand Carbon Storage Tax Credit.

Legislation to expand the 45Q carbon storage tax credit and make it permanent in the federal tax code was introduced in the U.S. House of Representatives. Section 45Q provides a tiered tax credit for projects that permanently store CO_2, with the current law requiring that projects begin before 2024 in order to qualify. In addition to making the credit permanent, *the legislation* would enhance the value of the credit by 25% for both tiers and reduce the minimum amount of CO_2 that must be stored for a direct air capture project to qualify from 100,000 tons to 50,000 tons. From *Ethanol Producer Magazine* on February 13, 2020.

EMISSIONS TRADING

Virginia House Legislation Includes Cap-and-Trade Language.

The Virginia House of Delegates passed legislation that includes language to add the state to the Regional Greenhouse Gas Initiative (RGGI) program. From *WHSV* on February 11, 2020.

RGGI Secondary Market Report Made Available.

The independent market monitor for the RGGI released a report containing information on the secondary market for RGGI CO_2 allowances, including future prices, market activity, and allowance holdings. Potomac Economics' "*Report on the Secondary Market for RGGI CO_2 Allowances: Fourth Quarter 2019*" addresses the period from October through December 2019. The report is part of Potomac's ongoing monitoring of the RGGI auctions and the secondary markets where CO_2 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 Release* on February 13, 2020.

IRS Issues Guidance on Carbon Capture Credits.

The U.S. Government Internal Revenue Service (IRS) issued guidance to help businesses understand legislation on claiming carbon capture credits. The IRS also announced plans for future guidance on the secure geologic storage of CO_2. *Notice 2020-12* provides guidance to help businesses determine when construction has begun on a qualified facility or on carbon capture equipment that may be eligible for the carbon capture credit. *Revenue Procedure 2020-12* creates a safe harbor that simplifies the application of carbon capture credit rules to partnerships able to claim the credit. From *IRS News Release* on February 19, 2020.

Partnership to Sell Carbon Offsets.

Spanish renewable energy company Acciona SA and Valencia-based Climate Blockchain Initiatives have partnered to support the global expansion of a carbon credits trading platform. The *ClimateTrade platform* uses blockchain technology to make commercial transactions of carbon offsets more efficient. From *Renewables Now* on February 19, 2020.

SCIENCE NEWS

Nitrogen-Fixing Trees Help Forests Store More CO_2.

According to a study *published in the journal Nature Communications*, the ability of tropical forests to store CO_2 depends upon the trees' capacity to fix nitrogen from the atmosphere. The study modeled how the mix of tree species growing in a tropical forest following a disturbance, such as clearcutting, can affect the forest's ability to store CO_2. The results showed that the presence of trees that fix nitrogen have the potential to double the amount of CO_2 a forest stores in its first 30 years of growth. Furthermore, the researchers found that at maturity, forests with nitrogen fixation stored 10% more CO_2 than those without. From *Phys.org* on February 13, 2020.

Oceans: Particle Fragmentation Plays a Role in Carbon Storage.

A team of French and British researchers analyzed a process that regulates the capacity of oceans to store CO_2. Photosynthesis performed by phytoplankton on the ocean's surface converts atmospheric CO_2 into organic particles, some of which sink to its depths, and are stored as oceanic carbon. By using a fleet of robots deployed in different oceans, scientists were able to study the particle flux and carbon storage potential. The results were *published in the online journal Science*. From *EurekAlert!* On February 13, 2020.

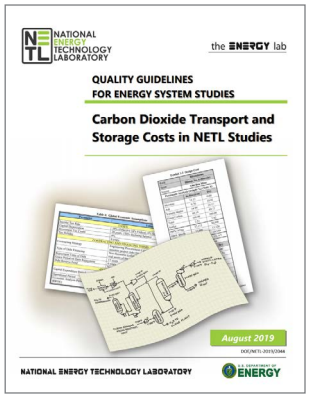
PUBLICATIONS

Pulverized Coal Carbon Capture Retrofit Database.

The following is a description of this DOE/NETL product: "This tool provides a high level analysis on the incremental costs for retrofitting point sources with CO_2 capture and compression systems. Options are available to include cost of other technological improvements that would be required to comply with various regulations and new source performance standard when installing CO_2 capture technology."

Quality Guidelines for Energy System Studies: Carbon Dioxide Transport and Storage Costs in NETL Studies.

The following is a description of this DOE/NETL product: "The costs to be used in energy system studies sponsored by the National Energy Technology Laboratory (NETL) for estimating the cost of carbon dioxide (CO_2) pipeline transport and storage (T&S) (rounded to the nearest whole, real dollar in 2018 dollars per metric ton [2018$/tonne])."



The fossil fuel industry's framing of carbon capture and storage: Faith in innovation, value instrumentalization, and status quo maintenance.

The following is from the abstract of this article: "Drawing from the critical theory of Herbert Marcuse, [the authors] expect that the fossil fuel industry will support carbon capture and storage (CCS) because it can further and prolong profitability in the industry. Through a qualitative analysis of fossil fuel company and trade organization framings of CCS, three frames are identified: (1) faith in innovation, or, the belief that any barrier that fetters technological solutions to environmental problems can be overcome; (2) value instrumentalization, or, the predominance of instrumental values when justifying or explaining the benefits of technological solutions; and (3) status quo maintenance, or, the application or anticipated application of technological solutions in order to reproduce the most fundamental processes and social structures that characterize modern societies. Frames tend to omit the following issues and concerns relevant to CCS: (4) potential social and environmental risks (risk minimization); (5) non-instrumental values (value restriction); and (6) possible future scenarios that are qualitatively different than a growing economy powered by increased energy throughput (possibility blindness). The potential climate and energy policy implications of these framings are analyzed and assessed." **Ryan Gunderson, Diana Stuart, and Brian Peterson,** *Journal of Cleaner Production*. (Subscription may be required).

Gas hydrate exploitation and carbon dioxide sequestration under maintaining the stiffness of hydrate-bearing sediments.

The following is from the abstract of this article: "To improve the stratum mechanical properties and prevent the geological disaster, [the authors] present a new approach by executing CH_4 hydrate exploitation and CO_2 sequestration below the freezing point of water to maintain the stratum stiffness during and after hydrate exploitation. An experimental method to clearly show the evolution of the stratum mechanical properties was built and a series of experiments were conducted to simulate the CH_4 exploitation and CO_2 sequestration process below and above the freezing point of water. The stratum stiffness was found to be maintained during the whole hydrate exploitation process when below the freezing point. Moreover, the presence of ice improves the stratum stiffness due to cementing the sandy grain. The CO_2 injection into the hydrate-bearing sediments would further enhance the mechanical properties and realize a CO_2 geological sequestration. Compared with hydrate exploitation above the freezing point, the CH_4 recovery efficiency is a little lower when under below the freezing point and it decreased with the increased hydrate saturation due to the CH_4 hydrate being surrounded by the generation of ice from hydrate dissociation. This phenomenon could be modified by injecting CO_2, from which the CH_4 recovery efficiency obviously improved for hydrate exploitation below the freezing point." **Liang-Liang Ren, Min Jiang, Ling-Ban Wang, Yi-Jian Zhu, Zhi Li, Chang-Yu Sun, and Guang-Jin Chen,** *Energy*. (Subscription may be required.)

Silicate mediated simultaneous in-situ CO_2 sequestration and nutrients removal in anaerobic digestion.

The following is from the abstract of this article: "This study investigated the reactions among CO_3^{2-}, PO_4^{3-}, NH_4^+, Mg^{2+}, and Ca^{2+}, under different CO_3^{2-} concentration and Mg^{2+}/Ca^{2+} ratio, and conducted sludge anaerobic digestion (AD) with silicate addition to achieve in-situ CO_2 sequestration and nutrients removal. High CO_3^{2-} concentration facilitated the formation of $MgNH_4PO_4$, and Mg^{2+}/Ca^{2+} ratio of 1:1 achieved best CO_3^{2-}, PO_4^{3-}, and NH_4^+ removal in simulated anaerobic digestate. Supplementation of 40 g/L magnesium silicate combined with 20 g/L wollastonite decreased CO_2 content in biogas from 28.2% to 19.0%, and removed PO_4^{3-} and NH_4^+ by 61.8% and 21.2%, respectively, in AD. Simultaneous in-situ CO_2 sequestration and nutrients removal was achieved by directed precipitation of PO_4^{3-}, NH_4^+, and CO_2 with silicate released Mg^{2+} and Ca^{2+}, to form $MgNH_4PO_4$ and $CaCO_3$. Meanwhile, methane production was improved by 51.2% with silicate supplementation. This study provides an attractive measure for CO_2 and nutrients removal as well as methane production enhancement of sludge AD." **He Liu, Linlin Gong, Yan Zhang, Qianqian Jiang, Minhua Cui, Jie Zhang, Bo Fu, and Hongbo Liu,** *Bioresource Technology*. (Subscription may be required.)

PUBLICATIONS *(cont.)*

Mechanism of the CO_2 storage and in situ hydrogenation to CH_4. Temperature and adsorbent loading effects over Ru-CaO/Al_2O_3 and Ru-Na_2CO_3/Al_2O_3 catalysts.

The following is from the abstract of this article: "The use of fossil fuels to satisfy the growing energy demand results in the emission of a huge amount of CO_2 to the atmosphere. One alternative to overcome this environmental issue is the CO_2 valorization through the storage and in situ hydrogenation to CH_4. In this work, Ru-CaO/Al_2O_3 and Ru-Na_2CO_3/Al_2O_3 dual function materials are synthesized with different adsorbent loadings, namely 5, 10 and 15 wt.%. The prepared catalysts are characterized in terms of surface area by N_2 adsorption and desorption, crystallinity by XRD, Ru dispersion by H_2-chemisorption and TEM, basicity by CO_2-TPD and reducibility and oxidation state of the noble metal by H_2-TPR and XPS. Temperature programmed surface reaction experiments with H_2 on samples with pre-adsorbed CO_2 reveal that the decomposition of surface carbonates and the subsequent hydrogenation occurs at lower temperatures for catalysts containing Na_2CO_3 than CaO. A complete reaction scheme describing the CO_2 adsorption and hydrogenation process has been proposed based on the temporal evolution of reactants and products. Oxides (CaO or Na_2O) and hydrated oxides ($Ca(OH)_2$ or NaOH) have been identified as CO_2 storage sites, the former oxides being more reactive towards the CO_2 adsorption. CH_4, H_2O and minor amounts of CO are detected during the hydrogenation step. The CO_2 storage and hydrogenation to CH_4 is promoted with increasing the adsorbent loading. Maximum CH_4 production of 414 $\mu molg^{-1}$ is observed for Ru15%CaO/Al_2O_3 at 400°C. High temperature is needed to efficiently decompose the highly stable carbonates formed onto CaO. On the other hand, the higher Ru dispersion along with a lower stability of carbonates in Ru10%Na_2CO_3/Al_2O_3 promotes CH_4 formation (383 $\mu molg^{-1}$) at notably lower temperature, i.e. 310°C. Thus, Ru10%Na_2CO_3/Al_2O_3 is regarded as a suitable catalyst for the CO_2 storage and in situ hydrogenation to CH_4." **A. Bermejo-López, B. Pereda-Ayo, J.A. González-Marcos, and J.R. González-Velasco,** *Applied Catalysis B: Environmental.* (Subscription may be required.)

Determinants of Soil Organic Carbon Sequestration and Its Contribution to Ecosystem Carbon Sinks of Planted Forests.

The following is from the abstract of this article: "The area of forest established through afforestation/reforestation has been increasing on a global scale, which is particularly important as these planted forests attenuate climate change by sequestering carbon. However, the determinants of soil organic carbon sequestration and their contribution to the ecosystem carbon sink of planted forests remains uncertain. By using globally distributed data extracted from 154 peer-reviewed publications and a total of 355 sampling points, [the authors] investigated above-ground biomass carbon (ABC) sequestration and soil organic carbon (SOC) sequestration across three different climatic zones (tropical, warm temperate, and cold temperate) through correlation analysis, regression models, and structural equation modeling (SEM). [The authors] found that the proportion of SOC sequestration in the ecosystem C sequestration averaged 14.1% globally, being the highest (27.0%) in the warm temperate and the lowest (10.7%) in the tropical climatic zones. The proportion was mainly affected by latitude. The sink rate of ABC (R_{ABC}) in tropical climates (2.48 Mg C ha^{-1} yr^{-1}) and the sink rate of SOC (R_{SOC}) in warm temperate climates (0.96 Mg C ha^{-1} yr^{-1}) were higher than other climatic zones. The main determinants of R_{SOC} were the number of frost-free days, latitude, mean annual precipitation (MAP), and soil organic carbon density (SOCD) at the initial observation; however, these variables depended on the climatic zone. According to the SEM, frost-free period MAT, and MAP are the dominant driving factors affecting R_{SOC} in Chinese plantations. MAT has an positive effect on R_{SOC}, and global warming may increase R_{SOC} of temperate plantations in China. [The authors'] findings highlight the determinants of SOC sequestration and quantitatively reveal the substantial global contribution of SOC sequestration to ecosystem carbon sink provided by planted forests. [The authors'] results help managers identify and control key factors to increase carbon sequestration in forest ecosystems." **Shiqiang Wang and Yao Huang,** *Global Change Biology.* (Subscription may be required.)

Projected trends of soil organic carbon stocks in Meghalaya state of Northeast Himalayas, India. Implications for a policy perspective.

The following is from the abstract of this article: "Agricultural and forestry activities can affect soil organic carbon (SOC) levels and CO_2 emissions from terrestrial ecosystems due to land use changes. In Northeast Himalayas, studies on the effects of forest conversion to temporary agricultural lands (*jhum*) on the loss of SOC and soil quality degradation have received the attention of policy makers and scientific research. Presently, local communities are now oriented towards the settled plantations systems with modern cash crops such as tea and rubber, that could act as potential SOC sinks. However, no information on SOC dynamics and simulation studies after land-use change from temporary agricultural lands (*jhum*) to settled cultivations and under climate change (CC) conditions are available for the Meghalaya state. Applying the RothC model, [the authors] focused on four different scenarios including the conversion from *jhum* to settled cultivation (rubber plantations and tea gardens), as well as continuous *jhum* cultivation and *jhum* to *jhum* with a period of secondary succession. Simulations under CC conditions indicated that SOC stocks significantly increased by 1.20 t C ha^{-1} yr^{-1} in tea gardens compared to rubber and *jhum* scenarios. Conversely, SOC stocks slightly decreased by 0.07 t C ha^{-1} yr^{-1} in rubber plantations, while the regrowth of a natural vegetation cover as secondary succession following the abandonment of the *jhum* fields, showed a lower SOC decrease (0.18 t C ha^{-1} yr^{-1}) compared to the continuous *jhum* cultivation (0.24 t C ha^{-1} yr^{-1}). Thus, for CC mitigation in a policy perspective, tea gardens could represent the best land use to store increasing amounts of SOC in the long-term perspective and optimize farmers' incomes, while in rubber plantations SOC storage is limited in time. *Jhum* cultivation can benefit in terms of productivity and profitability by extending the duration of the secondary succession period." **Gaurav Mishra, Krishna Giri, Abhishek Jangir, and Rosa Francaviglia,** *Science of The Total Environment.* (Subscription may be required.)

Ten-year long-term organic fertilization enhances carbon sequestration and calcium-mediated stabilization of aggregate-associated organic carbon in a reclaimed Cambisol.

The following is from the abstract of this article: "Soils play a vital role in the global carbon (C) cycle, yet little is known about the calcium (Ca)-mediated stabilization of soil organic carbon (SOC) in calcareous soils. With wet sieving, density fractionation and an incubation experiment from field soils, [the authors] investigated the effects of long-term fertilization on the Ca-mediated stabilization of aggregate-associated organic C and on the SOC stock at a soil depth of 0–20 cm in a reclaimed Cambisol on the Loess Plateau of China. Compared to the initial soil, after ten years the SOC stock increased by 50%, 76%, 94% and 110% in soils amended with no fertilizer (control), 100% chemical fertilizer, 50% chemical fertilizer plus 50% chicken manure compost and 100% chicken manure compost, respectively. The specific C mineralization rate (SCMR, rate per unit SOC) decreased as silt and clay > macroaggregate > microaggregate, indicating that SOC in microaggregates was more stable than in macroaggregates and the silt and clay fraction. The exchangeable Ca in the bulk soil ($P < 0.001$) and soil aggregates ($P < 0.001$) were positively correlated with the SOC, whereas the Ca carbonate ($CaCO_3$) was negatively correlated with the SCMR ($P < 0.001$). The application of compost not only increased the exogenous C inputs but also promoted the transformation of $CaCO_3$ to exchangeable Ca compared with the sole chemical fertilization. Furthermore, organic fertilization significantly increased the organic C in the heavy fraction (> 2.0 g cm^{-3}) compared with the sole chemical fertilization, which was positively correlated with the mass proportion of macroaggregates ($P < 0.001$). These results indicate that organic fertilization can enhance the availability of Ca for C binding possibly by forming organo-Ca complexes, which in turn improve soil aggregation, and thus contribute to a long-term SOC sequestration in reclaimed soils of the Loess Plateau of China." **Xiaolei Huang, Zhixin Jia, Junjie Guo, Tingliang Li, Dasheng Sun, Huisheng Meng, Guanghui Yu, Xinhua, He, Wei Ran, Shusheng Zhang, Jianping Hong, and Qirong Shen,** *Geoderma.* (Subscription may be required.)

PUBLICATIONS *(cont.)*

Effects of the EU Emission Trading Scheme on the international competitiveness of pulp-and-paper industry.

The following is from the abstract of this article: "[The authors] designed an interactive item between the EU ETS dummy and the number of patent applications to represent the EU ETS's indirect effect. Then, based on the panel data of 42 countries' pulp-and-paper industry from 1998 to 2013, [the authors] conducted the test by using the system generalized method of moments to address the endogeneity problem. The results show that the EU ETS's direct effect is insignificant, while its indirect effect is significantly positive. That is, the EU ETS can bring positive effect by stimulating the pulp-and-paper making enterprises toward technological innovation. [The authors'] analysis further finds that this indirect effect changes from being insignificant in Phase I to be significantly positive in Phase II and Phase III as well as gradually become larger, suggesting that the ETS-induced innovation gradually became more prominent. The above findings provide convincing new evidence that the ETS's 'innovative compensation effect' is greater than its cost-effect." **Weiming Lin, Jianling Chen, Yi Zheng, and Yongwu Dai,** *Forest Policy and Economics*. (Subscription may be required.)

Competitive strategies for original equipment manufacturers considering carbon cap and trade.

The following is from the abstract of this article: "This paper considers an original equipment manufacturer (OEM) faces competition from an independent remanufacturer (IR) and they both are regulated by carbon cap and trade policy (CTP). [The authors] develop models to explore the OEM's optimal competitive strategy in the face of IR's competition and environmental regulation. [The authors] first investigate the impact of CTP on the OEM and IR. Then, [the authors] analyze three competitive strategies that the OEM may choose: remanufacturing, fixed-fee licensing, and royalty licensing. [The authors] investigate their optimal decisions under each strategy and identify the conditions under which these strategies can coordinate the OEM and IR. Finally, [the authors] explore conditions under which [their] strategy is superior to another. The results show that the OEM is worse off when competing with the IR under CTP if the carbon cap allocated to the OEM is small. Fixed-fee licensing and royalty licensing can coordinate the OEM and IR not only from an economic perspective but also from an environmental perspective. The OEM's optimal competitive strategy is determined by thresholds of three critical parameters: the fixed cost of setting up a remanufacturing system, the fixed-fee, and the per-unit royalty. [The authors] provide specific guidance on strategy selection for the OEM." **Qiangfei Chai, Zhongdong Xiao, and Guanghui Zhou,** *Transportation Research Part D: Transport and Environment*. (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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NATIONAL ENERGY TECHNOLOGY LABORATORY

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