



U.S. DEPARTMENT OF  
**ENERGY**



NATIONAL  
ENERGY  
TECHNOLOGY  
LABORATORY

# CSN

# CARBON STORAGE

## NEWSLETTER

**VOL. 22, NO. 7**

### CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

- ▷ Carbon Storage Educational Resources
- ▷ Program Reports, Plans, and Roadmaps
- ▷ Conference Proceedings
- ▷ Carbon Storage Portfolio
- ▷ Systems Analysis
- ▷ Peer Review
- ▷ Best Practices Manuals
- ▷ Fossil Energy and Carbon Management Techlines

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/FECM/NETL  
HIGHLIGHTS

ANNOUNCEMENTS

PROJECT and BUSINESS  
DEVELOPMENTS

LEGISLATION  
and POLICY

EMISSIONS TRADING

SCIENCE

PUBLICATIONS

ABOUT CSN

## DOE/FECM/NETL HIGHLIGHTS



### DOE Announces BIL Effort to Establish DAC Hubs.

The U.S. Department of Energy (DOE) released a *Notice of Intent (NOI)* to fund the Bipartisan Infrastructure Law's (BIL) program to capture and store atmospheric carbon dioxide (CO<sub>2</sub>) emissions. The Regional Direct Air Capture (DAC) Hubs Program will support four large-scale, regional DAC hubs that each comprise a network of carbon dioxide removal (CDR) projects to help address potential impacts of climate change while creating good-paying jobs and prioritizing community engagement and environmental justice. The widespread deployment of DAC technologies and CO<sub>2</sub> transport and storage infrastructure plays a significant role in delivering on the Biden-Harris Administration's goal of achieving an equitable transition to a net-zero economy by 2050. Each of the projects selected will demonstrate the delivery and storage or end-use of removed atmospheric CO<sub>2</sub>. The hubs will have the capacity to capture and store at least 1 million metric tons of CO<sub>2</sub> from the atmosphere annually, either from a single unit or from multiple interconnected units. In the development and deployment of the four regional DAC hubs, DOE will also emphasize environmental justice, community engagement, consent-based siting, equity and workforce development, and domestic supply chains and manufacturing.

From *energy.gov*. May 2022.

## DOE/FECM/NETL HIGHLIGHTS *(cont.)*



### DOE Announces NOIs, Launches Online Resources.

The Biden-Harris Administration, through DOE, issued NOIs to fund two programs that will advance carbon capture demonstration projects and expand regional pipeline networks to transport CO<sub>2</sub> for geologic storage or conversion. Funded by the BIL, the [Carbon Capture Demonstration Projects Program](#) and the [Carbon Dioxide Transport/Front-End Engineering Design \(FEED\) Program](#) help to advance the administration's goal of a net-zero greenhouse gas (GHG) emissions economy by 2050. In addition, DOE's Office of Fossil Energy and Carbon Management (FECM) launched two new interactive tools to assist with advancing carbon management technologies and infrastructure in the United States. The [Carbon Matchmaker Tool](#) is an online

information resource designed to increase awareness of carbon management funding opportunities; support private sector development of carbon capture, storage, and transportation infrastructure and CDR pathways; and facilitate regional business development opportunities and education. The [Carbon Management Interactive Diagram](#) is an online tool that highlights carbon management programs in the BIL and through other DOE funding opportunities, as well as educates users about resources that fall under each program.

From [energy.gov](#). July 2022.

## ANNOUNCEMENTS



### Virtual Carbon Negative Shot Summit Hosted by DOE.

DOE hosted the virtual Carbon Negative Shot Summit on July 20, 2022. DOE launched the [Carbon Negative Shot](#), the third target within the [Energy Earthshots Initiative](#), to advance the development of the emerging CDR industry. More information about Carbon Negative Shot is available via [video](#) and [infographic](#).



**Brad Crabtree**, Assistant Secretary,  
Office of Fossil Energy and Carbon Management

### FECM Welcomes New Assistant Secretary.

DOE's FECM welcomed new Assistant Secretary Brad Crabtree, who has nearly three decades of experience in energy and climate policy. The Assistant Secretary will lead and direct FECM's research and development (R&D) programs that support the Biden Administration's goals of achieving net-zero GHG emissions by 2050.

### DOE's Clean Energy Corps Accepting Applications. (Video)

DOE's Clean Energy Corps comprises staff from more than a dozen offices across DOE to research, develop, demonstrate, and deploy next-generation clean energy technologies. The Clean Energy Corps is dedicated to fight climate change through public service and to support American competitiveness on a global scale. To meet this challenge, DOE is hiring a team of industry veterans, experienced

technical experts, and the next generation of climate leaders. More information is [available via the Clean Energy Corps webpage](#).



### DOE Investments to Accelerate CO<sub>2</sub> Storage Projects and Increase CO<sub>2</sub> Storage Sites.

DOE announced two Funding Opportunity Announcements (FOAs) and one NOI to advance carbon storage projects that reduce CO<sub>2</sub> emissions, address potential impacts of climate change, and create good-paying jobs while prioritizing community engagement and environmental justice. Projects funded under these three opportunities will be managed by DOE's FECM.

### DOE Funding to Develop Hydrogen Turbines and Production with CCS.

DOE announced funding for [six R&D projects](#) to develop technologies for more efficient hydrogen turbines and production with carbon capture and storage (CCS). DOE's National Energy Technology Laboratory (NETL), under the purview of FECM, will manage the projects.

### DOE/FECM Accepting Applications: RECS 2022.



Applications are being accepted for the 2022 Research Experience in Carbon Sequestration (RECS) Program, which will be held in person September 11–20, 2022, in Colorado and Wyoming. Supported by FECM and DOE/NETL, the [RECS Program](#) offers graduate students and early career professionals the opportunity to learn about all aspects of carbon capture, utilization, and storage (CCUS). The deadline to apply is August 5, 2022.

### DOE Welcomes DOT's CO<sub>2</sub> Pipeline Safety Measures.

DOE released a statement welcoming the [CO<sub>2</sub> pipeline safety measures announced](#) by the U.S. Department of Transportation's (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). The new guidance will be incorporated into DOE's research, development, demonstration, and deployment portfolio to ensure safe operations of commercial CO<sub>2</sub> pipelines in the United States. [PHMSA](#) establishes pipeline safety regulations at the federal level.



## ANNOUNCEMENTS *(cont.)*



### U.S. Supreme Court Ruling on EPA Climate Standards.

The U.S. Supreme Court released a decision on the U.S. Environmental Protection Agency's (EPA) authority to set climate standards for power plants. The opinion of the court is [available online](#).

### Report Calls for Scottish CCS Cluster.

An energy transition report recommended the United Kingdom (UK) government move forward with the Scottish CCS cluster. *Energy Transition 35* was produced by the Aberdeen & Grampian Chamber of Commerce, alongside KPMG and ETZ.



### Global Businesses Test Voluntary Carbon Market.

Global businesses were invited to test a *Provisional Claims Code of Practice* for corporate claims made regarding the voluntary use of carbon credits. The benchmarks within the Provisional Code, which were unveiled at an event co-hosted by the Voluntary Carbon Markets Integrity Initiative and the UK government, set claims in the context of progress made against the achievement of a company's long-term, net-zero commitment.

## PROJECT AND BUSINESS DEVELOPMENTS



### Red Trail Energy Begins CCS Operations.



Red Trail Energy LLC (RTE) announced the start of CCS operations at its ethanol facility located near Richardton, North Dakota (USA). According to RTE officials, it is the first CCS project allowed under state primacy in the United States. In October 2021, the North Dakota Industrial Commission approved the EPA Class VI injection well and the reservoir space RTE needed to operate the facility. The RTE ethanol plant releases an average of 180,000 metric tons of CO<sub>2</sub> per year from the fermentation process during ethanol production. With CCS, RTE will capture 100% of their CO<sub>2</sub> emissions from the fermentation process and inject approximately 500 metric tons of CO<sub>2</sub> per day. The CO<sub>2</sub> will then be stored below the

surface in the Broom Creek formation.

From *Ethanol Producer Magazine*. July 2022.

### Companies Reach Agreement to Transport, Store CO<sub>2</sub>.

Denbury Carbon Solutions and PCS Nitrogen Fertilizer (a subsidiary of Nutrien Ltd.) reached a term sheet agreement under which Denbury would transport and store CO<sub>2</sub> captured from a potential clean ammonia project in Geismar, Louisiana. Nutrien is evaluating its ammonia facilities in the area as a potential site for the project, which is expected to capture approximately 1.8 million metric tons per year of CO<sub>2</sub>. Under the agreement, Denbury would transport and store the CO<sub>2</sub> in Denbury's storage sites.

From *Business Wire*. May 2022.

### Canada Launches System to Support Domestic Carbon Offset Trading Market.

The Canadian government launched a credit system for GHG offsets as part of its overall plan to reduce carbon emissions. The GHG offset credit system is intended to support a domestic carbon offset trading market.

### Partnership Aims to Spur CO<sub>2</sub> Storage Investment.

Singapore's Climate Impact X and Finland's Puro.earth announced a partnership aimed at increasing the availability of nature- and technology-based carbon-removal credits. Through the partnership, the companies intend to spur investment in CCS projects by providing a choice of offsets to reduce emissions.

### CCUS-Focused Roundtable Held.

Experts and decision-makers convened in Doha, Qatar, to discuss the current and future role of CCUS. The "CEO Roundtable" was hosted by the Al-Attiyah Foundation—a non-profit global energy and sustainable development organization.

### Companies to Develop Louisiana Carbon Storage Project.

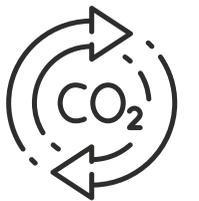
TotalEnergies, Mitsui, Mitsubishi, and Sempra Infrastructure signed a participation agreement to develop the proposed Hackberry Carbon Sequestration (HCS) project in Southwest Louisiana (USA). Under the agreement, the combined Cameron Liquefied Natural Gas (LNG) Phase I and proposed Phase II export projects would potentially serve as the source for the capture and storage of CO<sub>2</sub> by the HCS project. Last year, the HCS project applied for a Class VI Injection well permit from EPA for storage of up to 2 million metric tons of CO<sub>2</sub> per year.

From *Carbon Capture Journal*. May 2022.

### Energy Companies to Study CCUS in Oman.

Two development companies signed an agreement to study the potential for CCUS in Oman. Shell Development Oman and Petroleum Development Oman will explore key factors (i.e., technical matters, project time frame and cost, and support for a regulatory and fiscal framework) for CCUS in the country, with the aim of scaling-up Oman's CCUS industry while also working toward net-zero emissions.

From *Gas World*. May 2022.



## PROJECT AND BUSINESS DEVELOPMENTS *(cont.)*



### Loan Approved for Project Tundra.



Minnkota Power Cooperative received approval for a \$100 million loan to help advance Project Tundra—an effort at the Milton R. Young Station in North Dakota (USA) to capture and store more than 90% of the CO<sub>2</sub> emissions produced by the coal-based plant. Authorized by the North Dakota Industrial Commission, the loan was made available through the state's Clean Sustainable Energy Authority. Project Tundra is in an

advanced stage of development, which includes having a fully permitted CO<sub>2</sub> storage facility and an EPA-approved monitoring, reporting, and verification (MRV) plan for CO<sub>2</sub> storage.

From *Carbon Capture Magazine*. May 2022.

### Japanese Companies to Join CCS Project.

Three Japanese energy companies plan to join a CCS project in Australia. JERA, Tokyo Gas, and Inpex will look to transport, by sea, CO<sub>2</sub> released during the production of LNG in Japan to Australia for storage. The CCS plant, led by oil and gas company Santos, could have the potential to store up to 10 million tons of CO<sub>2</sub> per year. Planned for northern Australia, the plant is expected to be operational around 2025.

From *Nikkei Asia*. June 2022.

### Ethanol Plant to Transport CO<sub>2</sub> to Wyoming for Storage.

An ethanol plant in Eastern Nebraska has agreed to transport its CO<sub>2</sub> to a future storage plant in Wyoming (USA). According to company officials from Tallgrass, the system will be capable of capturing 10 million tons of CO<sub>2</sub> annually from an Archer Daniels Midland (ADM) plant in Columbus, Nebraska. The CO<sub>2</sub> will be transported through a former 400-mile natural gas pipeline to a storage hub in eastern Wyoming.

From *Brownfield Ag News*. May 2022.

## LEGISLATION AND POLICY

### Legislation to Accelerate CDR Introduced.

Legislation to reduce emissions by accelerating CDR technologies was introduced in the U.S. Senate. The ***Federal Carbon Dioxide Removal Leadership Act*** would leverage federal procurement to create a market for CDR by removing an increasing amount of CO<sub>2</sub> using DAC or other technology-based removal solutions; setting aside 20% of funds for promoting newer, innovative technologies; and prioritizing the creation of jobs domestically, supporting American competitiveness in developing climate solutions, and maximizing the efficacy of CDR techniques. The full bill text is [available for download](#).

From *U.S. Senator Sheldon Whitehouse News Release*. May 2022.



### Energy Producer Plans CCS Project.

Columbian energy producer Ecopetrol announced plans to start a pilot CCS project in 2023. According to company officials, the pilot aims to capture 1 million metric tons of CO<sub>2</sub> from its refineries and store it in a gas-depleted reservoir.

From *Reuters*. May 2022.



### Thai Company Looking to Develop CCS Project.



Thailand's national oil and gas company PTT Exploration and Production (PTTEP) announced plans to develop the country's first CCS project, as well as the initiation of CCS feasibility studies in other areas of Thailand. PTTEP concluded the feasibility study of its Pioneer CCS Project at the Arthit gas field, which covered the preliminary assessment of the carbon storage capacity of targeted geologic storage formations and a conceptual development plan. According to the company, the project is undergoing a pre-FEED study and is expected to start CCS operations by 2026. PTTEP ***signed a Memorandum of Understanding (MOU)*** with JGC Holdings and Inpex in April 2022 to study the potential development of CCS solutions to help industries reduce their CO<sub>2</sub> emissions.

From *Offshore Energy*. June 2022.



## EMISSIONS TRADING

### RGGI Report Tracks Investment of Auction Proceeds.

The states participating in the Regional Greenhouse Gas Initiative (RGGI) released a report tracking the investment of proceeds generated from their regional CO<sub>2</sub> allowance auctions in 2020. According to [Investment of RGGI Proceeds in 2020](#), which also provides state-specific success stories and program highlights, \$196 million in RGGI proceeds were invested in 2020 in programs such as energy efficiency, clean and renewable energy, and GHG abatement. Over their lifetime, these 2020 investments are projected to help households and businesses avoid the emissions of approximately 6.6 million short tons of CO<sub>2</sub>.

From *RGGI Press Release*. May 2022.



### Indian State to Set Up Carbon Market.

The Gujarat government signed an MOU with the Energy Policy Institute, the University of Chicago, and JPal of South Asia to set up a carbon market. The MOU is in line with the government's commitment to achieving net-zero emissions by 2070.

From *India Today*. May 2022.

## SCIENCE

### Battery-Like Device Could Help Power CCS Technologies.

Researchers from the University of Cambridge designed a battery-like device that could help power CCS technologies. The supercapacitor device is about the size of a coin and consists of two electrodes of positive and negative charge. By alternating from a negative to a positive voltage to extend the charging time from previous experiments, the research team found they could capture twice the amount of CO<sub>2</sub>. The results were [published in the journal \*Nanoscale\*](#).

From *SciTechDaily*. May 2022.

### Study: Thinning Forests Improve CO<sub>2</sub> Storage Potential.

According to a study conducted by scientists from the Agricultural and Forestry Systems Evaluation and Restoration (ERSAF) group at the University of Córdoba (Andalusia, Spain), decreasing the number of trees in a forest helps to increase the forest's CO<sub>2</sub> storage potential. ERSAF scientists coordinated a global study by performing forest "thinning" trials, with the help of [Silvadapt project's Adaptive Silviculture Plot Network](#),

### Results of 56th RGGI Auction Released.

The RGGI-participating states announced the results of their 56th auction of CO<sub>2</sub> allowances. A total of 22,280,473 CO<sub>2</sub> allowances were sold at a clearing price of \$13.90, with bids ranging from \$2.44 to \$27.00 per allowance. None of the 11.61 million cost containment reserve (CCR) allowances made available were sold, and none of the 10.96 million emissions containment reserve (ECR) allowances made available for withholding were withheld. (The CCR is a fixed additional supply of allowances made available for sale if the auction's interim clearing price exceeds \$13.91. The ECR is a designated quantity of allowances to be withheld if the auction's interim clearing price is below \$6.42.) Auction 56 generated \$309.7 million for states to reinvest in strategic programs, including energy efficiency, renewable energy, and GHG abatement programs. Additional details are available in the [Market Monitor Report for Auction 56](#).

From *RGGI Press Release*. June 2022.



during which both light and heavy reforestations of three Mediterranean pine species were performed. By gathering measurements such as soil organic carbon data and biomass, the researchers found that plots subject to a larger reduction in forest thickness stored more carbon. The results were [published in the journal \*Forests\*](#).

From *AZoCleantech*. June 2022.

### CCS Project to be Developed in Egypt.

The Egyptian government and the Italian oil and gas company Eni will develop a multi-phased CCS project in the Melehia field in northern Egypt. In the first phase, algae oil will be extracted for biofuel production, leading to the reduction of up to 1.2 million tons of CO<sub>2</sub> per year. In the second phase, 75,000 tons of biodegradable plastics will be produced, targeting the reduction of 45,000 tons of CO<sub>2</sub> annually. The third and final phase will focus on converting plastic waste into oil to be used as raw material in polyethylene production, aiming to reduce 63,000 tons of CO<sub>2</sub> annually.

From *Energy Capital and Power*. May 2022.



## PUBLICATIONS



### Cost Impacts of Risk-Based Methods for Defining AoR and PISC Duration of a CO<sub>2</sub> Storage Project Using NRAP Tools and FE/NETL CO<sub>2</sub> Saline Storage Cost Model.

The following is from the Executive Summary of this DOE/NETL report: “The purpose of this analysis is to assess the fiscal impact of using risk-based methods to define the area of review (AoR) and post-injection site care (PISC) duration for a geologic carbon dioxide (CO<sub>2</sub>) storage project. The Office of Fossil Energy (FE)/National Energy Technology Laboratory (NETL) CO<sub>2</sub> Saline Storage Cost Model (“cost model”) was utilized to evaluate CO<sub>2</sub> storage economics in this study. The cost model is a widely used tool for evaluating CO<sub>2</sub> storage costs in geologic settings. It estimates costs for storage operations conducted under compliance to the United States Environmental Protection Agency (EPA) Underground Injection Control (UIC) Class VI regulations. This analysis evaluates and compares the costs of storage (on a first-year break-even dollar per tonne [2018\$] basis) at the proposed FutureGen 2.0 site as a case-study storage location by implementing different approaches to determine AoR and PISC given the prevailing geologic conditions and injection volume and duration considerations. The approaches include the use of 1) risk-based methods to define AoR and PISC duration, 2) an EPA-approved AoR and PISC documented in the FutureGen 2.0 UIC Class VI permit applications, and 3) cost model default settings that utilize uncertainty multipliers to estimate CO<sub>2</sub> plume and pressure front extent as part of AoR determination, as well as a 50-year PISC default. From all three sources, the AoR and PISC specified in the Class VI permit applications for FutureGen 2.0 were the largest and longest relative to the other two sources...”



### Treatments of Exports in the EU CBAM.

The following from a description of this European Roundtable on Climate Change and Sustainable Transition (ERCST) report: “This new report examines one of the most critical issues in the current political debate on the EU’s Carbon Border Adjustment Mechanism (CBAM): the treatment of exports. Exports are currently not covered by the European Commission’s CBAM proposal. However, there are concerns that the exclusion of exports will open-up an export-related carbon leakage channel, thereby harming EU competitiveness and climate ambition. In this report, ERCST presents its recommendations on how to address exports in the EU CBAM.”



### Basin Management of Geologic CO<sub>2</sub> Storage: Effect of Well Spacing on CO<sub>2</sub> Plume and Pressure Interference.

The following is from the abstract of this paper: “Large-scale deployment of carbon capture and storage (CCS) is a key decarbonization approach to achieve drastic reductions in greenhouse gas emission levels. The United States Department of Energy’s National Energy Technology Laboratory, through the Carbon Storage Assurance Facility Enterprise Initiative projects, defines a commercial-scale CO<sub>2</sub> saline storage project as one in which at least 50 million tonnes of CO<sub>2</sub> are injected over the course of 20 to 30 years. Large-scale decarbonization through CCS may likely involve many commercial-scale CO<sub>2</sub> storage projects located in close proximity. Nearby injection operations may result in CO<sub>2</sub> plume commingling and create pressure buildup over time, which could cause pressure interference and may require preventative strategies to avoid exceedance of fracture pressure threshold. This study employs numerical modeling to analyze the evolution of the extent of CO<sub>2</sub> and pressure plumes in which the commercial-scale CO<sub>2</sub> storage projects inject simultaneously into a common storage formation from multiple projects located in proximity. Injection operations target an extensive saline formation with formation top of 1 km below ground surface, thickness of 200 m, horizontal and vertical permeabilities of 50 and 15 mD, porosity of 10%, and all external boundaries closed to fluid flow (i.e., top, bottom and all sides). The injection occurs at 1 million tonnes/year per well for 30 years, followed by a 50-year post-injection period (PISC). The effect of well spacing and resulting pressure buildup and CO<sub>2</sub> plume migration is explicitly evaluated...”

**Nur Wijaya, Derek Vikara, David Morgan, Timothy Grant, and Donald Remson, *SPE Western Regional Meeting (April 26–28, 2022; Bakersfield, California, USA).*** (Subscription may be required.)

### A bacteria-based carbon sequestration and waste recycling system.

The following is from the abstract of this article: “Achieving carbon neutrality requires a variety of technological approaches. In the present study, [the authors] confirmed the applicability of a carbon cycle system in several industrial fields using sulphur-oxidising bacteria. This system produces a nitrogen fertiliser, which decreases carbon emissions by recycling H<sub>2</sub>S and NH<sub>3</sub> pollutants discharged into the atmosphere or wastewater. It should be considered in industrial fields as a carbon reduction strategy.”

**Yeon Hwa La, Ki-Sung Lee, Tae-Wan Kim, and Jae Yang Song, *Nature.*** (Subscription may be required.)

## PUBLICATIONS (cont.)



### A multi-criteria CCUS screening evaluation of the Gulf of Mexico, USA.

The following is from the abstract of this article: “Continued research into reservoir characterization along with offshore carbon dioxide (CO<sub>2</sub>) transportation and infrastructure assets is needed to facilitate development of safe and successful carbon capture, utilization, and storage (CCUS) projects. This paper outlines a multi-criteria evaluation methodology that incorporates disparate sets of quantitative, spatially variable data into a decision-making framework for screening the Gulf of Mexico (GOM) outer continental shelf (OCS) for potentially viable CO<sub>2</sub> storage and enhanced oil recovery (EOR) sites. Criteria categories include favorable geologic characteristics, logistics, and potential risks. Data compiled for 14 criteria from several publicly available geographic information system (GIS) layers was aggregated over 2559 spatially balanced points across the study area using the National Energy Technology Laboratory (NETL)-developed Cumulative Spatial Impact Layers™ (CSIL) GIS tool. Criteria are weighted by qualitative expert opinion relative to their perceived importance to given scenarios— the output of combined criteria values and weights enables regional CO<sub>2</sub> storage suitability differentiation. The methodology considers both technical and non-technical factors impacting CCUS decision-making. The flexible methodology enables a systematic approach to regional ranking at high spatial resolution over a large study domain. Additionally, the framework enables high-grading of priority sites that warrant further characterization and follow-on analysis. Areas along the Louisiana coast and Mississippi River Delta consistently rank high for all scenarios largely a result of the favorable geology with the potential for stacked storage, as well as the density of existing pipelines and platforms, and proximity to several onshore CO<sub>2</sub> sources. High-graded regions for the CO<sub>2</sub> EOR-related scenarios are typically located further offshore towards the middle and edge of the OCS compared to higher priority regions for the geologic storage scenarios which fall closer to the Louisiana coastline.”

**Anna Wendt, Alana Sheriff, Chung Yan Shih, Derek Vikara, and Tim Grant,** *International Journal of Greenhouse Gas Control.* (Subscription may be required.)

### Thermodynamic loss analysis of a liquid-sorbent direct air carbon capture plant.

The following is from the abstract of this article: “Direct air capture of CO<sub>2</sub> is often presented as a promising technology to help mitigate climate change, although proposed processes are highly energy intensive. [The authors] analyze Carbon Engineering’s 1 Mt-CO<sub>2</sub>/year natural-gas-powered direct air capture (DAC) process, which requires 273.2 MW per plant, where [they] find that 252 MW are irreversibly lost, corresponding to a second-law efficiency of 7.8%. [The authors’] component-level analysis details the mechanisms by which these losses of thermodynamic work potential occur in the most energy-intensive plant segments. Here, [the authors] emphasize the effects of chemical exergy dissipation in the air contactor, where stored chemical exergy is released as low-grade heat into the environment. Other major losses occur in the calciner and its preheat cyclones due to the high temperature demanded by its internal chemical reaction, as well as in the water knockout system, CO<sub>2</sub> compression system, and power island. Finally, [the authors] illustrate the issues arising from the use of natural gas as a feedstock for heat and power, and suggest directions to pursue for further analysis and process improvements, which [the authors] consider imperative to make this DAC process a viable option for large-scale CO<sub>2</sub> removal toward IPCC targets.”

**Ryan Long-Innes and Henning Struchtrup,** *Cell Report Physical Science.* (Subscription may be required.)

### More sustainable vegetable oil: Balancing productivity with carbon storage opportunities.

The following is from the abstract of this article: “Intensive cultivation and post-harvest vegetable oil production stages are major sources of greenhouse gas (GHG) emissions. Variation between production systems and reporting disparity have resulted in discordance in previous emissions estimates. The aim of this study was to assess global systems-wide variation in GHG emissions resulting from palm, soybean, rapeseed and sunflower oil production. Such an analysis is critical to understand the implications of meeting increasing edible oil demand. To achieve this, [the authors] performed a unified re-analysis of life cycle input data from diverse palm, soybean, rapeseed, and sunflower oil production systems, from a saturating search of published literature. The resulting dataset reflects almost 6000 producers in 38 countries, and is representative of over 71% of global vegetable oil production. Across all oil crop systems, median GHG emissions were 3.81 kg CO<sub>2</sub>e per kg refined oil. Crop specific median emissions ranged from 2.49 kg CO<sub>2</sub>e for rapeseed oil to 4.25 kg CO<sub>2</sub>e for soybean oil per kg refined oil. Determination of the carbon cost of agricultural land occupation revealed that carbon storage potential in native compared to agricultural land cover drives variation in production GHG emissions, and indicates that expansion of production in low carbon storage potential land, whilst reforesting areas of high carbon storage potential, could reduce net GHG emissions whilst boosting productivity. Nevertheless, there remains considerable scope to improve sustainability within current production systems, including through increasing yields whilst limiting application of inputs with high carbon footprints, and in the case of palm oil through more widespread adoption of methane capture technologies in processing stages.”

**Thomas D. Alcock, David E. Salt, Paul Wilson, and Stephen J. Ramsden,** *Science of The Total Environment.* (Subscription may be required.)

### Carbon storage potential of *Avicennia marina* as influenced by soil factors in National Park Nayband, South Coast of Iran.

The following is from the abstract of this article: “The carbon storage potential varies according to plant species, locations, and soil parameters. This study conducted to calculate amounts of carbon storage and effects of soil factors on C storage *Avicennia marina* in the coastal area of Bradkhon-Mal Gonzeh in National Park Nayband, of Bushehr province. To conduct research, aboveground and belowground biomass, and a distance of 1.5 m in two depths (0–60 and 60–100 cm) in 5 sample plots in the habitat zone and control site in March 2019, samples of biomass and soil were taken. The aboveground and belowground biomass were estimated using the allometric equation. The soil factors in each sample point were done by laboratory methods. The relations between soil factors and C storage in above and below-ground biomass were determined using cluster analysis. The result showed that the amount of C storage in above and belowground biomass is 12.7 ± 1.08 and 5.7 ± 0.4 g/m<sup>2</sup>, respectively. The amount of carbon stored at the first depth of the soil was more than the second depth, this is due to the expansion of roots on the surface of the soil. The most important parameters influencing soil carbon storage is electrical conductivity (EC), total neutralizing value (TNV), percentage of sand, silt and clay, organic matter and nitrogen.”

**Fazel Amiri,** *Acta Ecologica Sinica.* (Subscription may be required.)

## PUBLICATIONS *(cont.)*



### Assessing the effects of ecological engineering on spatiotemporal dynamics of carbon storage from 2000 to 2016 in the Loess Plateau area using the InVEST model: A case study in Huining County, China.

The following is from the abstract of this article: "Implementation of the Grain for Green program (GGP) resulted in great changes in land use and cover in northwest China, and presumably in the region's carbon. However, accurate assessment of the effects of the GGP on carbon storage remains a challenge. The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model can map and evaluate natural goods and services that sustain life and quantify their impact from the changes in the ecosystem. Taking Huining County in China's Loess Plateau region as a case, the land use and land cover changes (LUCC) following the GGP were quantified, and their effects on carbon storage between 2000 and 2016 were evaluated using the InVEST model. The results showed that, a total area of about 3996.13 km<sup>2</sup> underwent changes following the GGP in Huining County during the study period, accounting roughly for 74% of the county. The total carbon storage increased from 6470.72 Gg in 2000 to 7335.07 Gg in 2016. Spatially, carbon density in the south of this county was greater than the northern part. Directly induced by the GGP (conversions of farmlands to forests and grasslands), the carbon storage increased by 786.84 Gg in total, with a rate of 46.28 Gg per year, the majority of which occurred during the first stage of the study period (from 2000 to 2008). The increase of carbon storage was mostly attributable to the increases in vegetation pool and the carbon density showed a strong spatial correlation with the growing season Normalized Difference Vegetation Index (NDVI). The similarities between carbon density and NDVI spatial patterns during the study period may have been shaped by the county's climate patterns, but not to any significant extent by climate change during the study period. This county-scale study allows for a deeper understanding of the links between LUCC induced by environmental restoration programs and carbon storage changes, and contributes to a greater accuracy in the estimation of carbon storage at the provincial (or larger) scale."

**Kongming Li, Jianjun Cao, Jan F. Adamowski, Asim Biswas, Junju Zhou, Yujia Liu, Yongkai Zhang, Chunfang Liu, Xiaogang Dong, and Yuli Qin, *Environmental Development*.** (Subscription may be required.)

### Experiment study on CO<sub>2</sub> adsorption performance of thermal treated coal: Inspiration for CO<sub>2</sub> storage after underground coal thermal treatment.

The following is from the abstract of this article: "Underground coal thermal treatment is a clean method of coal utilisation. Pyrolytic semi-coke provides a good storage vehicle for CO<sub>2</sub> geological storage, but there are few studies on the CO<sub>2</sub> adsorption capacity of pyrolytic semi-coke. To investigate the CO<sub>2</sub> storage potential of thermal treated coals, scanning electron microscopy, low temperature nitrogen adsorption, low-field nuclear magnetic resonance and thermogravimetric analysis were used in this paper to analyze the differences and the influence mechanisms of different thermal treated coals for CO<sub>2</sub> adsorption. The results showed the CO<sub>2</sub> maximum adsorption amount of different thermal treated coals decreased and then increased as the thermal treatment temperature increased, reaching a minimum at 773.15 K. Although the maximum adsorption amount of 773.15 K thermal treated raw coal was disadvantageous, the gas pressure <4.49 MPa showed superior adsorption advantage over the 303.15 K thermal treated coal. However, the KCl-impregnated coal showed an overall low adsorption capacity attributed to crystal blocking effects and catalysis. Although the adsorption pores of the high temperature thermal treated coals were substantially reduced, their ability to adsorb CO<sub>2</sub> was significantly higher than that of the low temperature thermal treated coals. Furthermore, the number of adsorption pores was closely related to CO<sub>2</sub> adsorption."

**Qingmin Shi, Shidong Cui, Shuangming Wang, Yichen Mi, Qiang Sun, Shengquan Wang, Chenyu Shi, and Jizhou Yu, *Energy*.** (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<sub>2</sub>, 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<sub>2</sub> emissions. The program also serves to increase the understanding of the effectiveness of advanced technologies in different geologic reservoirs appropriate for CO<sub>2</sub> 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<sub>2</sub> behaves in the subsurface. These objectives are key to increasing confidence in safe, effective, and permanent geologic CO<sub>2</sub> 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](#).

#### Get Social with Us

There are several ways to join the conversation and connect with NETL's Carbon Storage Program:



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## ABOUT NETL'S CARBON STORAGE NEWSLETTER

Compiled by the National Energy Technology Laboratory, this newsletter is a monthly summary of public and private sector carbon storage news from around the world. The article titles are links to the full text for those who would like to read more (note that all links were active at the time of publication).

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