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CARBON STORAGE NEWSLETTER

SEPTEMBER 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:

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- ▷ PROJECT and BUSINESS DEVELOPMENTS
- ▷ LEGISLATION and POLICY
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CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

- ▷ Carbon Storage Educational Resources
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- ▷ Conference Proceedings
- ▷ Carbon Storage Portfolio
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DOE/NETL HIGHLIGHTS

DOE/NETL 2020 Virtual Integrated Project Review Meeting Underway.

A series of free virtual sessions organized by the U.S. Department of Energy (DOE) and the National Energy Technology Laboratory (NETL) commenced with a three-day conference on carbon capture, utilization, and storage (CCUS) on August 17, 2020. Over a 12-week period, the 2020 Virtual Integrated Project Review Meeting will feature projects from several DOE Office of Fossil Energy (FE) portfolios, including Carbon Capture, Carbon Storage, and Carbon Utilization. Sessions focus on how DOE/FE-sponsored research and development (R&D) activities are advancing transformative science and technologies to support efficient and environmentally sound use of fossil fuels. A comprehensive schedule of the integrated virtual meeting, which will run through November 2020, is [available online](#). From *NETL News Release*. August 2020.



2020 INTEGRATED PROJECT REVIEW MEETING

DOE Offers Prize to Design Subsurface Visualization Tool.



DOE/FE will award up to \$1.5 million to winning innovators in a prize challenge to support their SMART (Science-informed Machine Learning to Accelerate Real-Time Decisions in the Subsurface) Initiative. The SMART Visualization Platform (VP) Challenge prize competition seeks competitors with software development expertise to create a new visualization platform that will assist in making subsurface insights accessible to a wider range of users and stakeholders.

SMART leverages the expertise of seven national laboratories, as well as industry partners, universities, unconventional field laboratories, and carbon storage regional initiatives, to realize breakthroughs in understanding the subsurface environment through machine learning. Registration information can be found on the [SMART VP Challenge website](#). The registration deadline is January 22, 2021. From *NETL News Release*. September 2020.

ANNOUNCEMENTS

NETL Posts Offshore Oil Field Case Studies.

NETL released three case studies regarding offshore carbon dioxide (CO₂) enhanced oil recovery (EOR). The studies (*Horn Mountain Oil Field Case Study*, *Cognac Offshore Oil Field Case Study*, and *Petronius Offshore Oil Field Case Study*) provide perspective into the challenges of evaluating offshore CO₂-EOR and CO₂ storage potential, and demonstrate the performance of the CO₂ Prophet Model EOR reservoir simulator. These studies, as well as other relevant documents, can be found on [NETL's Search Energy Analysis website](#) by searching "offshore EOR."



ANNOUNCEMENTS (cont.)

DOE Announces Funding for FLECCS Program.



DOE announced funding for 12 projects under Phase I of the *Advanced Research Projects Agency-Energy's (ARPA-E) FLExible Carbon Capture and Storage (FLECCS) Program*.

FLECCS Phase I project teams will design, model, and optimize carbon capture and storage (CCS) processes that enable flexibility on a high-variable renewable energy grid. At the conclusion of Phase I, teams will be downselected to Phase II to receive additional funding to further develop their technologies. The list of FLECCS projects is [available online](#).

Carbon Storage Study Update.

Giga Metals Corporation provided an update on its carbon storage research program at the *Turnagain Nickel Project*, located in British Columbia, Canada. The research is being conducted in conjunction with the University of British Columbia.



Study Shows CCS Role in Decarbonizing Electricity Grids.

Economists from the Brattle Group conducted a study assessing the cost-effectiveness of CCS for utilities in meeting decarbonization goals. *The study* found that opportunities to retrofit coal-fired power plants with CCS at low net costs exist, and that due in part to recent tax credits, CCS can be developed at a minimal incremental net cost.

Report Covers COVID-19 Impact Analysis on CCS Market.

Fortune Business Insights released a report analyzing the CCS market and the impact of the COVID-19 global pandemic. The report covers market trends and key industry developments by end use (e.g., EOR, CO₂ capture source, and geography). According to the report, the global CCS market size in 2019 was approximately \$1.6 billion and is projected to reach approximately \$6.1 billion by 2027.

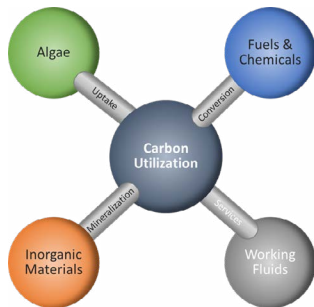
RGGI Secondary Market Report Made Available.

The independent market monitor for the Regional Greenhouse Gas Initiative (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: Second Quarter 2020" addresses the period from April through June 2020. The report is part of Potomac's ongoing monitoring of the RGGI auctions and secondary markets.

PROJECT and BUSINESS DEVELOPMENTS

CO₂ Conversion Projects Receive DOE Funding.

In June 2020, DOE/FE and NETL selected 11 projects to receive funding through the *Carbon Utilization Program*. The University of California, Los Angeles (UCLA) will *develop a process capable of converting CO₂ emissions into construction materials*. The technology captures CO₂ emitted from power plants, cement plants, and other CO₂ producers, using it to make a form of concrete known as *CO₂Concrete*, which is expected to have a carbon footprint 50 to 70% lower than that of regular concrete. In addition, the University of Louisiana at Lafayette will *develop a way to convert CO₂ into ethylene* with low pulses of electricity; by comparison, current methods of producing the chemical emit 200% more CO₂. From *UCLA News Release*, July 2020; and *The University of Louisiana at Lafayette*, August 2020.



at the 550-megawatt, natural gas-powered Elk Hills Power Plant. The project is a collaboration between the Electric Power Resource Institute (EPRI), California Resources Corporation, and Flour. The FEED is funded by DOE through collaboration with EPRI as part of a larger initiative to advance carbon capture technology development. From *Business Wire*. July 2020.

Geologic Carbon Storage Project Progresses.

The Wales-based Flexible Integrated Energy Systems (FLEXIS) Project is collaborating with Polish and German entities to establish an underground research observatory to study European coal reserves for carbon storage. The three-year ROCCS project (establishing a Research Observatory to unlock European Coal seams for Carbon dioxide Storage) will conduct in-situ tests at the Experimental Mine Barbara in Mikołów, Poland, where a horizontal well system will be installed for CO₂ injection. A large-scale commercial site will be selected and analyzed for CO₂ storage. From *Gasworld*. July 2020.

Australian CCUS Study Announced.

National Energy Resources Australia (NERA) and CO₂CRC announced a study into CCUS to assist the Australian energy resources sector in reducing CO₂ emissions. The two-phase study will first rank oil and gas basins in Australia



for their potential use of CO₂-EOR. The second phase will provide industry and government stakeholders with insight into potential CO₂-EOR opportunities at the field level in Australian onshore basins. In addition, the study will evaluate policies, incentives, and regulations with the potential to help Australia adopt CO₂-EOR and CO₂ storage. From *CO₂CRC Media Release*. July 2020.

KGS Joins DOE-Funded Project.

The Kansas Geological Survey (KGS) is *partnering with the Carbon Utilization and Storage Partnership (CUSP) to research CO₂ storage*. CUSP, made up of 15 other entities, is led by the Petroleum Recovery Research Center at the New Mexico Institute of Mining and Technology, which was awarded funding for the project by DOE. KGS will also work with CUSP members on methods to analyze data that may provide a better understanding of infrastructure development potential, infrastructure costs, and ways to optimize future project development. From *The University of Kansas*. August 2020.

DOE-Funded FEED Contract Awarded for CCS Project.

A front-end engineering and design (FEED) contract was awarded to Fluor Corporation for a CCS project in Tupman, California (USA). Flour will use its carbon capture technology to provide engineering services for the licensed process unit and required utility systems



PROJECT and BUSINESS DEVELOPMENTS *(cont.)*

Carbon Storage Company Acquired.

Oil and gas company Shell Australia is acquiring a carbon management firm as part of its net-zero emissions strategy. Shell will acquire the Australian-based Select Carbon for its Nature-Based Solutions business, which specializes in CO₂ storage in forests, grasslands, wetlands, and other natural ecosystems. From *Kallanish Energy*. August 2020.

Companies to Collaborate on CCS.

Petrofac, an international service provider to the energy industry, signed a Memorandum of Understanding (MOU) with Storegga Geotechnologies, an independent supporter of CCS, to build new energy capability and capacity in the United Kingdom. Under the MOU, the companies will collaborate on potential business development and project initiatives in CCS and other low-carbon projects. From *Petrofac Press Release*. August 2020.

JDA Signed to Develop CCUS Projects.

Carbon Clean Solutions Limited (CCSL) *signed a Joint Development Agreement (JDA)* with Marubeni Corporation, a Japanese integrated trading and investment company, to develop and invest in CCUS projects. The JDA builds on an existing relationship between the two companies; Marubeni previously invested in CCSL to help it deliver its CO₂ capture technology for CCUS projects across the steel, cement, waste management, and refining and petrochemicals sectors. From *Carbon Capture Journal*. August 2020.



LEGISLATION and POLICY

CO₂ Management Bill Proposed.

A proposed bill would establish a Committee on Large-Scale Carbon Management in the National Science and Technology Council and a Federal Carbon Removal Initiative, according to the U.S. congressional record bill summary. If enacted, *S. 4341* would create a large-scale CO₂ management program co-chaired by officials from DOE, as well as other institutions and U.S. departments, that would establish four working groups to pursue a Carbon Dioxide Removal (CDR) initiative. Using both natural and technological approaches, the working groups would focus on CDR in the oceans, atmosphere, and land. From *The Ripon Advance*. August 2020.

VA Governor Signs Legislation for Carbon-Free Future.

The Governor of Virginia (USA) signed legislation addressing the state's carbon-free transition. The *Virginia Clean Economy Act* establishes a renewable portfolio standard to achieve 30% renewable energy by 2030, an energy efficiency resource standard, and a path to a carbon-free electric grid by 2045. From *Governor Ralph Northam News Release*. August 2020.

EMISSIONS TRADING

RGGI States Release Investment Report.

The RGGI-participating states *released a report* tracking the investment of proceeds from their 2018 regional CO₂ allowance auctions.



The report, which provides state-specific data and highlights, found that in 2018, \$248 million in proceeds generated in RGGI auctions were invested in programs such as energy efficiency, clean and renewable energy, and greenhouse gas (GHG) abatement. Over their lifetime, the investments are projected to help reduce 4.6 million short tons of CO₂ emissions. From *RGGI News Release*. July 2020.

EU, Switzerland to Link ETS.

The European Commission announced the merger of European Union (EU) and Swiss carbon markets. Originally scheduled for May 2020, the launch was delayed until September 2020 due to the COVID-19 global pandemic. Allowance transactions traded between the two markets will be transferred on 10 separate one-day windows. The full calendar of transfer dates for 2021 will be released later in 2020. From *Reuters*. August 2020.

SCIENCE NEWS

DOE Researchers Develop CO₂ Conversion Method.



Researchers at DOE's Argonne National Laboratory (ANL) developed a method that converts CO₂ and water into ethanol with high energy efficiency and high selectivity for the desired final product. The electrocatalytic selectivity

of this process is more than 90%, which is higher than currently reported. *DOE's Office of Science* and *Office of Basic Energy* helped fund the research, which was conducted using two DOE Office of Science User Facilities located at ANL: the Advanced Photon Source and the *Center for Nanoscale Materials*. The results were *published in the journal Nature Energy*. From *Argonne National Laboratory Press Release*. August 2020.

Study Shows Amazon Gold Mining's Impact on CO₂ Storage.

A study focusing on the impacts of Amazon gold mining in Guyana (South America) found that forests remain barren at the abandoned goldmines three to four years after the conclusion of the mining, impacting the rainforest's ability to store CO₂. Published in the *Journal of Applied Ecology*, the research shows that the deforestation and recovery rates resulting from depleted nitrogen levels have the potential to reduce CO₂ storage across Amazonian secondary forests. From *Mongabay*. August 2020.

SCIENCE NEWS *(cont.)*

Study Provides Insight into CO₂ Storage.

Scientists from Scotland and Malaysia conducted a review of past, recent, and ongoing developments in CO₂ storage in saline formations. The results, highlighting the role of saline formations in the storage of CO₂, *were published in the Journal of Natural Gas Science & Engineering*. The scientists studied the different ways CO₂ can be trapped within the pore space of rocks. The findings are expected to improve understanding of different CO₂ trapping methods to maximize the storage potential of a CO₂ storage site, enabling further development of CCS projects. From *Carbon Capture Journal*. July 2020.

Scientists Study Trees' CO₂ Storage Ability.

A study conducted at the Harvard Forest Long-Term Ecological Research site found that the rate at which CO₂ is captured from the atmosphere at Harvard Forest nearly doubled from 1992 to 2015. Scientists attribute the forest's increase in CO₂ storage capacity to, among other things, the growth of 100-year-old oak trees, timber harvest, and a longer growing season. The study took CO₂ measurements from air, soil, water, and trees to document the flow of CO₂ through the forest. Results of the study were *published in the journal Ecological Monographs*. From *The Harvard Gazette*. August 2020.

PUBLICATIONS

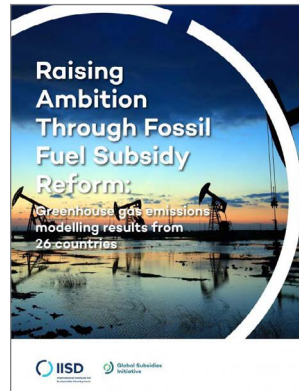
Carbon Capture and Storage (CCS) Market Size 2020 – Competitive Landscape and Growth Opportunity, Industry Status and Forecast to 2025.

The following is a description of this Market Research report: “[This report] offers a thorough investigation of Carbon Capture and Storage (CCS) Market, SWOT examination of the most prominent players right now. Alongside an industrial chain, market measurements regarding revenue, sales, value, capacity, regional market examination, section insightful information, and market forecast are offered in the full investigation, and so forth... Some of the major objectives of this report: [1] To provide a detailed investigation of the market structure alongside conjecture of the different sections and sub-portions of the worldwide Carbon Capture and Storage (CCS) Market. [2] To provide bits of knowledge about factors influencing market development. To examine the Carbon Capture and Storage (CCS) Market dependent on different variables value examination, store network investigation, porter five power investigation and so on. [3] To provide authentically and estimate the income of the Carbon Capture and Storage (CCS) Market portions and sub-fragments concerning four principle geographies and their nations North America, Europe, Asia, and the Rest of the World. [4] Nation level examination of the market regarding the present market size and future prospective. [5] To provide a national level examination of the market for section by Component, Technology, Application, End-Use, And Region. [6] To provide key profiling of key players in the market, thoroughly investigating their center capabilities, and drawing a serious scene for the market. [7] Track and break down serious advancements, for example, joint endeavors, key coalitions, mergers and acquisitions, new item improvements, and research and improvements in the worldwide Carbon Capture and Storage (CCS) Market.”

Researchers Study CO₂ Release in Tropical Soils.

According to a study conducted by researchers from the University of Edinburgh, tropical soils have the potential to release more CO₂ into the atmosphere than previously thought. The research team conducted a large-scale field experiment in a tropical forest in Panama, finding that soil carbon emissions may increase by 55% due to potential climate change. The results, *published in the journal Nature*, showed that from every hectare of tropical forest, up to eight extra tons of soil carbon would be released in the form of CO₂ each year in a potentially warming climate. From *Earth.com*. August 2020.

Raising Ambition Through Fossil Fuel Subsidy Reform: Greenhouse gas emissions results modelling from 26 countries.



The following is a description of this International Institute for Sustainable Development (IISD) report: “This working paper models the impact of the removal of fossil fuel subsidies on greenhouse gas (GHG) emission reductions for the following countries: Algeria, Bangladesh, Brazil, China, Egypt, Germany, Ghana, India, Indonesia, Iran, Iraq, Mexico, Morocco, Myanmar, Nigeria, Pakistan, Russia, Saudi Arabia, South Africa, Sri Lanka, Tunisia, United Arab Emirates, the United States, Venezuela, Vietnam and Zambia. The research found simple country average GHG emission reductions

of 6 per cent from 2018 until 2025, compared to business as usual. With an additional 10 per cent energy tax from 2025 until 2030 and a shift of 30 per cent of the savings from reforms and of revenues from taxation into investments in renewable energy and energy efficiency (i.e., a swap), GHG emission reductions improve to an average of 13.2 per cent by 2030. Cumulative fiscal savings from fossil fuel subsidy reform (FFSR) alone by 2030 total USD 2.56 trillion across the countries analyzed, with total cumulative GHG emissions abated from FFSR of 4.8 GtCO₂e by 2030. For every tonne of CO₂e removed through FFSR, governments save an average of USD 93. This study also includes a literature review of 60 pieces of research on global GHG emission reductions stemming from negative and positive carbon pricing. [The authors] reviewed 40 papers concerned with FFSR and 20 papers focused on fossil fuel energy or carbon taxation. [The authors’] review found that global studies of fossil fuel subsidy removal result in emission reductions of between 1 and 10 per cent by 2030 and between 6.4 and 8.2 per cent by 2050. Removing fossil fuel subsidies and applying appropriate taxation could reduce emissions by a much larger 28 per cent globally. Fossil fuel subsidies act as a negative carbon price and could also be considered along with carbon pricing discussions. Furthermore, governments could consider the co-benefits of GHG emission reductions from FFSR and taxation, and include these policies within second-generation Nationally Determined Contributions.”

PUBLICATIONS (cont.)

CSIRO In-Situ Lab: A multi-pronged approach to surface gas and groundwater monitoring at geological CO₂ storage sites.

The following is from the abstract of this article: "In February 2019, at the CSIRO In-Situ Laboratory CCS project, a test was conducted where 38 t of gaseous CO₂ were injected over 5 days into a fault zone at a depth of approximately 340 m. As a release test, this project enabled the testing and validation of surface and shallow well monitoring strategies at intermediate depths (i.e. depths much deeper than previous release projects and shallower than reservoirs used for CO₂ storage). One of the aims of this project is to understand how CO₂ would behave at intermediate depths if it did migrate from deeper depths (i.e. from a storage reservoir); the CO₂ was not intended to migrate to the shallow subsurface or to surface/atmosphere. To verify that the injected CO₂ remained in the subsurface, and to comply with environmental performance requirements on site, a comprehensive surface gas and groundwater monitoring program was conducted. The monitoring strategy was designed such that any leakage(s) to the surface of injected CO₂ would be detected, mapped and, ultimately, quantified. The surface air monitoring program was comprised of three different but complementary approaches allowing data to be efficiently collected over different spatial and temporal scales. These approaches included continuous soil-gas chamber measurements at fixed locations, periodic soil-gas chamber measurements on gridded locations and near-surface atmospheric measurements on a mobile platform. The surface air monitoring approaches gave self-consistent results and reduced the risk of 'false negative' test results. The only anomalous CO₂ detected at the surface flowed from the observation well and could be directly attributed to a breach in the well casing at the injection depth providing a conduit for CO₂/water to rise to the surface. Groundwater monitoring program revealed no impact on the groundwater resources attributable to the carbon injection project. Based on this work, [the authors] demonstrate that this multi-pronged monitoring strategy can be utilized to minimize the overall resources devoted to monitoring by increasing the number of monitoring approaches and diminishing the resources devoted to each technique. By maximizing the effectiveness of each element of the monitoring program, a cost-efficient and robust monitoring strategy capable of early leak detection and attribution of any leaking CO₂ can be achieved." **Matthew Myers, Cameron White, Bobby Pejic, Andrew Feitz, Jennifer Roberts, Yun-Yeong Oh, Liang Xu, Ludovic Ricard, Karsten Michael, Arsham Avijegon, Praveen Kumar Rachakonda, Martijn Woltering, Alf Larcher, Linda Stalker, and Allison Hortle**, *Chemical Geology*. (Subscription may be required.)

Optimization-based approach for CO₂ utilization in carbon capture, utilization and storage supply chain.

The following is from the abstract of this article: "Carbon dioxide (CO₂) is one of the primary anthropogenic greenhouse gases (GHGs), and its increasing emission has drawn wide attention from the international community. Among the strategies for CO₂ diminishment, carbon capture, utilization and storage (CCUS) is considered as the key option. The objective of this work is to develop an optimization-based assessment framework that aims to incorporate CO₂ storage and CO₂ utilization into an integrated framework. To achieve this goal, a superstructure network including all the sections of CCUS supply chain is proposed, which includes CO₂ capture, transportation, storage and utilization with 15 candidate conversion process paths. Based on this superstructure, a mathematical model for the optimal design of a supply chain of CCUS is developed. CO₂ would be stored underground and/or utilized to produce chemical products through candidate conversion paths. Finally, a case with real data of large emission sources in Northeast China is studied. Three different scenarios are investigated, according to key constraints on CCUS network: CO₂ emission source, raw material limits and products demands limits. Results show that adsorption is the preferred capture technology at relative high flue

gas flow rate and high CO₂ concentration. Storing CO₂ is the recommended approach compared with utilization from the point of economy, however, carbon utilization could be a more sustainable option and may generate a carbon-neutral cycle. With the increase of CO₂ utilization, the cost of CCUS supply chain also increase (Scenario A: 2.49 billion \$/y, Scenario B: 2.76 billion \$/y, Scenario C: 2.85 billion \$/y)." **Shuai Zhang, Yu Zhuang, Linlin Liu, Lei Zhang, and Jian Du**, *Computers & Chemical Engineering*. (Subscription may be required.)

Moisture-Driven CO₂ Sorbents.

The following is a summary of this article: "Moving the energy infrastructure away from fossil fuels to renewable energies to stop global warming is a challenging task. In the transition, CO₂ capture and storage (CCS) from point sources could reduce CO₂ emission. However, the objective of stabilizing atmospheric CO₂ at 450 ppm cannot be achieved by CCS alone. Here, the urgency of the development of CO₂ capture from ambient air, or 'direct air capture' (DAC) is demonstrated. A successful sorbent for DAC must (1) have fast reaction kinetics, (2) be low in cost, and (3) be able to regenerate with a low energy barrier to complete the whole CO₂ capture-release cycle. Most CO₂ sorbents failed in the third category as they had to overcome a large energy barrier to regenerate. This study presents an energy-saving sorbent to capture CO₂ simply by controlling the water quantities on it. [The authors] report the effects of parameters of the sorbents on CO₂ capture efficiency. The study can lead the way toward the optimization of sorbents for DAC. An energy-saving system containing ion-exchange or nanoporous materials and carbonate ions is proposed, which is capable of capturing CO₂ from ambient air simply by controlling the amount of water (moisture) in contact with the sorbent. The system binds CO₂ from the air when the surrounding is dry, whereas it desorbs CO₂ when it is wet. A design of such CO₂ sorption and desorption systems is investigated using quantum mechanics simulations and is verified by experiments. Its working mechanism is revealed as the free energy change of the chemical reaction of the carbonate ions and water molecules; the free energy change decreases when the number of water molecules in the materials decreases. The influence of pore size, spacing of cations, and surface hydrophobicity of the sorbents on CO₂ capture efficiency are elucidated. The study sheds light on ways to optimize an efficient direct air capture system and therefore contributes to the development of 'negative emission technologies.'" **Xiaoyang Shi, Hang Xiao, Kohei Kanamori, Akio Yonezu, Klaus S. Lackner, and Xi Chen**, *Joule*. (Subscription may be required.)

Modified phosphogypsum sequestering CO₂ and characteristics of the carbonation product.

The following is from the abstract of this article: "A method of PG carbonation to produce polymorphs of high-purity CaCO₃ was proposed. The effect of experimental conditions on transformation process from PG to calcium carbonate was systematically discussed. PG transformed into granular portlandite and fibrous quartz under the action of caustic soda at room temperature for 10min. The carbonation ratio (η) was 98.57%, and 1000kg of PG could produce 519kg of high-purity CaCO₃ and sequestered 228kg of CO₂. The spherical vaterite carbonation product met the relevant standards for the industrial precipitated calcium carbonate. A reaction mechanism of PG carbonation was also proposed by thermodynamic research of the gas-liquid-solid reaction. The products with a single vaterite structure, or a vaterite and calcite mixing structure or a vaterite, aragonite and calcite mixing structure were all successfully prepared. All of these indicated that the whole procedure setup of PG carbonation showed potential application for PG utilization and CO₂ sequestration." **Wenjin Ding, Qiuju Chen, Hongjuan Sun, and Tongjiang Peng**, *Energy*. (Subscription may be required.)

PUBLICATIONS (cont.)

Application of a dual tubing CO₂ injection-water production horizontal well pattern for improving the CO₂ storage capacity and reducing the CAPEX: A case study in Pohang basin, Korea.

The following is from the abstract of this article: "Water production is an efficient way of relieving pressure build-up and improving the CO₂ storage capacity (CSC) in the carbon capture and storage process. The additional offshore platforms, production wells, pipelines, and pumps required for water production, however, increase the capital expenditure (CAPEX) of the project. Therefore, a CO₂ injection method that can both improve the CSC and reduce the CAPEX is needed. This paper proposes a dual-tubing CO₂ injection-water production horizontal well (DTHW) pattern for improving the CSC, in which CO₂ is injected at the heel of the horizontal well while water is produced at the toe. The CSC and CAPEX of the proposed DTHW pattern were then compared to those of other cases in a saline aquifer in the Pohang basin, offshore Korea. The CCS Performance (CSC to CAPEX ratio) of the proposed DTHW pattern was larger than that of a typical CO₂ injection with a water production pattern for the all CO₂ injection-water production rate cases. The proposed DTHW pattern showed promising results in that the maximum CSC was improved by 98.2% compared to a single vertical CO₂ injection well pattern and the CAPEX was reduced by 37.1% compared to the typical CO₂ injection with a water production pattern. More CAPEX might be saved if a DTHW pattern is used in an onshore platform near a power plant because an additional offshore platform and pipeline are not required." **Min Kim and Hyundon Shin**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

Effects of land use and forest management on soil carbon in the ecoregions of Maryland.

The following is from the abstract of this article: "The impacts of forest-related land use and management on soil organic carbon (SOC) stocks have been investigated through years of primary research and review articles. This attention is justified given the importance of land use and management to greenhouse gas mitigation, soil and forest productivity, and other ecosystem services. However, there is a gap of scale and scope between site-level studies that control for sources of variation, producing high-confidence results for limited locations, and the broad reviews that offer more general conclusions. The present analysis is intended to fill that gap. Here, [the authors] focus on six ecoregions of the eastern United States, and integrate meta-analysis of published literature with synthesis of geo-referenced soil observations to: (1) test whether common land use and management practices quantitatively impact SOC; (2) identify key sources of variation in these effects; (3) assess how sources of variation translate to decisions about land use and management at ecoregional to landscape levels. Results corroborate general trends, such as O horizon SOC losses with harvesting and fire and SOC gains during reforestation, but provide greater detail about the influence of specific practices and site-level controls on SOC stocks and change in the study region. Results also show that: (1) harvest impacts depend upon landform and soil taxonomy; (2) harvesting forests that are recovering on previously cultivated lands decreases SOC; (3) tree biomass and SOC recovery increase concurrently during reforestation; (4) specific harvest, site preparation, and fire management practices affect the magnitude and variability of changes in SOC. Perhaps more importantly, ecoregional classification and soil taxonomy provide spatial frameworks for placing quantitative estimates of SOC stocks and changes in the geographic context of the study region, providing greater detail and specificity for individuals and institutions concerned with SOC management at more localized levels." **L.E. Nave, K. DeLyser, P.R. Butler-Leopold, E. Sprague, J. Daley, and C.W. Swanston**, *Forest Ecology and Management*. (Subscription may be required.)

Evolution of soil organic carbon in a carbonaceous glacial till as an effect of crop and fertility management over 50 years in a field experiment.

The following is from the abstract of this article: "Changes in soil organic carbon (SOC) content depending on different factors are extensively investigated when the soil is in steady-state equilibrium between formation and decomposition of soil organic matter. However, studies of SOC formation and dynamics in [initially] organic matter free soil are rare. Evolution of soil organic carbon was studied in a field experiment established in 1964 on a carbonaceous glacial till soil with very low initial SOC content (1.28g kg⁻¹). The effects on SOC content changes of bare fallow, barley and different perennial fodder crops such as grasses, clover-grass mixture, galega, hybrid lucerne and a turfgrass mixture, with or without mineral N and PK fertilisation and manure, were studied. There were 19 treatments in total and most had unchanged plant cover composition throughout the experiment. During 1964–2014, SOC stock increased in all treatments, by 0.11Mg ha⁻¹ y⁻¹ in bare fallow and by at most 0.50Mg ha⁻¹ y⁻¹ in the treatment with hybrid lucerne and manure. Average SOC sequestration rate was 0.35±0.11Mg ha⁻¹ y⁻¹. SOC changes were highly correlated with estimated C inputs and were therefore higher in treatments with perennials than with an annual barley crop. C retention efficiency for total crop-derived C inputs and for organic amendments was 6.1% and 22%, respectively. Water-soluble C measured in 2014 increased linearly with SOC, indicating that the quality of recently formed SOC was not strongly affected by the treatments. However, water-soluble C as a fraction of SOC was significantly lower in treatments with legumes than in treatments with bare fallow or a barley or grass crop. These results demonstrate that the quantity and quality of C inputs were both main drivers for observed changes in SOC. However, C retention efficiency of C inputs was relatively low. This may be related to soil texture with high sand proportion, suggesting that SOC sequestration rates in light-textured soils may be lower than expected even in case of low initial SOC content." **Karin Kauer, Alar Astover, Rein Viiralt, Henn Raave, and Thomas Kätterer**, *Agriculture, Ecosystems & Environment*. (Subscription may be required.)

Vulnerability of seagrass blue carbon to microbial attack following exposure to warming and oxygen.

The following is from the abstract of this article: "Seagrass meadows store globally-significant quantities of organic 'blue' carbon. These blue carbon stocks are potentially vulnerable to anthropogenic stressors. Here, [the authors] tested the impact of oxygen exposure and warming (major consequences of human disturbance) on rates of microbial carbon break-down in seagrass sediments. Active microbes occurred throughout seagrass sediment profiles, but deep, ancient sediments (~5000 yrs. old) contained only 3% of the abundance of active microbes as young, surface sediments (<2 yrs. old). Metagenomic analysis revealed that microbial community structure and function changed with depth, with a shift from proteobacteria and high levels of genes involved in sulfur cycling in the near surface samples, to a higher proportion of firmicutes and euryarchaeota and genes involved in methanogenesis at depth. Ancient carbon consisted almost entirely (97%) of carbon considered 'thermally recalcitrant', and therefore presumably inaccessible to microbial attack. Experimental warming had little impact on carbon; however, exposure of ancient sediments to oxygen increased microbial abundance, carbon uptake and sediment carbon turnover (34–38 fold). Overall, this study provides detailed characterization of seagrass blue carbon (chemical stability, age, associated microbes) and suggests that environmental disturbances that expose coastal sediments to oxygen (e.g. dredging) have the capacity to diminish seagrass sediment carbon stocks by facilitating microbial remineralisation." **P.I. Macreadie, T.B. Atwood, J.R. Seymour, M.L. Schmitz Fontes, J. Sanderman, D.A. Nielsen, and R.M. Connolly**, *Science of The Total 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 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](#).



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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