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# CARBON STORAGE NEWSLETTER

FEBRUARY 2021

This newsletter is compiled by the National Energy Technology Laboratory to provide information on recent activities and publications related to carbon storage. It covers domestic, international, public sector, and private sector news in the following areas:

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## CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

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## DOE/NETL HIGHLIGHTS

### *DOE/FE Funding to Include CCUS.*

The U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) announced the availability of financial assistance for cost-shared research and development (R&D) projects under a *Funding Opportunity Announcement (FOA)* that supports the initial engineering and design of carbon capture, utilization, and storage (CCUS) projects. Projects selected under the CCUS-focused Area of Interest (AOI) for this FOA will support the completion of an initial design of a commercial-scale CCUS-direct air capture system that separates, stores, or utilizes a minimum of 1,000 metric tons of carbon dioxide (CO<sub>2</sub>) per year from the air. The National Energy Technology Laboratory (NETL) will manage the projects, which will support DOE's *Carbon Capture Program*. Responses are due by March 5, 2021. From *energy.gov*. January 2021.



## ANNOUNCEMENTS

### *DOE Announces FOA in Support of CO<sub>2</sub> Utilization.*

DOE/FE will make available federal funding for cost-shared research, development, and testing of technologies that can utilize CO<sub>2</sub> from power systems for bio-mediated uptake by algal systems to create valuable products and services. *The FOA*, which supports DOE's *Carbon Utilization Program*, will seek applications that aim to perform engineering-scale testing and validation of algae-based technologies and bioproducts. Responses are due March 2, 2021.

### *DOE Announces Funding to Help Decarbonize Energy and Commodity Production.*

DOE/FE announced that federal funding is available for cost-shared R&D to help recalibrate the nation's fossil fuel and power infrastructure for decarbonized energy and commodity production. The funding is aimed at developing technologies for the production, transport, storage, and utilization of fossil-based hydrogen, with progress toward net-zero emissions. Projects selected under the *FOA* will be managed by NETL. Responses are due March 1, 2021.

### *RGGI Secondary Market Report Made Available.*

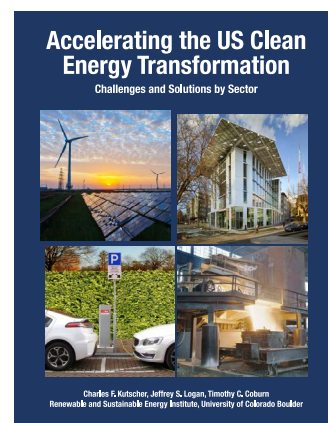
The independent market monitor for the Regional Greenhouse Gas Initiative (RGGI) released a report on the secondary market for RGGI CO<sub>2</sub> allowances, including future prices, market activity, and allowance holdings. Potomac Economics' "Report on the Secondary Market for RGGI CO<sub>2</sub> Allowances: Third Quarter 2020" addresses the period from July through September 2020. The report is part of Potomac's ongoing monitoring of the RGGI auctions and secondary markets.

### *Industry Research Report on CO<sub>2</sub>-EOR Market Released.*

A research report on the global CO<sub>2</sub>-enhanced oil recovery (EOR) market was released by a research and consulting services company. The report offers qualitative and quantifiable information on factors affecting or influencing market dynamics and market growth, including sections on global CO<sub>2</sub>-EOR market growth drivers, market trends, and market opportunities. (Purchase may be required.)

### *Report Outlines Potential Approaches to Reduce CO<sub>2</sub> Emissions.*

University of Colorado's (Boulder) Renewable and Sustainable Energy Institute (USA) released a report outlining steps the United States can take to reduce CO<sub>2</sub> emissions. "Accelerating the U.S. Clean Energy Transition: Challenges and Solutions by Sector" describes low- and zero-carbon solutions across a variety of sectors, laying out policy options for each. The report also provides an overview of technologies that have the potential to reduce CO<sub>2</sub> levels.



## PROJECT and BUSINESS DEVELOPMENTS

### Full-Scale CCS Facility to Be Installed in Norway.

A full-scale carbon capture and storage (CCS) facility will be installed at a cement plant in Brevik, Norway. The HeidelbergCement Norcem project is expected to capture and store 400,000 tons of CO<sub>2</sub> per year. Work on the facility is projected to begin in 2021, with the goal of beginning CO<sub>2</sub> separation from the cement process in later years. The outcome is expected to be a 50% reduction of emissions produced at the plant. From *The Baltic Course*. December 2020.

### MOU Signed to Further Develop CCUS Value Chain



Equinor Energy and Mitsubishi Heavy Industries signed a Memorandum of Understanding (MOU) for a low-carbon technology collaboration. Under the MOU, both companies will develop and use technology to reduce the CO<sub>2</sub> footprint of oil and gas operations. The companies will look to further develop the hydrogen and CCUS value chains. From *Mitsubishi Heavy Industries News Release*. December 2020.

### Norwegian CO<sub>2</sub> Storage, Transport Project to Proceed.

The Norwegian government has voted to fund the Northern Lights CO<sub>2</sub> transport and storage project, enabling it to proceed. *The Northern Lights project* will be an open and available infrastructure that enables the transport of CO<sub>2</sub> from industrial capture sites to a terminal in Øygarden for intermediate storage before being transported by pipeline for permanent storage in an underground reservoir. The project is the transport and storage component of *Longship*, the Norwegian government's full-scale CCS project. From *Carbon Capture Journal*. December 2020.

### Companies to Collaborate on CCUS Projects in India.

*Carbon Clean* and *Veolia* announced a joint venture to develop two CCUS projects in India. The newly established company, Veolia Carbon Clean, will finance, design, build, and operate the projects, as well as research the opportunity for other projects in India. From *Carbon Clean*. December 2020.



### Locations Being Investigated for Storage, Liquefaction of CO<sub>2</sub> in Sweden.

Five energy companies in Sweden will collaborate in a pre-study to investigate infrastructure for capturing and storing CO<sub>2</sub>. One location being studied by representatives of the Carbon Infrastructure Capture (CinfraCap) project is the Energy Terminal at the Port of Gothenburg (Sweden), where they are looking to identify a suitable location for intermediate storage and possible liquefaction of CO<sub>2</sub>. From *Port of Gothenburg News Release*. December 2020.

### Carbon Storage Consulting Services Contract Awarded.

Oxy Low Carbon Ventures was awarded a contract to provide carbon storage consulting services for Minnkota Power Cooperative's Project Tundra. Oxy Low Carbon Ventures, a carbon management company, will advise Minnkota on the design and overall requirements of the project's carbon storage facility. Minnkota is currently conducting front-end engineering and design studies. From *Yahoo!* December 2020.



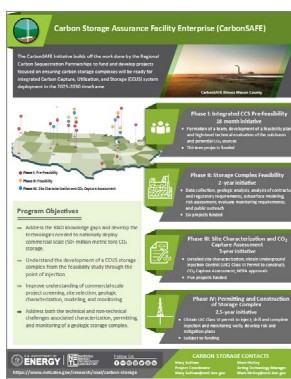
### UK Government to Fund CO<sub>2</sub> Reduction Projects.

Six projects across the United Kingdom (UK) were awarded funding from the UK government to form a "net-zero industrial zone." Among the projects is the Humber Industrial Cluster Plan, which will examine how hydrogen and CCS technology can be scaled up to help achieve net-zero emissions by 2040. From *Energy Live News*. January 2021.

## LEGISLATION and POLICY

### Bill Introduced to Support CO<sub>2</sub> Storage.

A bill was *introduced* in the U.S. House of Representatives that supports the buildout of the infrastructure necessary to transport CO<sub>2</sub> from where it is captured to where it could be stored. The *Storing CO<sub>2</sub> and Lowering Emissions (SCALE) Act* would also authorize DOE to provide grants for procuring carbon utilization products for infrastructure projects, as well as build upon *DOE's Carbon Storage Assurance Facility Enterprise (CarbonSAFE)* projects. Under the bill, increased funding would also enable the U.S. Environmental Protection Agency to review permit applications for Class VI CO<sub>2</sub> storage wells in a timely manner and provide grants for states to establish and operate their own Class VI permitting programs. From *Ethanol Producer*. December 2020.



CarbonSAFE Infographic

### IRS Finalizes Carbon Capture Tax Credits.

The U.S. Internal Revenue Service (IRS) and the U.S. Treasury Department *released final regulations* for businesses seeking to claim carbon capture tax credits under section 45Q. The final rules aim to help businesses understand how the tax credit for qualified carbon oxide storage can benefit companies claiming carbon capture credits. From *Accounting Today*. January 2021.



### New York State Establishes GHG Emissions Cap.

New York State adopted a regulation that requires statewide greenhouse gas (GHG) emissions limits. Under the New York Climate Leadership and Community Protection Act, emissions limits in the state are required to reflect a 40% reduction in statewide GHG emissions by 2030 and an 85% reduction by 2050 (both based on 1990 levels). From *Lexology*. December 2020.

### Agreement on Bill to Reduce CO<sub>2</sub> Emissions Reached.

Agreement was reached on a Massachusetts bill to reduce the state's CO<sub>2</sub> emissions by at least 85% below 1990 levels by 2050. The bill (*S. 2995*) would establish a net-zero GHG emissions limit for 2050, as well as statewide emissions limits every five years over the next three decades. From *Milford Daily News*. January 2021.

## LEGISLATION and POLICY (cont.)

### Researchers Produce CCUS Study.



Researchers from the University of Wyoming, the West Virginia University School of Law, and the U.S. Energy Association published a study identifying regulatory shortcomings that may impact the deployment of CCUS technologies in the United States. The study identified legal

and regulatory obstacles to CCUS deployment, such as land, mineral, pore space, or water rights; eminent domain; or pipeline or CO<sub>2</sub> storage regulations. The U.S. Energy Association [conducted a webinar](#) outlining the results of the study. From *Casper Star-Tribune*. December 2020.

### UK Oil and Gas Strategy Includes Support for CCS Projects.

The UK Oil and Gas Authority submitted a [revised strategy](#) in the UK Parliament that



**Oil & Gas Authority**

supports the government's net-zero targets. Under the revised strategy, industry is encouraged to collaborate with the supply chain and actively support CCS projects. From *Carbon Capture Journal*. December 2020.

### UK Energy White Paper Builds on CCS Development.

The UK government released an Energy White Paper that outlines plans to support a transition to net-zero. The white paper builds on the [Ten-Point Plan](#), which includes funding for the [development of four CCS hubs and clusters](#). From *Global CCS Institute*. December 2020.

## EMISSIONS TRADING

### RGGI States Initiative Auction Process for Auction 51.

The RGGI-participating states initiated the auction process for their 51st quarterly CO<sub>2</sub> auction, scheduled for March 3, 2021. Auction 51 will offer 23,467,261 CO<sub>2</sub> allowances for sale at a minimum reserve price of \$2.38. An 11,976,778 CO<sub>2</sub> allowance cost containment reserve (CCR) will also be made available (the CCR will be accessed if the interim clearing price exceeds the CCR trigger price of \$13.00). From *RGGI News Release*. January 2021.

### Daily Carbon Credit Assessment Launched.

IHS Markit launched a daily pricing suite for global voluntary carbon offset credits. According to the company, IHS Markit's OPIS Global Carbon Offset Report encompasses daily price assessments in response to demand for benchmark pricing for voluntary carbon credits. From *Nasdaq*. December 2020.

# RGGI Inc.



## SCIENCE

### Research Partnership to Use CCUS Technology.

A research partnership to use CCUS technology to produce plastic was formed. Braskem, a polyolefins producer, and the University of Illinois Chicago (UIC) (USA) will develop a new method for producing ethylene—a raw material used to make thermoplastic resins—that will utilize CCUS technology. The project will use the CCUS technology under development at UIC to connect the capture and conversion of waste CO<sub>2</sub> streams with the production of sustainable feedstock for making plastic. Braskem will assist with scale-up of the technology and help validate the theoretical and experimental studies produced by UIC. From *Braskem News Release*. December 2020.

### Scientific Development Could Improve CO<sub>2</sub> Capture.

Researchers from Swansea University (UK) developed a new way of producing carbon spheres that has the potential to improve carbon capture technologies. According to scientists, carbon spheres play an important role in gas adsorption and storage. The Swansea team adapted an existing method of creating carbon spheres (chemical vapor deposition) by using pyromellitic acid as both a carbon and oxygen source and applied the method at different temperatures. From *Swansea University Press Release*. December 2020.

### Scientists Convert CO<sub>2</sub> into Jet Fuel.

Scientists from Oxford University successfully converted CO<sub>2</sub> into jet fuel using a technique that reverses the process of burning fuel by relying on the organic combustion method. By heating a mix of citric acid, hydrogen, and an iron-manganese-potassium catalyst, the team was able to convert CO<sub>2</sub> into a liquid fuel capable of powering jet aircraft. According to the scientists, the technique has the potential to make conventionally powered aircrafts with net-zero CO<sub>2</sub> emissions. From *Yahoo!* December 2020.



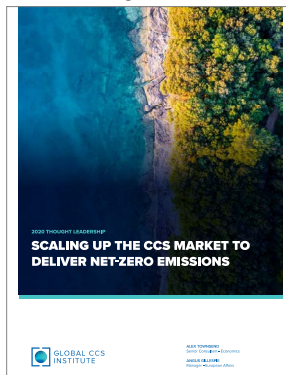
## PUBLICATIONS

### *CCS deployment at dispersed industrial sites.*

The following is from the Executive Summary of this UK Department for Business, Energy & Industrial Strategy (BEIS) research paper: "The Department for Business Energy and Industrial Strategy commissioned Element Energy in 2019 to identify and assess the range of high-level deployment options for Industrial Carbon Capture (ICC) technology on sites isolated from CO<sub>2</sub> transport and storage infrastructure in the United Kingdom. This area is of particular relevance because most of the existing Carbon Capture and Storage (CCS) reports in the UK focus on how shoreline CCS clusters can be developed. Isolated or inland emitters and clusters are generally excluded in these reports, or high-level onshore pipelines routes are presented in the longer term once the shoreline hubs are developed; the level of thinking and evidence are therefore limited in this area. In this work [the authors] identify key dispersed sites in the UK as well as their unique challenges and barriers to CCS deployment. Next, [the authors] appraise a range of high-level options for CCS deployment and the risks associated with each challenge and finally [the authors] assess the most promising options based on their cost, risk and emission reduction potential. [The authors] also include a comparison of CCS against alternatives such as carbon utilisation and hydrogen fuel switching based on the same metrics. This work has been supported by a period of stakeholder engagement during which organisations involved across a wide range of the CCS value chain were consulted."

### *Scaling Up the CCS Market to Deliver Net-Zero Emissions.*

The following is from the Executive Summary of this Global CCS Institute report: "Understanding how the carbon capture and storage (CCS) market is likely to develop over the coming years is of interest to a wide range of stakeholders. It can help inform the timing and design of policies introduced by governments, the scale of the market for potential investors, and the challenges associated with meeting long-term climate targets. This report aims to inform the discussion on these topics by providing an overview of the near-term and longer-term developments in the CCS market. It reviews the current CCS facility pipeline, and how that could change in the next few years given project lead-in times. It then considers how this compares to projections of the number of CCS facilities needed to meet long-term climate goals. Throughout the report the number of CCS facilities deployed is used as a proxy for the size of the CCS market. The current CCS facility pipeline provides a relatively robust indicator of the CCS market in the next few years, particularly given it takes around 6-8 years for projects to progress through the full development cycle. There are currently 51 large-scale CCS facilities in the CCS facility pipeline, with 19 in operation, 4 under construction, 10 in advanced development and 18 in early development. Most of the large-scale facilities in operation are in North America, with the remainder in Norway, China, Brazil, Saudi Arabia, Australia and the UAE. The projects tend to be concentrated in industries where the unit cost of capturing CO<sub>2</sub> is low, such as natural gas processing, fertiliser and ethanol production."



### *A knowledge-data framework and geospatial fuzzy logic-based approach to model and predict structural complexity.*

The following is from the abstract of this article: "Prediction of structural complexity for geohazard and subsurface resource applications requires constraining and interpreting data that are often ambiguous or lack key information. Moreover, structural complexity is a subjective term, requiring context for quantification. Recognizing this, a new knowledge-data framework and a geospatial fuzzy logic method is developed to represent and predict structural complexity in the subsurface. A conceptual model for known structural complexity serves as a basis for associating geospatial representations with types of damage zones. A second conceptual model for zones of structural complexity facilitates its prediction, notably in areas with limited explicit structural data. For each conceptual model, a fuzzy logic inference model is developed to incorporate geospatial data and estimate structural complexity potential. This approach is demonstrated using several public geospatial datasets within the state of Oklahoma. Explicit fault and earthquake location data were integrated using a fuzzy model of known structural complexity to train topographic, lithologic, and geophysical proxy datasets, applied to a fuzzy model to predict structural complexity, and evaluated with Receiver Operating Characteristic analyses and error classification. The final model output, displayed in maps and cross sections, offers comparison with interpreted structural data for validation. Together, these results demonstrate the effectiveness and limitations of the new approach as a screening tool for predicting structurally complex areas."

**Devin Justman, C. Gabriel Creason, Kelly Rose, and Jennifer Bauer,** *Journal of Structural Geology.* (Subscription may be required.)

### *A European Optimisation Tool for Carbon Capture and Storage, Accounting for Delays in Public Procurement.*

The following is from the abstract of this article: "The global anthropogenic generation of greenhouse gasses experienced an exponential increase compared to pre-industrial levels and, among these, CO<sub>2</sub> is the most abundant, with an emission that rose globally from 2 Gt/year in 1850 to over 35 Gt/year in 2010. Carbon capture and storage has been highlighted among the most promising options to decarbonise the energy sector, especially considering the European context which heavily relies on fossil fuels. When dealing with the strategic design and planning of an international carbon capture and storage infrastructure, the necessity of taking into account the differential behaviour among the European countries in terms of public procurement and assignation delays emerges as a key requirement for attaining an effective implementation of the network. This contribution proposes a mixed integer linear programming modelling framework for the economic optimisation of a multinational European carbon capture and storage supply chain, including the effects of countrywide delays in public procurement. Assignation lags are implemented as an additional cost for the installation of the network. Results show that only minor modifications in the supply chain design should be taken into account with respect to an equivalent non-delayed scenario, with a consequent just moderate increase in transport costs (+ 3 %). Moreover, it is shown that capture and sequestration stages are barely not affected by the introduction of assignation lags among countries." **Federico d'Amore, Leonardo Lovisotto, and Fabrizio Bezzo,** *Computer Aided Chemical Engineering.* (Subscription may be required.)

## PUBLICATIONS (cont.)

### *Coal phase-outs and carbon prices: Interactions between EU emission trading and national carbon mitigation policies.*

The following is from the abstract of this article: "The European Union Emission Trading System (EU ETS) constitutes the core instrument of the European Union climate protection policy. It limits greenhouse gas emissions of its member states and aims at facilitating an efficient allocation of emission reduction across national borders. Accompanying this policy at the European level, individual member states have introduced national mitigation policies, including renewable energy (RES) expansion measures or coal phase-outs. This study examines to what extent national policies affect the effectiveness of the EU ETS and to what degree the impact is reflected in prices for European Union Allowances (EUA). To investigate this question, a fundamental optimization model of the European electricity markets is deployed and model endogenous EUA prices are derived with a set of future market scenarios. Overall findings indicate that fundamental market forces strongly affect EUA prices. Furthermore, national policies play a critical role: The expansion of RES does not affect the capacity of the EU ETS to provide sufficient price signals for the desired level of decarbonization but a coal phase-out has a strong price-suppressing effect. A withdrawal of certificates can re-establish the effectiveness of the EU ETS but prices can rise drastically when overestimating the necessary amount." **Carl-Philipp Anke, Hannes Hobbie, Steffi Schreiber, and Dominik Möst**, *Energy Policy*. (Subscription may be required.)

### *Machine learning based co-optimization of carbon dioxide sequestration and oil recovery in CO<sub>2</sub>-EOR project.*

The following is from the abstract of this article: "This paper presents a machine learning assisted computational workflow to optimize a CO<sub>2</sub>-WAG project considering both hydrocarbon recovery and CO<sub>2</sub> sequestration efficacies. A compositional field-scaled numerical simulation model is structured to investigate the fluid flow dynamics of an on-going CO<sub>2</sub>-EOR project in the Farnsworth Unit (Texas, US). Artificial-neural-network (ANN) based proxy models are trained to predict time-series project responses including hydrocarbon production, CO<sub>2</sub> storage and reservoir pressure data. The outputs of the proxy model not only serve for evaluating the objective function but also provide significant physical and economic constraints to the optimization processes. In this work, the objective function considers both the oil recovery and CO<sub>2</sub> sequestration volume. Moreover, the project net present values (NPV) and reservoir pressure are employed to screen the optimum solutions. The proposed optimization workflow couples the Particle Swarm Optimization (PSO) algorithm and the ANN proxies to maximize the prescribed objective function. The results of this work indicate that the presented workflow is a more robust approach to co-optimize the CO<sub>2</sub>-EOR projects. Results show that the optimized case can store about 94% of the purchased CO<sub>2</sub> within Farnsworth Unit. Comparing to the baseline case, the CO<sub>2</sub> storage amount of the found optimal case increases by 21.69%, and the oil production improves 8.74%. More importantly, the improvements in CO<sub>2</sub> storage and hydrocarbon recovery lead to 8.74% greater project NPV and 19.79% higher overall objective function value, which confirms the success of the developed co-optimization approach for CO<sub>2</sub> sequestration and oil recovery. The lessons and experiences earned from this work provides significant insights into the decision-making process of similar CO<sub>2</sub>-EOR cases." **Junyu You, William Ampomah, Qian Sun, Eusebio Junior Kutsienyo, Robert Scott Balch, Zhenxue Dai, Martha Cather, and Xiaoying Zhang**, *Journal of Cleaner Production*. (Subscription may be required.)

### *Carbon sequestration and vegetation properties across the age of community managed exclosures in Northern Ethiopia.*

The following is from the abstract of this article: "Exclosure management is becoming a common approach to rehabilitate and increase net biomass productivity of extremely degraded areas in Northern Ethiopia. However, the effect of age of exclosures on vegetation and soil property of communal lands is not yet well studied. In this study, the effect of land exclusion and age of exclosure on plant species richness, diversity, density and dominance, herbaceous standing biomass, woody biomass, woody biomass carbon, soil organic carbon (SOC) and other soil properties were assessed. To study the above listed variables, exclosures in three age classes (5–7, 12–15 and >20 years) and adjacent free grazing areas were selected. [The authors] replicate each age class three times considering agroecological similarity. From each exclosure and free grazing area, six larger plots (10m × 20m) each having five small quadrats were taken. Totally, 72 larger plots and 360 small quadrats were sampled. The result of this study indicates that exclusion of communal lands significantly improved species richness, diversity, biomass, woody biomass carbon, SOC, total nitrogen (TN) and total potassium (TK). Similarly, the density of perennial species and the density of grass species were found increased with the age of exclosure. Herbaceous species richness, diversity and annual species density were higher in the young-aged exclosures than in the older exclosures. Woody species richness, diversity, density, biomass, and woody biomass carbon were highest in the older exclosures. Besides, age of exclosure increases the content of SOC, TN and TK. Furthermore, it was found that the old-aged exclosures stored more biomass carbon (267 %) and SOC (37.66 %) than the young-aged exclosures. The study indicates the benefits of land exclosure for permanent carbon storage, which is vital to reduce atmospheric greenhouse gas concentration." **Gebreaweria Kidane Reda, Teame Gebrehiwot Kebede, Shishay Tekklay Kahsay, and Berhane Hagos Gebrehiwot**, *Journal for Nature Conservation*. (Subscription may be required.)

### *Carbon dioxide wettability of South West Hub sandstone, Western Australia: Implications for carbon geo-storage.*

The following is from the abstract of this article: "CO<sub>2</sub>-rock wettability is a key factor which determines the fluid dynamics and CO<sub>2</sub> geo-storage capacity. However, the full understanding of real reservoir CO<sub>2</sub>-wettability is yet to be gained. [The authors] thus systematically analysed the wettability of CO<sub>2</sub>/brine/South West Hub sandstones at various pressures (0.1 MPa, 5 MPa, 10 MPa, 15 MPa, and 20 MPa) at 334 K. A new procedure based on organic carbon isotope tracking ( $\delta^{13}\text{C}_{\text{org}}$ ) was proposed to eliminate the effect of artificial organic matter introduced by drilling mud penetration. The results indicate that the advancing ( $\Theta_a$ ) and receding ( $\Theta_r$ ) water contact angles for the CO<sub>2</sub>/brine/South West Hub sandstone system increase with increase in pressure (ranging from 71° to 118° and 66° to 111°). It can thus be suggested that the system is weakly water-wet to intermediate-wet. When the samples were treated with dichloromethane, a slight decline in organic content was observed leading to slight decrease in water contact angles (i.e. TOC decreased from 0.019% to 0.003% for core C, and the corresponding  $\Theta_a$  and  $\Theta_r$  decreased from 118° and 111° to 110° and 104°, respectively, at 20 MPa and 334 K). This wettability analysis demonstrates that (a) of the contact angle is very sensitive to the amount of organic matter and therefore care should be taken to remove artificial organic matter from the sample, and that (b) this condition prevails in a real proposed CO<sub>2</sub>-storage site. This analysis thus has important implications for assessing the feasibility of long-term CO<sub>2</sub> storage and enabling large-scale industrial carbon geological storage projects." **Cut Aja Fauziah, Ahmed Z. Al-Yaseri, Nilesh Kumar Jha, Christopher Lagat, Hamid Roshan, Ahmed Barifcani, and Stefan Iglauer**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

## PUBLICATIONS *(cont.)*

### *Sustainable utilization and storage of carbon dioxide: Analysis and design of an innovative supply chain.*

The following is from the abstract of this article: "A mixed integer linear programming model is developed for the optimal design of carbon capture utilization and storage supply chain in Germany. A sensitivity analysis shows that for the optimal supply chain the total costs are 97.9 billion €/year with a NPV of 675 billion € and a PB of 2.71 years: the economic profitability is ensured only due to the use carbon tax. Also, 160 MtonCO<sub>2</sub> year are captured to produce methanol, concrete, wheat, lignin, polyurethane, calcium carbonate, urea and concrete by red mud. It is found that the selection of capture material/technology depends on CO<sub>2</sub> composition, flue gas flow rate and CO<sub>2</sub> final use. The high flow rate of flue gasses with a CO<sub>2</sub> composition between 13 mol% and 22 mol%, is most effectively captured by absorption technology. A Monte Carlo simulation is carried out to evaluate the uncertainties regarding the selling price and national demand of compounds." **Grazia Leonzio, Pier Ugo Foscolo, and Edwin Zondervan**, *Computers & Chemical Engineering*. (Subscription may be required.)

### *Zeolite and fly ash in the composition of oil well cement: Evaluation of degradation by CO<sub>2</sub> under geological storage condition.*

The following is from the abstract of this article: "The performance of cement class G used in cementation of oilfield wellbores with addition of pozzolans was evaluated under geological carbon storage conditions. Two commercial synthetic zeolites types (4A-1 and 4A-2) and fly ash from a coal-fired plant were used as pozzolanic materials in amounts of 5 and 10% in weight replacing the cement. After curing, the cement samples were submitted to degradation tests in CO<sub>2</sub>-saturated water at 15 MPa and 90°C for 7 and 14 days. The cement chemical degradation by CO<sub>2</sub> was investigated using scanning electron microscopy (SEM), X-ray diffraction (XRD) and compressive strength tests. The chemically altered layer thickness was averaged 3.46 mm for standard cement after 14 days of exposure to CO<sub>2</sub>. On the other hand, cement systems with 10% wt. of pozzolanic material varied from 1.70 to 5.50 mm depending on the type of pozzolan and level of cementitious matrix porosity related to pozzolanic particle clustering. In general, 4A-1 zeolite presented better performance in terms of resistance to CO<sub>2</sub> attack and higher compressive strength after 14 days when compared to 4A-2 zeolite. The results showed that the addition of fly ash improved the compressive strength of the samples but increased the chemically altered layer due to CO<sub>2</sub> diffusion. SEM and XRD analyses showed that the portlandite was consumed and carbonation occurred in the chemical modified layer due to cement reaction with aqueous CO<sub>2</sub>. Most cement systems with and without pozzolanic material exhibited no expressive loss on compressive strength after being exposed to CO<sub>2</sub>-rich environment up to 14 days. On the contrary, some cement systems with 4-A1 zeolite and fly ash exhibited a mechanical resistance increase due to the carbonation process."

**Roger Braun Ledesma, Natália Feijó Lopes, Katryanne Georg Bacca, Martimiano Krusciel de Moraes, Giovanni dos Santos Batista, Marçal Rodrigues Pires, and Eleani Maria da Costa**, *Journal of Petroleum Science and Engineering*. (Subscription may be required.)

## ABOUT DOE'S CARBON STORAGE PROGRAM

The **Carbon Storage Program** at the National Energy Technology Laboratory (NETL) is focused on developing and advancing technologies to enable safe, cost-effective, permanent geologic storage of CO<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](#).



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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### Get Social with Us

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



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