

## CSN

CARBON STORAGE  
NEWSLETTER

MAY 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:

- ▷ DOE/NETL HIGHLIGHTS
- ▷ ANNOUNCEMENTS
- ▷ PROJECT and BUSINESS DEVELOPMENTS
- ▷ LEGISLATION and POLICY
- ▷ EMISSIONS TRADING
- ▷ SCIENCE
- ▷ PUBLICATIONS

CARBON STORAGE PROGRAM  
DOCUMENTS and  
REFERENCE MATERIALS

- ▷ Carbon Storage Educational Resources
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- ▷ Conference Proceedings
- ▷ Carbon Storage Portfolio
- ▷ Systems Analysis
- ▷ Peer Review
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## DOE/NETL HIGHLIGHTS

***DOE Announces Funding to Enhance Safety, Security of CO<sub>2</sub> Storage.***

The U.S. Department of Energy (DOE) announced funding for four research and development (R&D) projects to enhance the safety and security of carbon dioxide (CO<sub>2</sub>) storage. The selected projects will look to address challenges related to long-term, commercial-scale storage of CO<sub>2</sub>, working to improve the tools to monitor the seal integrity of caprocks used in CO<sub>2</sub> storage complexes and identify and reduce the risk of potential seismic activity. The projects will be managed by DOE's Office of Fossil Energy and Carbon Management's (FECM) National Energy Technology Laboratory (NETL) and will support the goals of the *Advanced Storage R&D* technology development area in *DOE's Carbon Storage Program*. From *DOE's Office of Fossil Energy and Carbon Management*. May 2021.

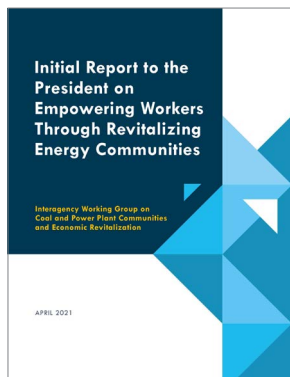
***DOE Announces Funding Focused on CCS for Power Generation.***

DOE's FECM announced federal funding for cost-shared R&D projects under a Funding Opportunity Announcement (FOA) titled "*Carbon Capture R&D for Natural Gas and Industrial Sources and Front-End Engineering Design Studies for Carbon Capture Systems at Industrial Facilities and Natural Gas Plants.*" The funding is focused on carbon capture and storage (CCS) for power generation and industrial applications, with a goal of commercial deployment by 2030. NETL will manage the projects, which will support *DOE's Carbon Capture Program*. From *DOE's Office of Fossil Energy and Carbon Management*. April 2021.

## ANNOUNCEMENTS

***NETL FY 2020 Science and Technology Accomplishment Book Available.***

NETL's FY 2020 Science & Technology Accomplishments book is available. These demonstrated accomplishments, which represent a selection of NETL researchers' achievements, characterize NETL's six Core Competencies: Computational Science and Engineering, Energy Conversion Engineering, Geological and Environmental Sciences, Materials Engineering and Manufacturing, Program Execution and Integration, and Systems Engineering and Analysis. The NETL research portfolio also includes R&D conducted through partnerships, cooperative R&D agreements, financial assistance, and contractual arrangements with universities, research organizations, the private sector, and other national laboratories.

***White House Report Outlines Revitalization in Coal, Power Plant Communities.***

The White House Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization *released a report of recommendations* to the President to catalyze robust economic activity and support workers in America's energy sector. NETL supported the drafting of the report for the *Interagency Working Group*, of which NETL Director Brian Anderson, Ph.D., has been *named Executive Director*. The Interagency Working Group was formed in response to President Biden's Executive Order 14008, "*Tackling the Climate Crisis at Home and Abroad.*"

## ANNOUNCEMENTS *(cont.)*

### *Project Tundra Informational Video Available.*

Minnkota Power Cooperative, with research support from the University of North Dakota's Energy and Environmental Research Center's (EERC), is implementing *Project Tundra*, which is a carbon capture, utilization, and storage (CCUS) retrofit project for Minnkota Power's Milton R. Young station located in North Dakota, USA. The project is in part funded by DOE's *Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative*, which builds on work done by the Regional Carbon Sequestration Partnerships (RCSPs) to fund and develop projects that focus on developing commercial-scale carbon storage complexes that will be ready for integrated CCUS system deployment in the 2025–2035 timeframe.



### *CO<sub>2</sub> Pipeline Guidance Published.*

DNV published guidance for transporting CO<sub>2</sub> via pipelines and strengthening the development of CCS projects. The procedures were published based on results from a joint industry project between Energy Pipelines CRC and DNV, which involved two large-scale CO<sub>2</sub> “crack arrest tests” to better understand CO<sub>2</sub> releases.



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### *Carbon and Ecosystems Services Portfolio Launched.*

Corteva Agriscience—an American agricultural chemical and seed company—created a “Carbon and Ecosystems Services” portfolio to help enable the development of carbon storage and ease access to carbon credits. In addition, the company created the 2021 Climate Positive Leaders Program, which is a nomination-based program to recognize those in the agricultural community who have successfully implemented “climate-positive” agricultural practices.



### *CCS Facility Reaches Milestone.*

SaskPower's Boundary Dam 3 CCS facility has captured and prevented 4 million metric tons of CO<sub>2</sub> from entering the atmosphere according to the International CCS Knowledge Centre. Experience gained through the design, construction, and operation of the facility has led to two studies—the *Shand CCS Feasibility Study* and the *Lehigh CCS Feasibility Study*.



SaskPower's Boundary Dam CCS facility.

### *Global CCS Institute Gets New Member.*

An energy commodity trader has joined the *Global CCS Institute*. Gunvor Group—whose main trading offices are located in Geneva, Singapore, Houston, and London—has shifted approximately half of its trading to “transitional commodities,” according to EU Taxonomy. One part of their Energy Transition strategy includes CCS. The Global CCS Institute's mission is to accelerate the deployment of CCS, and its international membership includes governments, global corporations, private companies, research bodies, and non-governmental organizations.



## PROJECT and BUSINESS DEVELOPMENTS

### *Company Focuses Artificial Intelligence on Characterizing Subsurface Stresses.*

Petrolern—a technology company working on subsurface solutions for carbon storage, geothermal, and oil and gas projects—will use a DOE grant to develop and commercialize artificial intelligence-based technology for estimating Earth stresses. A better understanding of the Earth's stress field at a project site can improve subsurface operations, such as enhanced oil recovery (EOR) and carbon storage. Petrolern's technology can also be used in geothermal energy applications and in both conventional and unconventional oil and gas resource development. From *Journal of Petroleum Technology*. April 2021.

### *Partnership to Develop Industrial CCS Pipeline System.*

Valero—a U.S.-based renewable fuel producer—joined a partnership to build an industrial-scale CO<sub>2</sub> pipeline system to support CCS in the Midwest United States. Teaming with BlackRock Global Energy & Power Infrastructure Fund and Navigator Energy Services, Valero will be an “anchor shipper” on the CCS pipeline system. The first phase is expected to have more than 1,200 miles of CO<sub>2</sub>-gathering pipelines across five Midwest states (Nebraska, Iowa, South Dakota, Minnesota, and Illinois) with the potential to store up to 5 million metric tons of CO<sub>2</sub> per year. Startup is planned in 2024. From *S&P Global*. March 2021.

### *LNG Company Proposes CCS Project.*



NextDecade Corp.—a U.S. liquefied natural gas (LNG) company—is looking to develop a CCS project at its proposed Rio Grande LNG export plant in Texas (USA). According to NextDecade, the CCS project would have the potential to reduce CO<sub>2</sub> emissions at Rio Grande by more than 90%. From *Reuters*. March 2021.

### *MOU to Explore Carbon Capture, Transport, and Storage Project.*

Baker Hughes and Horisont Energi signed a Memorandum of Understanding (MOU) for the Polaris carbon storage project in Norway. Under the MOU, the companies will explore the development and integration of technologies to minimize the cost and delivery time of carbon capture, transport, and storage. Horisont's Polaris offshore carbon storage project is part of its “*Barents Blue*” project, which has the potential to store more than 100 million tons of CO<sub>2</sub>. In addition, the companies will collaborate on new processes and technologies across the carbon capture, transport, and storage value chain. From *Horisont Energi Press Release*. March 2021.

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

### *Companies to Develop CCS Plant.*

Equinor and SSE announced they will develop two low-carbon United Kingdom (UK) power stations, one of which would be equipped with CCS technology. Under the cooperative agreement, Equinor—a Norwegian state-owned energy company—and SSE—an energy company headquartered in Scotland—will help support the UK's transition to net-zero. Keadby 3, the planned plant with CCS, would be a 900-megawatt (MW) power station fueled by natural gas and fitted with carbon capture technology; the captured CO<sub>2</sub> would be transported via pipeline for storage under the southern North Sea. From *S&P Global*. April 2021.

### *Testing Initiated at CO<sub>2</sub> Circulation Plant.*

DENSO began testing a demonstration facility designed to capture and recycle CO<sub>2</sub> at its Anjo Plant's Electrification Innovation Center. The *CO<sub>2</sub> circulation plant* is designed to capture CO<sub>2</sub> generated by the plant and recycle it as an energy source for the facility. From *After Market News*. April 2021.

## LEGISLATION and POLICY

### *Lawmakers Introduce Legislation to Plant Trees, Store CO<sub>2</sub>.*

A group of U.S. Senators and U.S. Representatives introduced the *Repairing Existing Public Land by Adding Necessary Trees Act (REPLANT Act)* in the U.S. Senate. The bill would help reforest 4.1 million acres by planting 1.2 billion trees over the next 10 years, which has the potential to store 758 million metric tons of CO<sub>2</sub> over the trees' lifetime. A summary of the bill is [available online](#). From *U.S. Senate Committee on Agriculture, Nutrition, and Forestry Press Release*. March 2021.

## EMISSIONS TRADING

### *RGGI States Initiate Auction Process for Auction 52.*



The states participating in the Regional Greenhouse Gas Initiative (RGGI) initiated the auction process for their 52nd quarterly CO<sub>2</sub> auction, scheduled for June 2, 2021. Auction 52 will offer 22,987,719 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*. April 2021.

### *RGGI Releases Compliance Report.*

The RGGI-participating states released the *Compliance Summary Report* for RGGI's fourth three-year control period (January 1, 2018–December 31, 2020). The report found that 198 of the 203 power plants (97.5%) subject to RGGI requirements met their compliance obligations. The RGGI program requires fossil fuel power plants 25 MWs or larger to purchase and hold one CO<sub>2</sub> allowance for each ton of CO<sub>2</sub> released during the control period. From *RGGI News Release*. April 2021.

### *Company Introduces CCUS Technology.*

A South Korea-based chemical company is using gas separation membranes to increase the purity of CO<sub>2</sub> and change it to industry materials. Lotte Chemical installed a demonstration facility in the southern industrial port of Yeosu, where they plan to operate a commercial facility by 2023. According to the company, the facility would capture more than 60,000 tons of CO<sub>2</sub> per year and use it to produce dry ice and semiconductor cleaning liquid. From *Aju Business Daily*. April 2021.

### *Large-Scale CCS Project Selects Technologies.*

Wabash Valley Resources selected a range of Honeywell UOP technologies to capture and store up to 1.65 million tons of CO<sub>2</sub> annually from a repurposed gasification plant in West Terre Haute, Indiana (USA). UOP will provide technology licenses, basic engineering, and specialty equipment to store CO<sub>2</sub> and process synthesis gas from the gasification unit. From *Oil & Gas 360*. April 2021.



### *Climate Bill Passes Washington State Senate.*

The Washington State Senate passed a bill that would institute a decreasing cap on CO<sub>2</sub> emissions. In addition, the *Climate Commitment Act (CCA)* would include investments in new infrastructure, transit, agriculture, forestry, and shipbuilding projects to spur job growth. CCA also includes provisions to prioritize historically overburdened communities, including the establishment of an Environmental Justice and Equity Advisory Panel. From *PR Newswire*. April 2021.

### *German Government Adopts Carbon Release Rules.*

The German government adopted a Carbon Leakage Ordinance aimed at providing relief for companies impacted by the German national carbon emissions trading system. Implemented in 2021, the German national carbon emissions trading system complements the European Union emissions trading system (EU ETS). While the EU ETS applies to large industrial facilities, Germany created a similar cap-and-trade system for the heating and transportation sectors. From *Lexology*. April 2021.

### *Companies to Sell Emissions Credits Under MOU.*

A U.S. Agricultural company and a Japanese trading house entered into an MOU to utilize agricultural land to store CO<sub>2</sub>. By using organic fertilizers and improving soil, Indigo Ag and Sumitomo Corp. will increase the amount of CO<sub>2</sub> that can be absorbed into the ground and then sell the amount that has been reduced from the atmosphere as an emissions allowance. Joint research will also be conducted on CO<sub>2</sub> storage in paddy fields. From *Nikkei Asia*. April 2021.

### *Carbon Trading Desk Launched.*

Trafigura—a global commodities trading firm—launched a carbon trading desk. The Geneva-based firm will be involved in voluntary offsets, as well as regulated carbon markets in the United States and the EU. From *Yahoo! Finance*. April 2021.



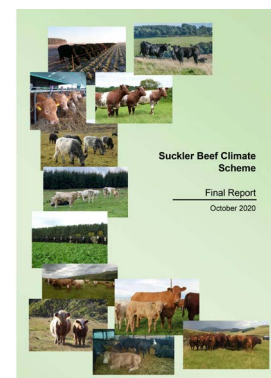
## SCIENCE

**Concrete Reduces CO<sub>2</sub> Emissions.**

A California (USA)-based company developed a process for injecting concrete with CO<sub>2</sub> emissions from power plants or other industrial facilities. CarbonBuilt Inc.'s approach uses hydrated lime as a base material for the manufacture of concrete, then injects the CO<sub>2</sub> emissions to cure the concrete into usable form. As a result, the CO<sub>2</sub> is stored in the concrete, reducing emissions from the concrete manufacturing process by 50 to 70%, according to the company. CarbonBuilt completed two pilot projects that demonstrated the technology and is one of several teams that qualified for the final round of the *XPrize competition*, which supports the development of technologies that convert CO<sub>2</sub> into usable products. From *Los Angeles Business Journal*. April 2021.

**Report: Carbon Storage Key to Net-Zero Farming.**

According to a report by the Scottish Suckler Beef Climate Change Group, the beef industry could play a major role in making farming a net-zero business by focusing on carbon storage practices. *The report* found that the Scottish Suckler-based beef industry has the potential to reduce greenhouse gas emissions by 24 to 39% by increasing soil carbon storage where possible. From *The Scottish Farmer*. April 2021.



## PUBLICATIONS

**A Review of International Field Experience with Well Integrity at Carbon Utilization and Storage Sites.**

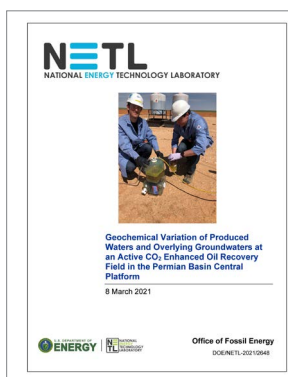
The following is the description of this DOE-funded report: "This report details findings from a survey of well integrity experiences elicited from operators of geologic carbon storage (GCS) and carbon dioxide enhanced oil recovery (CO<sub>2</sub>-EOR) sites around the world. The survey consisted of 41 questions organized in four sections and its goal was to obtain information about site characteristics and operator experiences with well integrity, monitoring methods, and risk assessment of legacy wells. Current literature relevant to the survey questions was also reviewed and summarized to provide context for survey responses and identify areas where field experiences with well integrity do and do not align with the current state of research."

**Carbon Capture, Utilization, and Storage Game Changers in Asia: 2020 Compendium of Technologies and Enablers.**

The following is from the Overview of this Asian Development Bank publication: "This compendium deals with four interesting carbon dioxide capture technologies, five carbon dioxide utilization technologies, one utilization storage technology, and one enabler concept. The technologies presented are in various stages, ranging from research and development to commercial deployment. The enabler concept introduced in this compendium is an initiative to accelerate collaboration and deployment of CCUS. The technologies and enablers included in this compendium were furnished by CCUS technology providers and enablers through their responses to an e-mail questionnaire prepared by the consultant team of the Asian Development Bank (ADB) through regional technical assistance, Integrated High Impact Innovation in Sustainable Energy Technology (Subproject 2): Prefeasibility Analysis for Carbon Capture, Utilization, and Storage. ADB would like to clarify that the compendium is not exhaustive. Other ideas are available and may also be added to this but—because of time constraints—they are not added here. ADB looks forward to other opportunities to add to this collection of ideas on CCUS, which could help ADB developing member countries achieve low-carbon growth." (Purchase may be required.)

**Geochemical Variation of Produced Waters and Overlying Groundwaters at an Active CO<sub>2</sub> Enhanced Oil Recovery Field in the Permian Basin Central Platform.**

The following is a description of this DOE-funded report: "This report discusses the results of baseline geochemical data from a carbon dioxide (CO<sub>2</sub>) enhanced oil recovery (EOR) field in the Permian Basin's Central Basin Platform. This report focuses on understanding the variability in geochemistry during normal oil field practices, including the transition from water flooding to a water-alternating-gas (WAG) technique. The primary objectives of this study were to focus on 1) determining the best general geochemical parameters to identify produced water intrusion into overlying groundwaters, 2) observing if there was any intrusion during the sampling period, and 3) identifying changes in produced water following CO<sub>2</sub> injection."

**Carbon Capture and Storage Market to Make Great Impact in Forecast Period 2021-2026.**

The following is from a description of this document: "This study is a perfect blend of qualitative and quantifiable information highlighting key market developments, industry and competitors' challenges in gap analysis, and new opportunities and maybe trending in the Global Carbon Capture and Storage Market. This report encloses a comprehensive analysis of the market and is assessed through volume and value data validated on approaches including top companies' revenues. It concludes with precise and authentic market estimations considering all the parameters and market dynamics. Every crucial and decisive detail for the development and restriction of the market is mentioned in fine points with solutions and suggestions that may affect the market in near future. Segmentation of the market is studied specifically to give profound knowledge for supplementary market investments. Competition intensity of the global Carbon Capture and Storage Market is also an integral report section that allows readers and manufacturers to gauge into the stiffening competition augmented by novice entrants, besides other versatile market veterans peaking competition with their unique business delivery models, growth strategies, regional investments, as well as technological milestones and pipeline projects. All profiled market participants have been subject to tremendous assessment based on advanced evaluation techniques, aligning with the report objective of the unbiased evaluation... Global Carbon Capture and Storage market also specifically underpins end-use application scope and their improvements based on technological developments and consumer preferences." (Purchase may be required.)

## PUBLICATIONS (cont.)

### *Evaluation of multiple time carbon capture and storage network with capital-carbon trade-off.*

The following is from the abstract of this article: "The carbon dioxide emission from the industrial sector and the power plant contribute significantly to global climate change for several decades. The carbon capture and storage technology is the primary solution to reach the reduction target of carbon dioxide emissions. The carbon capture and storage activities involve CO<sub>2</sub> capturing, transporting, and storing in geological storage, requires number planning. The process integration approach by pinch analysis method can be used for the carbon capture and storage planning problem and to develop the carbon capture and storage network design. However, the applicability of the method needs to be evaluated when some constraints in carbon capture and storage network design are applied. This paper proposes an improved pinch analysis based method for carbon capture and storage target and network design. The method begins with targeting the maximum carbon exchange in the carbon capture and storage system, which is followed by designing the carbon capture and storage network. Next, the capital-carbon trade-off is introduced as a new strategy for assessing carbon capture and storage network design to show the economic feasibility of the design. Four case studies demonstrate the applicability of the proposed method to the carbon capture and storage systems in the central and western part of Indonesia. The application of this new strategy in the western part of Indonesia as a single region system revealed that the flat minimum of the total annual cost is obtained at a five year time difference with the amount of up to US\$ 149.3 million." **Annasit Mualim, Hairul Huda, Ali Altway, Juwari Purwo Sutikno, and Renanto Handogo**, *Journal of Cleaner Production*. (Subscription may be required.)

### *The effects of renewable energy, spatial spillover of CO<sub>2</sub> emissions and economic freedom on CO<sub>2</sub> emissions in the EU.*

The following is from the abstract of this article: "Renewable energy is a variable influencing CO<sub>2</sub> emission. Previous studies investigated its effects on CO<sub>2</sub> emission in the European Union (EU) countries using classical econometrics method. However, if there was a spatial dependence between CO<sub>2</sub> emissions of the EU countries, the results of previous studies may have been biased. Another gap in the literature is nonlinear effects of economic freedom on CO<sub>2</sub> emissions. To fill these gaps, the present study explored the aforementioned issues in the framework of environmental Kuznets curve in the EU countries for period 2000 to 2017 using a spatial dynamic panel data model. The results showed that the renewable energy consumption had a negative effect on CO<sub>2</sub> emissions, and the relationship between economic freedom and CO<sub>2</sub> emissions was U-shaped. Finally, a significant positive spatial lag coefficient was found for CO<sub>2</sub> emissions, indicating that the CO<sub>2</sub> emissions of a country were positively correlated with those of its neighbors." **Rouhollah Shahnazi and Zahra Dehghan Shabani**, *Renewable Energy*. (Subscription may be required.)

### *Effect of nanofluid on CO<sub>2</sub>-wettability reversal of sandstone formation; implications for CO<sub>2</sub> geo-storage.*

The following is from the abstract of this article: "Hypothesis—Nanofluid treatment is a promising technique which can be used for wettability reversal of CO<sub>2</sub>-brine-mineral systems towards a further favourable less CO<sub>2</sub>-wet state in the existence of organic acids. However, literature requires more information and study with respect to organic acids and nanoparticles' effect at reservoir (high pressure and high temperature) conditions. Experiments—Therefore, [the authors] have measured in this study that what influence small amounts of organic acids exposed to quartz for aging time of (7 days and 1 year) have on their wettability and how this impact can be reduced by using different concentrations of nanoparticles at reservoir conditions. Precisely, [the authors] have tested lignoceric acid (C<sub>24</sub>), stearic acid (C<sub>18</sub>), lauric acid (C<sub>12</sub>) and hexanoic acid (C<sub>6</sub>) at 10<sup>-2</sup> Molarity, as well as, [the authors] have also used different concentrations (0.75 wt%, 0.25 wt%, 0.1 wt%, 0.05 wt%) of silica nanoparticles at realistic storage conditions. Findings—The quartz surface turned significantly hydrophobic when exposed to organic acids for longer aging time of 1 year, and significantly hydrophilic after nanofluid treatment at

optimum concentration of 0.1 wt%. It was observed that most nanoparticles were mechanically irreversibly adsorbed on the surface of quartz sample. This wettability shift thus may increase CO<sub>2</sub> storage capacities and containment security." **Muhammad Ali, Muhammad Faraz Sahito, Nilesh Kumar Jha, Zain-Ul-Abedin Arain, Shoaib Memon, Alireza Keshavarz, Stefan Iglauer, Ali Saeedi, and Mohammad Sarmadivaleh**, *Journal of Colloid and Interface Science*. (Subscription may be required.)

### *Life cycle environmental impact assessment of coupled underground coal gasification and CO<sub>2</sub> capture and storage: Alternative end uses for the UCG product gases.*

The following is from the abstract of this article: "Underground coal gasification (UCG) has the potential to provide a source of energy or chemical feedstock derived from coal seams, where traditional mining methods are not suitable or are uneconomical. This paper presents the life cycle inventory models developed for the UCG processes and three alternative syngas utilisation options with and without CO<sub>2</sub> capture and storage. The paper compares the life cycle carbon footprint of two different conventional above ground coal fired power generation options with UCG Integrated Gasification Combined Cycle power generation with/without CCS for two different lignites and one bituminous coal. One of the lignites is then used to compare the life cycle performance of different syngas utilisation options: power generation, ammonia production with power generation, and methanol production with power generation. It was found that the life cycle carbon footprint of conventional above ground coal fired power generation is very much dependent on the in-situ methane content of the coal used, and methane emissions experienced during mining and accompanying upstream processes, whereas the same for UCG-IGCC power depends more on the process dependent syngas composition. UCG methanol production with associated power and CCS is shown to release more life cycle CO<sub>2</sub>-eq emissions per tonne of lignite consumed than that of UCG ammonia production with associated power and CCS and UCG CCGT power generation with CCS. Furthermore, when chemicals production from UCG is considered as the main objective, the most substantial improvements in comparison to conventional methods are associated with UCG ammonia process per tonne of chemical produced." **Anna Korre, Sevket Durucan, and Zhenggang Nie**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)

### *The impact of the global stock and energy market on EU ETS: A structural equation modelling approach.*

The following is from the abstract of this article: "The industrial revolution has brought about great development in the economy, but it has also increased the dependence on fossil energy. The emissions of CO<sub>2</sub> and other greenhouse gases have contradicted economic development and the ecological environment. The establishment of the EU Emission Trading System (EU ETS) has improved the global carbon emission price mechanism, but as a new commodity, its price trend will affect buyers' risk evaluation. Therefore, it is influential to master the driving factors behind carbon emission prices and make effective predictions. First, the paper points out that the driving factors are divided into macroeconomic risk factors and energy factors. Second, the Bayesian Network is used to select variables and make prediction of carbon prices. The results show that its accuracy exceeds other machine learning algorithms. Third, a structural equation model is used to study the impact of the selected markets on the carbon market. Finally, from the perspective of global carbon emission reduction, the relationship between driving factors and the carbon futures market is explained. The empirical results show that Cotation Assistée en Continu 40, natural gas and Brent crude oil will directly affect the yield of European Union Allowances and Certified Emission Reduction futures, and the Standard Poor 500 and Global Clean Energy Index will indirectly affect the yield of European Union Allowances and Certified Emission Reduction futures. The energy market will affect the carbon market through the intermediary effect of the stock market, in which the clean energy index is the most relevant factor. From the perspective of how to improve the carbon trading system, this paper proposes suggestions for the sustainable development of the world to promote the virtuous cycle of the global carbon emission market and the high-quality development of the global economy." **Zi-Jie Wang and Lu-Tao Zhao**, *Journal*

of Cleaner Production. (Subscription may be required.)

## PUBLICATIONS *(cont.)*

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### *Structural controls on the location and distribution of CO<sub>2</sub> emission at a natural CO<sub>2</sub> spring in Daylesford, Australia.*

The following is from the abstract of this article: “Secure storage of CO<sub>2</sub> is imperative for carbon capture and storage technology, and relies on a thorough understanding of the mechanisms of CO<sub>2</sub> retention and leakage. Observations at CO<sub>2</sub> seeps around the world find that geological structures at a local and regional scale control the location, distribution and style of CO<sub>2</sub> emission. Bedrock-hosted natural CO<sub>2</sub> seepage is found in the Daylesford region in Victoria, Australia, where many natural springs contain high concentrations of dissolved CO<sub>2</sub>. Within a few meters of the natural Tipperary Mineral Spring, small CO<sub>2</sub> bubble streams are emitted from bedrock into an ephemeral creek. [The authors] examine the relationship between structures in the exposed adjacent outcropping rocks and characteristics of CO<sub>2</sub> gas leakage in the stream, including CO<sub>2</sub> flux and the distribution of gas emissions. [The authors] find that degassing is clustered within ~1 m of a shale-sandstone geological contact. CO<sub>2</sub> emission points are localised along bedding and fracture planes, and concentrated where these features intersect. The bubble streams were intermittent, which posed difficulties in quantifying total emitted CO<sub>2</sub>.

Counterintuitively, the number of bubble streams and CO<sub>2</sub> flux was greatest from shale dominated rather than the sandstone dominated features, which forms the regional aquifer. Shallow processes must be increasing the shale permeability, thus influencing the CO<sub>2</sub> flow pathway and emission locations. CO<sub>2</sub> seepage is not limited to the pool; leakage was detected in subaerial rock exposures, at the intersection of bedding and orthogonal fractures. These insights show the range of spatial scales of the geological features that control CO<sub>2</sub> flow. Microscale features and near surface processes can have significant effect on the style and location and rates of CO<sub>2</sub> leakage. The intermittency of the bubble streams highlights challenges around characterising and monitoring CO<sub>2</sub> stores where seepage is spatially and temporally variable. CCS monitoring programmes must therefore be informed by understanding of shallow crustal processes and not simply the processes and pathways governing CO<sub>2</sub> fluid flow at depth. Understanding how the CO<sub>2</sub> fluids leaked by deep pathways might be affected by shallow processes will inform the design of appropriate monitoring tools and monitoring locations.” **Jennifer J. Roberts, Aero Leplastrier, Andrew J. Feitz, Zoe K. Shipton, Andrew F. Bell, and Rūta Karolytė**, *International Journal of Greenhouse Gas Control*. (Subscription may be required.)



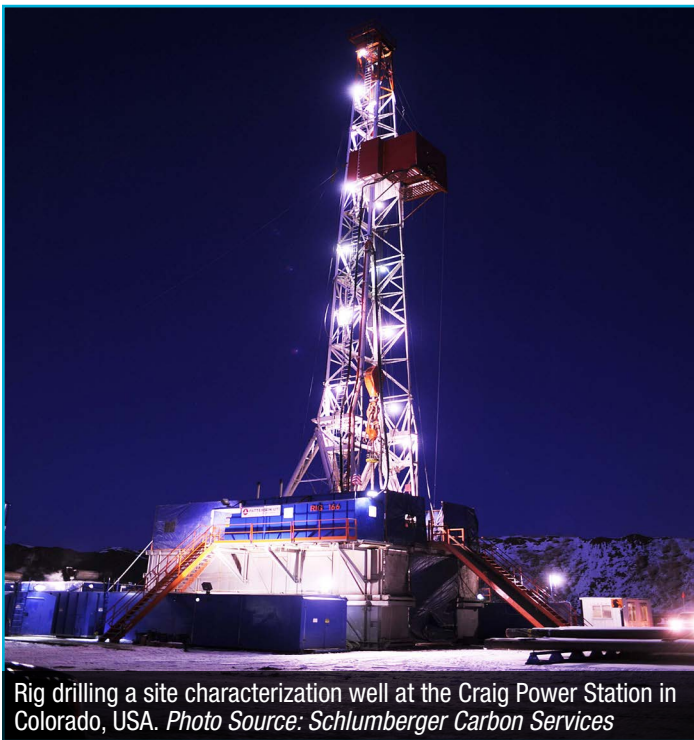
## ABOUT DOE'S CARBON STORAGE PROGRAM

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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