# CSN

# CARBON STORAGE NEWSLETTER

## MARCH 2019

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

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▷ REPORTS and OTHER PUBLICATIONS

### CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

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▷ Program Reports, Plans, and Roadmaps

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## NATIONAL ENERGY TECHNOLOGY LABORATORY

## DOE/NETL HIGHLIGHTS

### Eight Projects Selected to Receive Federal Funding.

Eight projects have been selected to receive federal funding for cost-shared research and development (R&D) for "Novel and Enabling Carbon Capture Transformational Technologies." The scope of the projects aligns with the U.S. Department of Energy's (DOE) ministerial-level Mission Innovation report, titled "*Accelerating Breakthrough Innovation in Carbon Capture, Utilization, and Storage.*" The projects are funded by the Office of Fossil Energy's (FE) *Carbon Capture Program* and will be managed by the National Energy Technology Laboratory (NETL). From *energy.gov* on February 28, 2019.

## ANNOUNCEMENTS

### NETL Director Delivers Lecture.

NETL Director Brian Anderson, Ph.D., gave an in-depth description of NETL's fossil energy research priorities, activities, and capabilities at the 2019 Carnegie Mellon University Wilton E. Scott Institute for Energy Innovation Distinguished Lecture Series in Pittsburgh, Pennsylvania (USA). Highlighted NETL fossil energy priorities included reducing the cost of carbon capture, utilization, and storage (CCUS).



Dr. Brian Anderson

### DOE's Office of Science Graduate Student Research Program Accepting Applications.

DOE's Office of Science Graduate Student Research (SCGSR) Program is now accepting applications for the 2019 Solicitation. The SCSGR Program provides supplemental awards to U.S. graduate students to pursue part of their graduate thesis research at a DOE laboratory/facility. *Priority Research Areas for 2019 Solicitation 1* include Biological and Environmental Research (BER), which contains improving carbon storage capabilities. Applications are due May 9, 2019.

### $CO_2$ Storage ISO Standard Published.

The first edition of an International Organization for Standardization (ISO) standard that applies to quantifying and documenting the total carbon dioxide ($CO_2$) stored in association with $CO_2$ enhanced oil recovery (EOR) was published. Members of NETL's Regional Carbon Sequestration Partnership Initiative participated in the ISO working group that drafted ISO-27916, which is titled "Carbon dioxide capture, transportation and geological storage – Carbon dioxide storage using enhanced oil recovery ($CO_2$-EOR)."

## ANNOUNCEMENTS *(cont.)*

### RGGI States Submit Comments on Re-Proposed Virginia Regulation.

The U.S. states participating in the Regional Greenhouse Gas Initiative (RGGI) *submitted comments* to Virginia regarding the state's re-proposed regulation with the existing RGGI 2017 Model Rule.

**RGGI Inc.**

### RGGI Releases Two Reports.

The independent market monitor for RGGI released a report containing information on the secondary market for RGGI $CO_2$ allowances, including future prices, market activity, and allowance holdings. Potomac Economics' "*Report on the Secondary Market for RGGI $CO_2$ Allowances: Fourth Quarter 2018*" addresses the period from October through December 2018. In addition, RGGI also made available the "*2018 Interim Compliance Summary Report*," which contains data regarding $CO_2$ allowances provided by $CO_2$ budget sources to meet their 2018 interim control period compliance obligation. RGGI's fourth three-year control period took effect on January 1, 2018, and extends through December 31, 2020.

### Advisory Council Updates Analysis on CCS Policy.

The European Academies' Science Advisory Council *released a statement* updating their previous analysis on the role of bioenergy with carbon capture and storage (BECCS). The new analysis factors in recent peer-reviewed papers and international reviews.

**European Academies**
**easac**
**Science Advisory Council**

## PROJECT and BUSINESS DEVELOPMENTS

### DOE Research Grant Awarded for $CO_2$ Storage Monitoring.

As part of a new project awarded by DOE, GroundMetrics Inc. will use proprietary sensor systems and machine learning to monitor $CO_2$ in the subsurface. In partnership with DOE, Lawrence Berkeley National Laboratory (LBNL), and Expero Inc., GroundMetrics will develop a continuous monitoring system to measure resistivity changes in the subsurface, enabling $CO_2$ saturation to be monitored and providing insight into how the $CO_2$ is distributed underground. From *Business Insider* on February 21, 2019.

### CCS Project Publishes Findings.

The ACT Acorn project announced findings of its research into the feasibility of establishing a carbon capture and storage (CCS) facility in the North Sea. Geologists involved in the international research project analyzed sandstone and caprock samples at two potential storage sites in the North Sea to determine if they were suitable for the injection and long-term storage of $CO_2$. The *key findings from the ACT Acorn project* evaluated the potential value of the United Kingdom's (U.K.) existing North Sea oil and gas transport infrastructure coupled with a natural $CO_2$ geologic storage resource. From *Phys.Org* on February 20, 2019.

### BECCS Pilot Plant Operations Underway.

The BECCS demonstration plant at Drax Power Station, near Shelby in North Yorkshire, U.K., has begun operations to capture one metric ton of $CO_2$ per day. Data being obtained during the pilot will be analyzed to understand the utilized technology's potential to be scaled-up and to identify and develop methods to store the captured $CO_2$. From *Drax Press Release* on February 7, 2019.

### Project Looks to Store $CO_2$ in Salt Caverns.

Research conducted at the Research Center for Gas Innovation (RCGI) has shown the potential to store $CO_2$ in salt caverns. According to RCGI, an Engineering Research Center (ERC) funded by São Paulo (Brazil) Research Foundation, the first "pilot cavern" may be ready by 2022. The site of the pilot has not yet been determined. From *Phys.Org* on February 14, 2019.

**Research Centre for Gas Innovation**

## LEGISLATION and POLICY

### Bill to Support CCS Introduced in US Senate.

A bill that would address a tax credit to better support CCS for coal power plants was introduced in the U.S. Senate. The "*Carbon Capture Modernization Act*" updates the tax credit system for coal producers and incentivizes the usage of modern technology for underground $CO_2$ storage. From *U.S. Senator Tina Smith Press Release* on February 11, 2019.

### South African Parliament Approves Carbon Tax Bill.

South Africa's parliament approved a carbon tax bill that establishes a state tax of 120 rand (approximately $8.50) per metric ton of carbon dioxide equivalent ($CO_2$e). South Africa pledged to reduce $CO_2$ emissions by almost half by 2030. From *Nasdaq.com* on February 19, 2019.

## EMISSIONS TRADING

### California's New Underground Injection Rules to go into Effect.

California's (USA) underground injection requirements will go into effect on April 1, 2019. According to the states' Department of Conservation, approximately 55,000 underground injection control wells will be affected under the new regulations, elements of which include (but are not limited to) testing requirements to identify potential leaks, continuous well-pressure monitoring, and monitoring for seismic activity. From *Oil & Gas Journal* on February 21, 2019.

### UK Working on Carbon Trading System.

The U.K. is working to establish a domestic carbon emissions trading system (ETS). According to the energy minister, the U.K. will look to link to the existing European Union (EU) ETS beginning in January 2021. The U.K. government plans to launch a consultation on its plans in April 2019. From *Reuters* on February 27, 2019.

# SCIENCE NEWS

### Seismic Waves Reveal CO₂ Storage Plume in NETL-Supported Research.

Researchers from Penn State University and LBNL are using seismic waves to track $CO_2$ plumes underground. Supported by NETL, the research found that coda waves, which come after P and S waves following an earthquake or explosion, have the potential to reveal where $CO_2$ is stored underground. Researchers believe that using permanent seismic sources and coda wave analysis will enable more frequent monitoring than the current standard of intervals. From *Penn State University News* on February 26, 2019.

### Scientists Study Long-Term Storage Capability of Peatlands.

An international group of scientists conducted a study of global peatland and carbon storage over the last 130,000 years to gauge peatlands' effectiveness as a long-term carbon storage mechanism over a long timescale. Peatlands, which are a type of wetland formed by incompletely decomposed organic matter and water, comprise approximately three percent of the Earth's land area, but contain approximately one-third of the global soil carbon, according to the study. From *EurekAlert!* on February 25, 2019.

# JOURNAL ARTICLES

### Carbon sequestration in biogenic magnesite and other magnesium carbonate minerals.

The following is the Abstract of this article: "The stability and longevity of carbonate minerals make them an ideal sink for surplus atmospheric [$CO_2$]. Biogenic magnesium carbonate mineral precipitation from the magnesium-rich tailings generated by many mining operations could offset net mining greenhouse gas emissions, while simultaneously giving value to mine waste products. In this investigation, cyanobacteria in a wetland bioreactor enabled the precipitation of magnesite ($MgCO_3$), hydromagnesite [$Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$], and dypingite [$Mg_5(CO_3)_4(OH)_2 \cdot 5H_2O$] from a synthetic wastewater comparable in chemistry to what is produced by acid leaching of ultramafic mine tailings. These precipitates occurred as micrometer-scale mineral grains and microcrystalline carbonate coatings that entombed filamentous cyanobacteria. This provides the first laboratory demonstration of low temperature, biogenic magnesite precipitation for carbon sequestration purposes. These findings demonstrate the importance of extracellular polymeric substances in microbially enabled carbonate mineral nucleation. Fluid composition was monitored to determine carbon sequestration rates. The results demonstrate that up to 238 t of $CO_2$ could be stored per hectare of wetland/year if this method of [$CO_2$] sequestration was implemented at an ultramafic mine tailing storage facility. The abundance of tailings available for carbonation and the anticipated global implementation of carbon pricing make this method of mineral carbonation worth further investigation." Jenine McCutcheon, Ian M. Power, Jeremiah Shuster, Anna Lee Harrison, Gregory Dipple, and Gordon Southam, *Environmental Science & Technology*. (Subscription may be required.)

### Integrated assessment for solar-assisted carbon capture and storage power plant by adopting resilience thinking on energy system.

The following is the Abstract of this article: "Integrating solar-thermal energy into the power plant with post-combustion [CCS] can reduce the energy penalty derived from solvent regeneration. However, few metrics exist to evaluate the trade-off associated with technic, economic and ecological perspectives for different integration schemes of the three subsystems, namely the solar field, power plant and carbon capture system. This paper analysis five configurations of coal-fired power plant with and without solar field as well as CCS technology based on the resilience concept. Still at the budding stage, the status of resilience definitions and evaluation methods related to energy system is reviewed. The resilience level for five configurations of coal-fired power plant both with and without solar-field, together with the CCS system is measured, which takes into consideration five critical characteristics towards resilience: fossil fuel depletion potential (CADP), global warming potential (GWP), levelized cost of energy (LCOE), solar to electricity fraction and spare capacity. Results indicate that among all the configurations, the solar-assisted power generation CCS power plant with 90% capture rate shows the highest resilience level. However, the scheme which utilizes solar energy to assisted solvent regeneration, shows limited advantage in terms of resilience level due to high CADP and LCOE." Junyao Wang, Jun Zhao, Shuai Deng, Taiwei Sun, Yanping Du, Kaixiang Li, and Yaofeng Xu, *Journal of Cleaner Production*. (Subscription may be required.)

### Retrofitting carbon capture and storage to natural gas-fired power plants: A real-options approach.

The following is the Abstract of this article: "This paper presents a real-options approach to assess the value of retrofitting [CCS] technology to an existing natural gas-fired base-load power plant. Operating in a deregulated electricity market, a power plant owner seeks to decide whether to retrofit and at what techno-economic conditions to retrofit [CCS]. The value of the plant is determined based on clean spark spread options. Two alternative [CCS] technologies, post-combustion and oxy-fuel combustion, are evaluated. Price uncertainties of electricity and natural gas are modeled as mean-reverting processes. The plant is abided by the emission reduction policy of carbon tax or price. Results show that a plant owner would opt for retrofitting post-combustion technology to an existing power plant if the carbon price hits to at least 140 dollars per ton of [$CO_2$], and would select oxy-fuel combustion technology if the carbon price moves further to 185 dollars per ton of [$CO_2$] or above. Since parameters of [CCS] vary widely across the literature, sensitivity tests of the expected values to different costs, prices, and volatility parameters are also presented for an insightful comparative view of which [CCS] technology to adopt at what techno-economic conditions." R.S. Elias, M.I.M. Wahab, and L. Fang, *Journal of Cleaner Production*. (Subscription may be required.)

### Carbon dioxide sequestration and methane production promotion by wollastonite in sludge anaerobic digestion.

The following is the Abstract of this article: "This study investigated the feasibility and performance of simultaneous in-situ $CO_2$ sequestration and [methane ($CH_4$)] production promotion by wollastonite addition in sludge AD. A maximum $CH_4$ yield increment of 30.8% and maximum methane production rate increment of 64.9% with wollastonite addition at dosage of 16.25 g/L were achieved. $CO_2$ was efficient sequestered by wollastonite addition and resulted in a higher $CH_4$ content of 81.7%–82.4%. The mechanism of $CO_2$ sequestration by wollastonite was confirmed as $Ca^{2+}$ release and subsequently carbonation based on cation and precipitates analysis. The results demonstrated that wollastonite could be applied as an effective additive for simultaneous in-situ $CO_2$ sequestration and $CH_4$ production promotion of sludge AD." Yan Zhang, Lihui Zhang, He Liu, Linlin Gong, Qianqian Jiang, Hongbo Liu, and Bo Fu, *Bioresource Technology*. (Subscription may be required.)

## JOURNAL ARTICLES *(cont.)*

### *Geologic $CO_2$ sequestration monitoring design: A machine learning and uncertainty quantification based approach.*

The following is the Abstract of this article: "Monitoring is a crucial aspect of geologic $CO_2$ sequestration risk management. Effective monitoring is critical to ensure $CO_2$ is safely and permanently stored throughout the life-cycle of a geologic $CO_2$ sequestration project. Effective monitoring involves deciding: (i) where is the optimal location to place the monitoring well(s), and (ii) what type of data (pressure, temperature, $CO_2$ saturation, etc.) should be measured taking into consideration the uncertainties at geologic sequestration sites. [The authors] have developed a filtering-based data assimilation procedure to design effective monitoring approaches. To reduce the computational cost of the filtering-based data assimilation process, a machine-learning algorithm: Multivariate Adaptive Regression Splines is used to derive computationally efficient reduced order models from results of full-physics numerical simulations of $CO_2$ injection in saline aquifer and subsequent multi-phase fluid flow. [The authors] use example scenarios of $CO_2$ leakage through legacy wellbore and demonstrate a monitoring strategy can be selected with the aim of reducing uncertainty in metrics related to $CO_2$ leakage. [The authors] demonstrate the proposed framework with two synthetic examples: a simple validation case and a more complicated case including multiple monitoring wells. The examples demonstrate that the proposed approach can be effective in developing monitoring approaches that take into consideration uncertainties." Bailian Chen, Dylan R. Harp, Youzuo Lin, Elizabeth H. Keating, and Rajesh J. Pawar, *Applied Energy*. (Subscription may be required.)

### *Effects of $N_2$ and $H_2S$ binary impurities on $CO_2$ geological storage in stratified formation – A sensitivity study.*

The following is the Abstract of this article: "Impurities are unavoidable during $CO_2$ geological storage, and they would potentially affect the plume spread as well as storage capacity and/or efficiency of $CO_2$. The current study numerically investigated the effects of binary impurities comprising typical components [nitrogen ($N_2$)] and [hydrogen sulfide ($H_2S$)] on $CO_2$ geological storage in stratified formations. For a fixed total content of the binary impurities, increasing ratio of $N_2/H_2S$ resulted in larger plume spread which meant a higher dissolution trapping efficiency. Because of the backflow of formation brine during the post-injection period, the residual trapping efficiency decreased while the dissolution trapping efficiency increased. This tendency was reinforced with increasing ratio of $N_2/H_2S$. Besides, this work examined the effects of the ratio of vertical permeability (*kv*) to horizontal permeability (*kh*) and the addition of an injection point in the stratified formation. It was found that lower *kv/kh* shrunk the plume spread and intensified the maximum pressure build-up. However, in the case of two injection points, the plume in the vertical direction was elongated and the maximum pressure build-up was lessened. The results should be taken into consideration to determine the types and concentrations of impurities allowed in the injected $CO_2$ stream as well as the site selection and injection design for impure $CO_2$ geological storage in stratified formation." Didi Li, Hongcheng Zhang, Yang Li, Wenbin Xu, and Xi Jiang, *Applied Energy*. (Subscription may be required.)

### *Drivers of tree carbon storage in subtropical forests.*

The following is the Abstract of this document: "Tropical and subtropical forest ecosystems play an important role in the global carbon regulation. Despite increasing evidence for effects of biodiversity (species diversity, functional diversity and functional dominance), stand structural attributes, stand age and environmental conditions (climate and topography) on tree carbon storage, the relative importance of these drivers at large scale is poorly understood. It is also still unclear whether biodiversity effects on tree carbon storage work through niche complementarity (i.e. increased tree carbon storage due to interspecific resource partitioning) or through the mass-ratio effect (tree carbon storage regulated by dominant traits within communities). Here [the authors] analyze tree carbon storage and its drivers using data of 480 plots sampled across subtropical forests in China. [The authors] use multiple regression models to test the relative effects of biodiversity, stand structural attributes, stand age and environmental conditions on tree carbon storage, and use a partial least squares path model to test how these variables directly and/or indirectly affect tree carbon storage. [The authors'] results show that tree carbon storage is most strongly affected by stand age, followed by climate, biodiversity and stand structural attributes. Stand age and climate had both direct and indirect (through species diversity, functional dominance and stand structural attributes) effects. [The authors] find that tree carbon storage correlates with both species diversity and functional dominance after stand age and environmental drivers are accounted for. [The authors'] results suggest that niche complementarity and the mass-ratio effect, not necessarily mutually exclusive, both play a role in maintaining ecosystem functioning. [The authors'] results further indicate that biodiversity conservation might be an effective way for enhancing tree carbon storage in natural, species-rich forest ecosystems." Yin Li, Weikai Bao, Frans Bongers, Bin Chen, Guoke Chen, Ke Guo, Mingxi Jiang, Jiangshan Lai, Dunmei Lin, Chunjiang Liu, Xiaojuan Liu, Yi Liu, Xiangcheng Mi, Xingjun Tian, Xihua Wang, Wubing Xu, Junhua Yan, Bo Yang, Yuanrun Zheng, and Keping Ma, *Science of The Total Environment*. (Subscription may be required.)

### *Full-infinite interval two-stage credibility constrained programming for electric power system management by considering carbon emission trading.*

The following is the Abstract of this article: "In this study, a full-infinite interval two-stage credibility constrained programming (FITCP) method is developed for optimizing electric power system (EPS) by considering $CO_2$ mitigation and air pollutant emission control. Through integrating full-infinite programming (FIP), interval two-stage programming (ITSP) and credibility constrained programming (CCP) within a general framework, the developed FITCP method can tackle multiple uncertainties in terms of interval values (both crisp and functional interval values), probabilistic and possibilistic distributions. Then, a FITCP-based electric power system (FITCP-EPS) model has been formulated for EPS planning where carbon emission trading (CET) scheme and air pollutant emission limitation are introduced to cope with the problem of carbon and air pollutant mitigation. Scenarios in response to diverse carbon mitigation levels, different trading schemes and different environmental policies are generated. Moreover, sensitive analysis and value of information analysis are conducted to help decision makers to have a clear view of the effects of data variation and uncertainty data collection. Results reveal that (i) CET scheme can bring more economic benefits for power plants especially when mitigation level is high; (ii) whether the CET is carried out or not, a corresponding construction of [CCS] infrastructure should be implemented to achieve the mitigation target; (iii) the expected system benefit would increase [0, 2.17] % by resolving the uncertainty of $CO_2$ emission levels. The results also indicate that FITCP-EPS model can not only provide an effective linkage between the pre-regulated generation targets and environmental policies, but also generate more decision options under different credibility levels and $CO_2$ emission levels, which are useful for helping decision makers to make appropriate generation targets, plan electricity generation mix, as well as gain in-depth insight into the effects of carbon emission trading and pollutant control on EPS." J.W. Gong, Y.P. Li, and C. Suo, *International Journal of Electrical Power & Energy Systems*. (Subscription may be required).

## REPORTS and OTHER PUBLICATIONS

### DOE/NETL Capture Program R&D: Compendium of Carbon Capture Technology.

The following is from the Overview of this DOE/NETL document: "The DOE Fossil Energy Program has adopted a comprehensive, multi-pronged approach to the research and development (R&D) of advanced $CO_2$ capture technologies for today's coal power platforms as well as for future platforms. NETL is implementing the Carbon Capture R&D program to develop the next generation of advanced $CO_2$ capture concepts. The success of this research will enable cost-effective implementation of CCS technologies throughout the power generation sector and ensure the United States will continue to have access to safe, reliable, and affordable energy from fossil fuels. DOE's CCS R&D effort is conducted as part of the CCS and Power Systems program under the overarching Clean Coal and Carbon Management Research Program (CCCMRP). The CCCMRP is implemented by NETL through contracted research activities and on-site research at NETL. Research projects are carried out under various award mechanisms — including partnerships, cooperative agreements, and financial assistance grants — with corporations, small businesses, universities, nonprofit organizations, and other national laboratories and government agencies. The Carbon Capture program consists of two core research areas, Post-Combustion Capture and Pre-Combustion Capture, composed of projects with technology readiness levels (TRL) ranging from conceptual engineering and materials design (i.e., TRL 2) to 25 MW-electrical (MWe) equivalent pilot testing (i.e., TRL 5-7). These two core areas are focused on creating technological improvements providing a step-change in both cost and performance as compared to current state-of-the-art solvent-based capture systems. Post-combustion systems separate $CO_2$ from the flue gas stream produced by conventional pulverized coal power plants after fuel combustion in air. In this approach, $CO_2$ is separated from nitrogen ($N_2$), the primary constituent of the flue gas. Pre-combustion systems are designed to separate $CO_2$ and hydrogen ($H_2$) from the syngas stream produced by the gasifier in integrated gasification combined cycle (IGCC) power plants. In both cases, R&D is underway to develop solvent-, sorbent-, and membrane-based capture technologies, as well as novel technologies. This Technology Compendium provides a technical summary of DOE/NETL's Carbon Capture program, assembling $CO_2$ capture technology R&D descriptions for 91 projects in a single document. As of September 1, 2017, there were 47 active projects and 44 completed projects."

### Computed Tomography Scanning and Geophysical Measurements of the Salina Formation from the #36 Brine Well.

The following is the Abstract of this DOE/NETL document: "The computed tomography (CT) facilities and the Multi-Sensor Core Logger (MSCL) at NETL in Morgantown, West Virginia were used to characterize core of the Salina Formation from a vertical well (Brine Well #36) from Marshall County, West Virginia at a depth of 6,555.6 to 6,719.5 ft. The primary impetus of this work is a collaboration between West Virginia Geological and Economic Survey (WVGES) and NETL to characterize core from multiple wells to better understand the key formations in West Virginia. As part of this effort, bulk scans of core were obtained from the Brine Well #36, provided by the WVGES. This report, and the associated scans generated, provide detailed datasets not typically available for researchers to analyze. The resultant datasets are presented in this report, and can be accessed from NETL's Energy Data eXchange (EDX) online system using the following link: *https://edx.netl.doe.gov/dataset/salina-well*. All equipment and techniques used were non-destructive, enabling future examinations and analyses to be performed on the cores. Low-resolution CT images with the NETL medical CT scanner were obtained for the entire core and high-resolution CT images with the NETL industrial CT scanner were obtained for sections of the core. Qualitative analysis of the medical CT images coupled with X-ray fluorescence (XRF) measurements from the MSCL were useful in identifying zones of interest for more detailed analysis. The ability to quickly identify key areas for more detailed study with higher resolution will save time and resources in future studies. The combination of methods used provides a multi-scale analysis of this core and descriptions of the core that are relevant for many subsurface examinations that have traditionally been performed at NETL."

### The Shand CCS Feasibility Study: Public Report.

The following is from this International CCS Knowledge Centre document: "The Canadian province of Saskatchewan is a world-leader in CCS. Saskatchewan and its provincial utility, SaskPower, pioneered the way for full-scale carbon capture facilities around the world with their fully-integrated [CCS] demonstration project on Unit 3 of the Boundary Dam coal-fired power plant (BD3). Operations at BD3 have steadily improved since initial startup. The facility has addressed safety issues and has recently started to demonstrate a level of reliability that is consistent with a thermal-generating facility, although still at below design $CO_2$ production levels. Once stable operation of the facility is achieved, it will allow the plant operations and support staff to focus on improving the efficiency and cost effectiveness of the operation. As with any world-first project, many lessons were learned through the design, construction and operations of the facility. These lessons have resulted in novel optimizations, operating methods and overall learnings for the facility and its role as a power generator in the power utility. While ongoing improvements are anticipated, second-generation CCS will undoubtedly realize many improvements over the first generation – which this report will highlight…"

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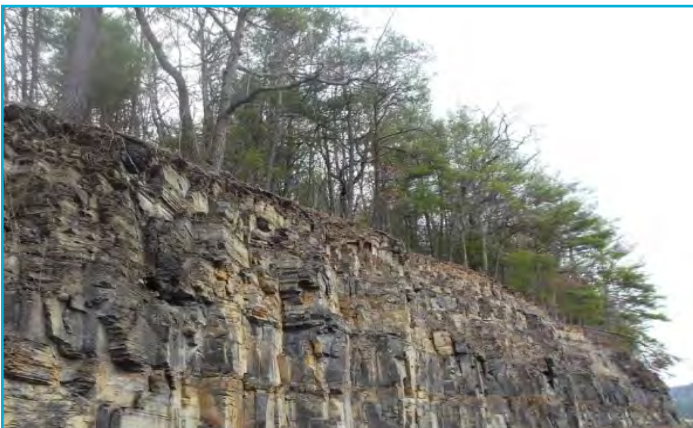CARBON STORAGE NEWSLETTER MARCH 2019

# ABOUT DOE'S CARBON STORAGE PROGRAM

The **Carbon Storage Program** at the National Energy Technology Laboratory (NETL) is focused on developing and advancing technologies to enable safe, cost-effective, permanent geologic storage of $CO_2$, both onshore and offshore, in different depositional environments. The technologies being developed will benefit both industrial and power sector facilities that will need to mitigate future $CO_2$ emissions. The program also serves to increase the understanding of the effectiveness of advanced technologies in different geologic reservoirs appropriate for $CO_2$ storage—including saline formations, oil reservoirs, natural gas reservoirs, unmineable coal, basalt formations, and organic-rich shale basins—and to improve the understanding of how $CO_2$ behaves in the subsurface. These objectives are key to increasing confidence in safe, effective, and permanent geologic $CO_2$ storage.

The *Carbon Storage Program Overview* webpage provides detailed information of the program's structure, as well as links to the webpages that summarize the program's key elements.

## Carbon Storage Program Resources

Newsletters, program fact sheets, best practices manuals, roadmaps, educational resources, presentations, and more information related to the Carbon Storage Program is available on *DOE's Energy Data eXchange (EDX) website*.



Parallel, vertical, orthogonal natural fracture faces (joint sets) in an outcrop of organic-rich Millboro Shale (Marcellus equivalent), Clover Creek, VA. Photo by Dan Soeder, 2014.

# 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.

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