CSN CARBON STORAGE NEWSLETTER

SEPTEMBER 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:

CARBON STORAGE PROGRAM DOCUMENTS and REFERENCE MATERIALS

NATIONAL ENERGY TECHNOLOGY LABORATORY

DOE/NETL HIGHLIGHTS

NETL Hosts Inaugural Comprehensive Annual Project Review Meeting.

The National Energy Technology Laboratory (NETL) hosted the inaugural Carbon Capture, Utilization, Storage, and Oil & Gas Technologies Integrated Project Review Meeting, showcasing research aimed at developing novel technological solutions to the nation's energy challenges. "Addressing the Nation's Energy Needs Through Technology Innovation" combined four Office of Fossil Energy (FE) research programs, offering attendees an opportunity to share in the knowledge and insights gained from more than 200 research projects sponsored by the U.S. Department of Energy's (DOE) *Carbon Capture*, *Utilization* and *Storage*, and *Oil and Natural Gas Programs*. From *energy.gov* on August 30, 2019.

ANNOUNCEMENTS

NETL Director Testifies Before US Senate Energy and Natural Resources Committee.

NETL Director Brian Anderson appeared before the U.S. Senate Energy and Natural Resources Committee to discuss how NETL develops innovative energy technologies that promote economic growth and competitiveness. To highlight the technology advances, the Director submitted *NETL's 2018 Science and Technology Accomplishments publication* for the hearing record. An archived webcast of the hearing is *available online*.

DOE Invests in Large-Scale Fossil Fuel Pilot Projects.

DOE's FE selected six projects to receive federal funding to support future design and construction of the next generation of coal-fired power plants that are flexible, resilient, economical, and emit near-zero emissions, including carbon dioxide (CO_2). The projects were selected under Phase II of the "*Fossil Fuel Large-Scale Pilots*" Funding Opportunity Announcement (FOA), which was issued in August 2017 and includes three phases, with competitive down-selections made between each phase. All of the selected projects will be managed by NETL.

ANNOUNCEMENTS *(cont.)*

NETL Releases Additional Infographics Highlighting Carbon Capture Work.

NETL is releasing a series of eight infographics that explain the structure of its Carbon Capture Program, illustrating its impact and highlighting achievements and notable research and development (R&D) projects that are reducing costs to ensure the availability of clean, reliable, and affordable energy from America's abundant domestic resources. Infographics that have been released to date are *available on the NETL website*.

DOE's NCCC Welcomes New Member.

The French energy company Total has joined DOE's National Carbon Capture Center (NCCC), becoming the second oil and gas producer to sponsor NCCC. According to NCCC, the addition of Total reflects the center's focus on carbon capture, utilization, and storage (CCUS) solutions for natural gas-based power generation. NCCC serves as a research facility to advance technologies that reduce greenhouse gas (GHG) emissions from fossil-based power plants.

Agreement Reached to Explore CCS.

ExxonMobil announced it would explore carbon capture and storage (CCS) for industrial uses at scale through an agreement with chemical and engineering firm Mosaic Materials. This announcement follows *ExxonMobil announcing an agreement with DOE's NETL and National Renewable Energy Laboratory* to research and develop advanced lower-emissions technologies.

Event Highlights Potential for Hydrogen Production with CCS.

An event at Federation University Australia, Gippsland Campus, highlighted the potential for hydrogen production with CCS in Australia's Gippsland region. *Hydrogen Forum: A pathway to environmental & regional prosperity – Where to for Gippsland?* covered the pathways to hydrogen production, including those from fossil fuels with CCS.

PROJECT and BUSINESS DEVELOPMENTS

Companies Collaborate for Forest Carbon Storage Opportunities.

Two Canadian companies—AurCrest Gold Inc. and Blue Source Canada ULC—signed a Carbon Development and Marketing Agreement (CDMA) to develop forest carbon storage opportunities. Under the CDMA, Lac Seul First Nation (Canada) will also collaborate with the companies to assess the potential of forests to capture and store CO_2 within First Nation's traditional territory for the development of GHG offsets and other potential environmental attributes. Blue Source prepared an initial carbon assessment. From *StreetInsider* on August 19, 2019.

Australian CCS Project Begins Operation.

The CO_2 injection system at the Gorgon natural gas facility on Barrow Island off the coast of Western Australia has begun operations. Once fully operational, the system will reduce Gorgon's GHG emissions by approximately 40 percent (more than 100 million metric tons over the life of the project). The Australian government contributed to the capital cost of the Chevron Australia and Gorgon Joint Venture project as part of the Low-Emissions Technology Demonstration Fund. From *Carbon Capture Journal* on August 9, 2019.

Carbon Farming Incentive Offered in Australia.

A soil carbon farming developer in Australia announced a cash prize for carbon farming within the country. According to AgriProve, their 20/20 Olsen Prize for Soil Carbon Farming is designed to spur innovation in regenerative agriculture, encourage farmers to register projects under the Australian Emissions Reduction Fund (ERF), and build an evidence base for soil carbon farming. The prize will be awarded to the first farmer under an ERF project that achieves 20 metric tons of dry matter yield plus an additional 20 metric tons of soil carbon abatement per hectare (~2.5 acres) in a 12-month period. The Australian Broadcasting Commission highlighted the carbon farming incentive in an *audio segment*. From *AgriProve* on August 5, 2019.

LEGISLATION and POLICY

Low-Carbon Fuel Policy Boosts CCS Opportunities.

A *new amendment to California's Low-Carbon Fuel Standard* has created an incentive for the bioethanol industry to utilize CCS technology for the production of low-emissions bioethanol. Due to its *highly concentrated CO_2 waste stream*, bioethanol production presents an opportunity for near-term CCS deployment; applying CCS to the fermentation and distillation process in the biorefinery has the potential to *reduce the fuel's carbon intensity*. From *Global CCS Institute* on August 7, 2019.

New Zealand Government Announces Climate Action Plan.

The New Zealand government *released their Climate Action Plan* in response to the New Zealand Productivity Commission's inquiry into the low-emissions economy. In 2017, the Productivity Commission was asked to identify options for New Zealand to reduce its GHG emissions, taking into account the country's intention to set emissions-reduction goals through the Zero-Carbon Bill. From *New Zealand Government Press Release* on August 3, 2019.

Report Reviews Global Storage Regulations.

A report published by the *CO_2 Capture Project* analyzed recent developments in regulations for CO_2 storage projects globally, finding an increase in confidence for CCS policy and growth in regulatory regimes for CO_2 storage worldwide. The "Survey of CO_2 Storage Regulations" report examined key developments, issues, and gaps that may affect the commercial success of CCS. From *Carbon Capture Journal* on August 28, 2019.

EMISSIONS TRADING

RGGI Secondary Market Report Made Available.

The independent market monitor for the Regional Greenhouse Gas Initiative (RGGI) released a report containing information on the secondary market for RGGI CO_2 allowances, including future prices, market activity, and allowance holdings. Potomac Economics' "*Report on the Secondary Market for RGGI CO_2 Allowances: Second Quarter 2019*" addresses the period from April through June 2019. The report is part of Potomac's ongoing monitoring of the RGGI auctions and the secondary markets in which CO_2 allowances are traded, and is based on data reported to the U.S. Commodity Futures Trading Commission and the Intercontinental Exchange, as well as other data. From *RGGI News Release* on August 21, 2019.

RGGI Releases Results of 45th Auction of CO_2 Allowances.

The RGGI-participating states released the results of their 45th auction of CO_2 allowances. Auction 45 saw 13,116,447 CO_2 allowances sold at a clearing price of $5.20, with bids ranging from $2.26 to $8.00 per allowance. None of the 10 million cost containment reserve (CCR) allowances made available were sold. (CCR is a fixed additional supply of allowances only available for sale if CO_2 allowance prices exceed certain price levels [$10.51 in 2019].) More information is available in the *Market Monitor Report for Auction 45*. From *RGGI News Release* on September 6, 2019.

SCIENCE NEWS

Study Identifies Way to Enhance Soil Sustainability.

Scientists from the University of Plymouth (United Kingdom) demonstrated that adding biochar (a product of biomass) to soils constructed from waste materials has the potential to improve manufactured soil sustainability by enhancing conditions suitable to sustain plant growth, such as carbon storage capacity. The study was *published in the journal Science of the Total Environment*. From *University of Plymouth News* on August 2, 2019.

Refitted Oil Rigs Could Store CO_2.

A research study found that North Sea oil and gas rigs could be modified to pump CO_2 emissions into formations below the seabed. Researchers from the University of Edinburgh used a computer model to analyze data from the Beatrice oil field (located 15 miles off the north east coast of Scotland), and found that making modifications to existing platforms is potentially less costly than decommissioning the oil field. The study was *published in the International Journal of Greenhouse Gas Control*. From *University of Edinburgh School of Geosciences* on August 9, 2019.

Structurally Complex Forests Better at Carbon Storage.

According to a study *published in the journal Ecology*, a forest's structural complexity is a better predictor of its carbon storage potential than tree species diversity. The study, conducted by researchers from Virginia Commonwealth University (USA), found that forests in the Eastern United States with highly varied arrangements of vegetation have the potential to store more carbon. The study suggests that using light detection and ranging to map forest structure could predict the potential of forests to store carbon in biomass better than conventional approaches. From *Phys.Org* on August 12, 2019.

Study Looks Into Plants' CO_2 Storage Potential.

A team of international researchers mapped the potential of today's plants and trees to store extra CO_2 by the end of the century. By analyzing 138 experiments, the researchers found that trees and plants have the potential to increase their biomass (organic material) by 12% when exposed to concentrations of CO_2 predicted for the year 2100. According to the results, *published in the journal Nature Climate Change*, the extra growth could draw enough CO_2 from the atmosphere to remove several years of current emissions. From *Imperial College London* on August 12, 2019.

JOURNAL ARTICLES

Quest carbon capture and storage offset project: Findings and learnings from 1st reporting period.

The following is from the abstract of this article: "Quest is a fully integrated CCS project that started CO_2 injection in August of 2015. The Quest CCS Project is located near Fort Saskatchewan, Alberta, Canada. It includes a capture facility which uses a Shell amine technology, a pipeline of about 65 km length, and three injection well pads. Each injection well pad has an injection well, a deep monitoring well, and shallow groundwater wells. The storage complex is geologically defined by the injection reservoir, a deep saline aquifer called the Basal Cambrian Sand (BCS) (about 45 m thick) and several seals, including the Middle Cambrian Shale (about 50 m thick) and Lotsberg Salts (about 120 m thick). As of August 2018, over three million [metric tons] of CO_2 have been safely injected and permanently stored in the BCS. The Alberta Carbon Competitiveness Incentive Regulation (CCIR) requires the use of standard methods of quantification for reporting GHG emissions for facilities with over 100,000 [metric tons] of carbon dioxide equivalent (CO_2e) per year. An emission offset project is required to comply with CCIR, associated standards and protocols, to demonstrate a reduction in the specified gas emissions and, in the case of Quest, geological sequestration. Quest is the first CCS project to implement an offset project in the context of commercial scale on-shore CO_2 geological sequestration within a saline aquifer. Quest uses the Quantification Protocol for CO_2 Capture and Permanent Storage in Deep Saline Aquifers, from Alberta Environment and Parks. An offset project must develop an offset project plan (OPP) which demonstrates how the project meets the requirement of the protocol, describes how GHG emissions reductions are achieved, identifies risks associated with the quantification of emission reduction benefits, and describes methodologies used to quantify sources and sinks. Subsequent to completing the OPP, an offset project will put together offset project reports (OPR) to report on the net reductions of GHG emissions for a specific period. The intent of this paper is a) to provide an overview of the OPP and OPR for the Quest CCS project, and b) to discuss learnings from the initial compilation and submission of offset project reports. The key learning at this time is associated to the equipment improvements to the injection gas online analyzer." **Celina Duong. Charles Bower, Ken Hume, Luc Rock, and Stephen Tessarolo,** *International Journal of Greenhouse Gas Control.* (Subscription may be required.)

Possibilities of CO_2 purification coming from oxy-combustion for enhanced oil recovery and storage purposes by adsorption method on activated carbon.

The following is the abstract of this article: "The results of laboratory and numerical investigations of oxy-combustion flue gas purification for enhanced oil recovery (EOR) as well as storage purposes using the adsorption method were presented. The experimental investigations provided results of purification process and allowed to determine the correction factors for validation and calibration of the elaborated numerical model. In turn, the numerical simulations were used to extensive research on the purification process at different thermodynamic conditions and process configurations, other than applied at laboratory tests. Neither experimental research nor numerical simulations confirmed the possibility of enrichment the oxy-combustion flue gas to meet the conceptual design purity limits of oxygen at the level of 10ppmv (recommended by NETL) for EOR and storage purposes, but the purity of the product was met in the case of higher ones, described in the literature. The conducted analysis of the energy demand shows that the one-stage vacuum-pressure swing adsorption (VPSA) purification process requires about 57 kWh/t_{CO2} at recovery of 73.58% and product purity of 97.78% when the product is at the ambient pressure, 128 kWh/t_{CO2} when the product is at 18 bar and 161 kWh/t_{CO2} at the pressure equals 120 bar. Obtained results were also compared with the literature data." **Dariusz Wawrzyńczak, Marcin Panowski, and Izabela Majchrzak-Kucęba,** *Energy.* (Subscription may be required.)

Managing the invasion of guava trees to enhance carbon storage in tropical forests.

The following is the abstract of this article: "Tropical forests account for a substantial percentage of the world's carbon stocks, but the consequences to carbon storage of the rapid invasiveness of the guava tree in these forests is not known. Two different forest management strategies are practiced in a tropical forest in western Kenya: (1) a protection strategy where human entry is prohibited except for minimalistic human presence (e.g., research activities); and (2) a conservation strategy where human access to the forest and its resources are permitted. [The authors] assessed the effects of these management strategies and different levels of disturbance caused by the legacy effects of legal logging activities and the contemporary effects of unauthorized harvesting of forest products on the abundance of guava and non-guava trees and carbon storage in both plant biomass and soil in this forest. [The authors] found that guava trees were less likely to thrive and carbon storage in plants and soils was similar in sites with minimal disturbance under both the protection and conservation strategies. However, as disturbance increased, whether by the historical or contemporary effects of human activities, guava trees were more likely to thrive and carbon storage in plants shifted from non-guava trees to guava trees, but without an effect on more stable soil carbon. [The authors] conclude that regulations should be strictly enforced to prevent all logging activity, but the conservation strategy would provide similar effects on both forest plant and soil carbon to the protection strategy, while providing benefits to the surrounding community who rely on the forest for cultural and spiritual nourishment." **Rael Adhiambo, Francis Muyekho, Irena F. Creed, Eric Enanga, William Shivoga, Charles G. Trick, and John Obiri,** *Forest Ecology and Management.* (Subscription may be required.)

Soil organic matter priming and carbon balance after straw addition is regulated by long-term fertilization.

The following is from the abstract of this article: "Straw incorporation is crucial to soil organic carbon (SOC) sequestration… The fate of straw C and the associated net SOC balance remain largely unexplored, particularly in soils subjected to long-term mineral and organic fertilization. To address this, soil ($\delta^{13}C$: –19‰) that had been continuously cropped with maize for 31 years and subjected to five long-term fertilization regimes, including (i) control (Unfertilized), (ii) mineral fertilizer (NPK) application, (iii) 200% NPK (2×NPK) application, (iv) manure (M) application, and (v) NPK plus manure (NPKM) application, was incubated with or without addition of rice straw ($\delta^{13}C$: –29‰) for 70 days. Straw addition largely primed SOC mineralization. The priming effect (PE) was considerably higher in 2 × NPK (+122% of CO_2 from soil without straw addition) but lower in M (+43%) relative to the unfertilized soil (+82%), highlighting the importance of fertilization in controlling PE intensity. Fertilization increased the straw-derived microbial biomass C by 90–577% and straw-derived SOC by 34–68% compared to the unfertilized soil, primarily due to the increased abundance of Gram-negative bacteria and cellobiohydrolase activity. Straw-derived SOC was strongly positively correlated with straw-derived microbial biomass C, suggesting that dead microbial biomass (necromass) was a dominant precursor of SOC formation. Consequently, fertilization facilitated microbial utilization of straw C and its retention in soil, particularly in the M and NPKM fertilized soils. The amounts of straw-derived SOC overcompensated for the SOC losses by mineralization, resulting in net C sequestration which was highest in the NPK fertilized soil. [The authors'] study emphasizes that NPK fertilization decreases the intensity of the PE induced by straw addition and increases straw C incorporation into SOC, thus facilitating C sequestration in agricultural soils." **Lei Wu, Wenju Zhang, Wenjuan Wei, Zhilong He, Yakov Kuzyakov, Roland Bol, and Ronggui Hu,** *Soil Biology and Biochemistry.* (Subscription may be required.)

JOURNAL ARTICLES *(cont.)*

Study of convective-diffusive flow during CO_2 sequestration in fractured heterogeneous saline aquifers.

The following is the abstract of this article: "CO_2 sequestration in naturally fractured saline aquifers is important to be studied. This paper investigates the convective-diffusive flow to study CO_2 sequestration by dissolution in single and multi-fractured heterogeneous saline aquifers. The effect of fractures density, orientation, permeability, aperture and surface roughness on CO_2 dissolution and propagation of density-driven fingers are investigated. The results indicate that a single fracture causes the growing density fingers to deviate towards the high permeability path of the fracture. Additionally, the higher vertical fracture orientation, aperture and permeability will lead to a higher CO_2 storage. In the multiple fracture systems, matrix permeability has a dominant and positive effect on CO_2 storage. Nevertheless, the effect of fractures properties such as fracture density, spacing, permeability, aperture and surface roughness on the CO_2 storage are dependent on the fractures orientation. For instance, having fractures with rough surface can cause CO_2 dissolution retardation in the aquifers with only vertical fractures. This study provides more insights into dissolution trapping of CO_2 in fractured heterogeneous saline aquifers." **Mohamed Gamal Rezk and Jalal Foroozesh,** *Journal of Natural Gas Science and Engineering*. (Subscription may be required.)

Incentive model for enterprises based on carbon emission intensity.

The following is the abstract of this article: "A pilot scheme for a carbon emissions trading market has been launched in China. Some problems within the market include insufficient incentives, inefficient emissions reduction, and inequitable distribution. While previous studies adopted a state or provincial level perspective to examine such issues, little research has focused on enterprises at a business level. This article proposes a new incentive model that aims to resolve these problems. This model was developed while considering the carbon emission intensity of enterprises and cooperative game theory. According to the advanced value and average value of carbon emission intensity, the model classifies enterprises into three regions. The quota in the second year is related to its own emission intensity and the number of enterprises located in the region, which not only stimulates the enthusiasm of the enterprise to reduce emissions, but also serves to encourage more enterprises to participate in emission reductions. This article presents a study of 16 textile enterprises in Shandong Province. Depending on the model's calculation, the quota can be redistributed. Different emission intensity brings different emission reduction costs, which can intuitively show different responsibilities. The result is fairer and more reasonable than distributions that are based on a historical emissions quota." **Kai Wang, Linyu Xu, and Johannes Kals,** *Journal of Cleaner Production*. (Subscription may be required.)

Estimation of CO_2 sequestration potential by afforestation in the arid rangelands of Western Australia based on long-term empirical data.

The following is from the abstract of this article: "In this study (1999–2015), in an arid area near Leonora, Western Australia (annual rainfall: 220 mm $year^{-1}$; pan evaporation: 3400 mm $year^{-1}$), carbon sequestration was assessed in above and below ground biomass in Eucalyptus camaldulensis under ambient conditions and with active site amelioration (combination of water harvesting with large mounds and hardpan blasting). The carbon sequestration rate was estimated at 7.92 Mg-CO_2-e ha^{-1} $year^{-1}$ for a total carbon sink of 230 Mg-CO_2-e ha^{-1}. Carbon mitigation may thus be a viable option in arid regions, not only in Western Australia but globally, and can be enhanced with active site engineering." **Hideki Suganuma, Shin-ichi Aikawa, Yuji Sakai, Hiroyuki Hamano, Nobuhide Takahashi, Kiyotaka Tahara, Satoko Kawarasaki, Hajime Utsugi, Yasuyuki Egashira, Takuya Kawanishi, Richard J. Harper, Hiroyuki Tanouchi, Toshinori Kojima, Yukuo Abe, Masahiro Saito, Shigeru Kato, John Law, and Koichi Yamada,** *Ecological Engineering*. (Subscription may be required.)

Acorn: Developing full-chain industrial carbon capture and storage in a resource- and infrastructure-rich hydrocarbon province.

The following is from the abstract of this article: "Through assessment of Acorn's publicly-available outputs, [the authors] identify strategies which may help to enhance the viability of early-stage CCS projects. Initial capital costs can be minimised by infrastructure re-use, particularly pipelines, and by re-use of data describing the subsurface acquired during oil and gas exploration activity. Also, development of the project in separate stages of activity (e.g. different phases of infrastructure re-use and investment into new infrastructure) enables cost reduction for future build-out phases. Additionally, engagement of regional-level policy makers may help to build stakeholder support by situating CCS within regional decarbonisation narratives. [The authors] argue that these insights may be translated to general objectives for any CCS project sharing similar characteristics such as legacy infrastructure, industrial clusters and an involved stakeholder-base that is engaged with the fossil fuel industry." **Juan Alcalde, Niklas Heinemann, Leslie Mabon, Richard H. Worden, Heleen de Coninck, Hazel Robertson, Marko Maver, Saeed Ghanbari, Floris Swennenhuis, Indira Mann, Tiana Walker, Sam Gomersal, Clare E. Bond, Michael J. Allen, R. Stuart Haszeldine, Alan James, Eric J. Mackay, Peter A. Brownsort, Daniel R. Faulkner, and Steve Murphy,** *Journal of Cleaner Production*. (Subscription may be required.)

Carbon policy in developing countries: Giving priority to non-price instruments.

The following is the abstract of this article: "Carbon pricing might not be appropriate as the main element of the carbon policy package in emerging and developing countries (DCs), because the political economy constraints are greater than in developed countries. Non-price instruments and policies such as efficiency standards, market-oriented regulation, subsidies for clean technologies and public programs involving low carbon infrastructure should be preferentially developed to deal with market and regulatory failures, which are more widespread than in developed countries. These approaches are most effective in orientating technology and infrastructure, the principal means to achieving the mitigation imperative in DCs. Moreover, even if, in theory, policy packages using non-price instruments are less socially efficient than those focused on carbon pricing, they allow governments to circumvent political economy constraints, because their costs to consumers and citizens are not generalized and tend to be much less visible, while their redistributive effects are, if appropriately designed, generally not too regressive. In the end, developing a carbon policy that emphasizes non-price instruments and measures will pave the way to leverage carbon pricing as the main pillar of their future carbon policy in long term." **Dominique Finon,** *Energy Policy*. (Subscription may be required.)

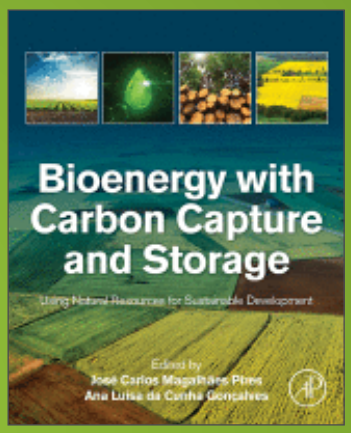
Carbon tax incidence on household demand: Effects on welfare, income inequality and poverty incidence in Thailand.

The following is the abstract of this article: "Studying the impact of a carbon tax on household demand can be relevant in terms of securing public acceptance of a carbon tax and clarifying the implications for policy design. This paper aims to fill a gap in the academic literature by simulating carbon tax scenarios and estimating distributional effects of the tax on household welfare, income inequality, and poverty rates based on household consumption in Thailand. The study employs a microsimulation model incorporating the economy-wide effects of the tax on prices and consumers' behavioral responses to changes in prices. The results indicate that a carbon tax is progressive in Thailand under revenue-recycling scenarios by expanding social transfer programs. When carbon tax revenues are recycled through pensions for elderly people, the carbon tax could reduce the poverty rate and improve the welfare of households in the lowest quintile. The results imply that the distributional impacts of environmental taxes could result in favorable outcomes for income inequality and poverty reduction in developing countries." **Supawan Saelim,** *Journal of Cleaner Production*. (Subscription may be required.)

REPORTS and OTHER PUBLICATIONS

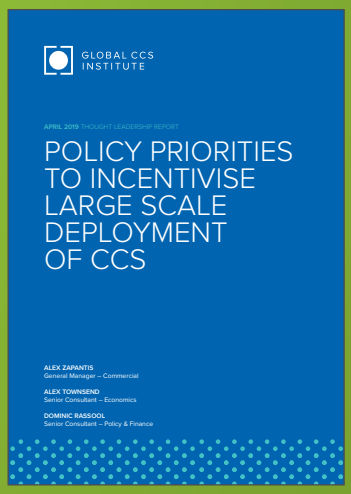
Bioenergy with Carbon Capture and Storage: Using Natural Resources for Sustainable Development.

The following is from a description of this book: "Bioenergy with Carbon Capture and Storage: Using Natural Resources for Sustainable Development presents the technologies associated with bioenergy and CCS and its applicability as an emissions reduction tool… Sections offer an overview of several routes to use biomass and produce bioenergy through processes with low or even negative CO_2 emissions. Associated technology and the results of recent research studies to improve the sustainability of the processes are described, pointing out future trends and needs. This book can be used by bioenergy engineering researchers in industry and academia and by professionals and researchers in carbon capture and storage."



Policy Priorities to [Incentivize] Large Scale Deployment of CCS.

The following is from the Executive Summary of this Global CCS Institute document: "CCS prevents CO_2 from being released into the atmosphere. The technology involves capturing CO_2 produced by large industrial plants, compressing it for transportation and then injecting it deep into a rock formation at a carefully selected and safe site, where it is permanently stored… It is the only feasible technology that can deliver deep emissions reductions in many industrial processes that are vital to the global economy, such as steel, cement and chemicals production. In combination with bioenergy used for power generation or biofuel production, it provides one of the few technologies that can deliver negative emissions at scale; unambiguously required to limit temperature rises to no more than 2°C. CCS can also be applied to coal and gas fired power plants, providing dispatchable generation capacity to complement the increased deployment of intermittent renewables, and in the production of low emissions hydrogen for heat and transport. While the critical role of CCS has been demonstrated in many reports, the policies in place today are insufficient to ensure CCS deployment scales up at the rate required. This paper seeks to address the current policy gap by describing priorities for policymakers to support the transition from current to future rates of deployment of CCS. It starts by reviewing the barriers to investment in CCS and how these have been overcome for the eighteen large scale facilities currently in operation and five under construction. It then develops a framework to support the scaling up of CCS deployment. It concludes with recommendations for policymakers..."



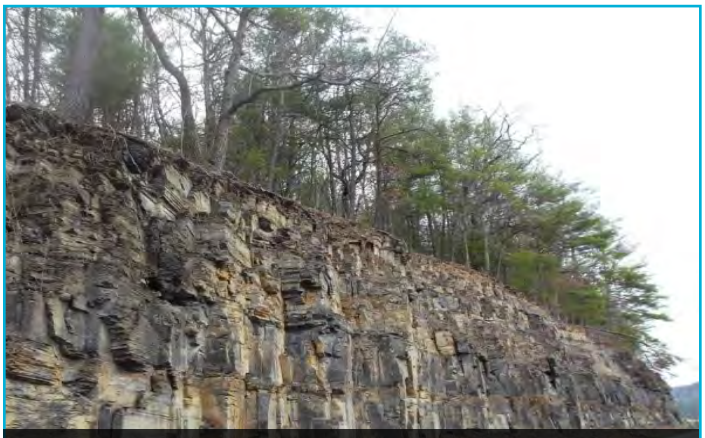
ABOUT DOE'S CARBON STORAGE PROGRAM

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 (note that all links were active at the time of publication).

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1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

Program staff are also located in
Houston, Texas and **Anchorage, Alaska**.

CUSTOMER SERVICE: 1-800-553-7681

www.netl.doe.gov

Contact

Andrea McNemar
304-285-2024
Andrea.McNemar@NETL.DOE.GOV

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