CSN CARBON STORAGE NEWSLETTER

NOVEMBER 2018

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

Energy Department Seeks Information on Transformational Sensing for the Subsurface.

The U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) *issued a Request for Information (RFI)* on the development of transformational sensing capabilities for monitoring parameters associated with subsurface carbon dioxide (CO_2) storage. The objective of the RFI is to assess relevant state-of-the-art sensor technologies and determine future needs associated with CO_2 injection, including requirements of the future storage industry for cost-effective monitoring, the priority of technology opportunities for developing transformational sensor capabilities for monitoring parameters, and ways to improve how technology can be effectively measured at minimum cost. Stakeholder responses to the RFI are due to the National Energy Technology Laboratory (NETL) by December 3, 2018. From *energy.gov* on November 5, 2018.

ANNOUNCEMENTS

Director Appointed to DOE's NETL.

Steven Winberg, DOE's Assistant Secretary for Fossil Energy, appointed Brian J. Anderson, Ph.D. as the new director of DOE's NETL. Dr. Anderson previously served as director of West Virginia University's (WVU) Energy Institute. As part of the move, NETL's Acting Director, Sean Plasynski, Ph.D., will transition into his new role as NETL's Deputy Director and Chief Operating Officer.

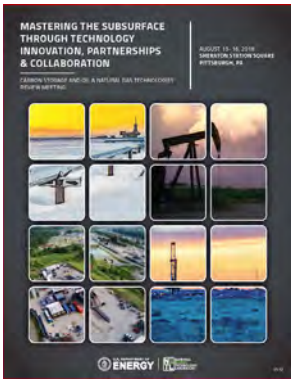
Dr. Brian Anderson

DOE Announces Intent to Fund R&D to Advance Coal Technologies.

DOE's FE announced its intent to fund competitive research and development (R&D) that will advance first-of-a-kind coal generation technologies. The effort, referred to as the Coal FIRST (Flexible, Innovative, Resilient, Small, Transformative) Initiative, will look to develop the coal plant of the future while also reducing emissions.

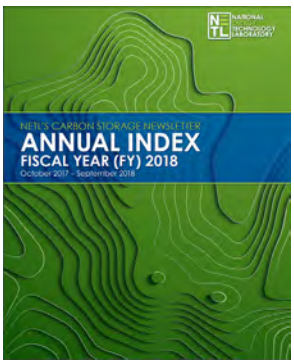
DOE/NETL Conference Proceedings Available Online.

Proceedings from the "2018 Mastering the Subsurface Through Technology Innovation, Partnerships, and Collaboration: Carbon Storage and Oil and Natural Gas Technologies Review Meeting," held in Pittsburgh, Pennsylvania (USA), on August 13-16, 2018, are available online. Included are posters and presentations from the meeting.



FY 2018 Carbon Storage Newsletter Annual Index Available.

The Fiscal Year (FY) 2018 Carbon Storage Newsletter Annual Index is available online. The document is a compilation of NETL's Carbon Storage Newsletters published over the October 2017 through September 2018 timeframe, organized by section. Outdated information (e.g., conference dates, paper submittals, expired Funding Opportunity Announcements [FOAs]) has been removed.



DOE Invests to Develop Products from CO_2.

DOE's FE selected 17 projects to receive federal funding for cost-shared R&D to develop technologies to generate novel, marketable products using CO_2 or coal as a feedstock. The projects are supported through DE-FOA-0001849, titled "Novel Methods for Making Products from Carbon Dioxide or Coal."

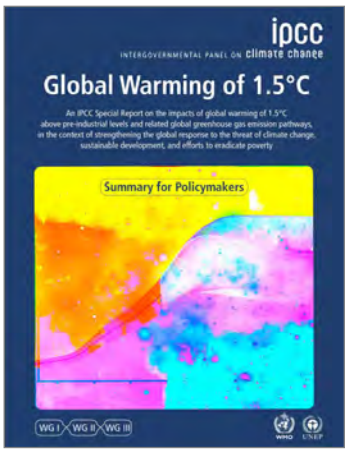
ANNOUNCEMENTS *(cont.)*

U.S Cities Awarded Resources, Technical Support to Reduce Carbon Emissions.

Four U.S. cities (Pittsburgh, Philadelphia, Boston, and Washington, D.C.) were selected to receive resources and technical support from The Bloomberg American Cities Climate Challenge. Under the program, which is part of Bloomberg's American Cities Initiative, the four cities will be accepted into a two-year acceleration program that will provide them with resources to help meet or beat their near-term carbon-reduction goals. A total of 20 U.S. cities will be awarded under the program.

IPCC Releases Report.

The Intergovernmental Panel on Climate Change (IPCC) *released* a special report and *Summary for Policy Makers* on the impacts of potential climate change. A total of 91 authors and editors from 40 countries prepared the report, which was developed in response to an invitation from the United Nations Framework Convention on Climate Change (UNFCC).



The National Academies of SCIENCES ENGINEERING MEDICINE

New Report on CO_2 Utilization Technologies.

A new report by the National Academies of Sciences, Engineering, and Medicine identifies R&D to improve the commercial viability of carbon utilization technologies. The report offers an agenda for research to advance these technologies, including R&D to improve utilization methods. The report, titled "*Gaseous Carbon Waste Streams Utilization*," was sponsored by DOE.

PROJECT and BUSINESS DEVELOPMENTS

Ground Broken on STEP Pilot Power Plant.

A groundbreaking ceremony was held for a *Supercritical Transformational Electric Power (STEP) pilot plant* in San Antonio, Texas, USA. Project partners include DOE, Southwest Research Institute (SwRI), the Gas Technology Institute (GTI), and GE Global Research. The 10-megawatt (MW) supercritical carbon dioxide (sCO_2) facility will demonstrate the next generation of higher-efficiency, lower-cost electric power technology. Current power plants use water as a thermal medium in power cycles; replacing it with sCO_2 increases efficiency by as much as 10 percent. Because of the efficiency of sCO_2 as a thermal medium, STEP turbomachinery can be one-tenth the size of conventional power plant components. From *SwRI Press Release* on October 15, 2018.

Companies Sign MOU to Support CCS.

Technology Centre Mongstad (TCM) (Norway) and DNV GL signed a Memorandum of Understanding (MOU) to form a global advisory partnership to support carbon capture technologies. The partnership will build on current carbon capture and storage (CCS) efforts and deliver advisory and verification services for CO_2 capture technology. Technology companies currently conduct advanced testing of their carbon capture technologies at TCM; integration of technology verification is expected to expedite new solutions to the market. From *Carbon Capture Journal* on October 28, 2018.

EOR Pipeline Proposed.

A Texas (USA) company is proposing a 110-mile CO_2 pipeline in Montana (USA) that has the potential to release as many as 400 million barrels of oil through enhanced oil recovery (EOR). Subsidiaries of Denbury Resources, Inc. proposed the Cedar Creek Anticline CO_2 pipeline, which would deliver CO_2 from Bell Creek oil field in southwest Montana to the Cedar Creek Anticline fields in eastern Montana near the North Dakota border over several decades. If approved, Denbury plans to begin construction on the pipeline in 2019. From *Great Falls Tribune* on October 9, 2019.

CO2 TECHNOLOGY CENTRE MONGSTAD

LEGISLATION and POLICY

Norway to Increase CCS Efforts.

The Norwegian government's *national budget for 2019* proposes to allocate approximately $80 million for CCS, representing an increase of more than nearly $19 million compared to the final budget for 2018. The proposal includes funds for continuing the work on a new, full-scale CCS project in Norway, as well as increased funding for TCM. Knowledge and experience gained from TCM is expected to be used for planning the full-scale CCS project. From *Carbon Capture Journal* on October 15, 2018.

North Carolina Sets GHG Reduction Goal.

The Governor of North Carolina (USA) *signed an executive order* to reduce the state's greenhouse gas (GHG) emissions by 40 percent by 2025. In addition, the order creates a committee that will work with the state's Department of Environmental Quality to develop a report on how the state's government can use more renewable energy sources. From *The News & Observer* on October 29, 2018.

Saskatchewan Introduces Legislation.

The Saskatchewan (Canada) environment minister introduced legislation to implement industry performance standards. "*The Management and Reduction of Greenhouse Gases Amendment Act, Bill 132*," will also provide regulatory framework for emitters contributing to a green technology fund or purchasing performance credits and carbon offset credits. Under the bill, those emitting more than 10,000 metric tons of CO_2 annually will be required to track their emissions, while those with emissions exceeding 25,000 metric tons will be required to comply with performance standards. From *Global News* on October 30, 2018.

EMISSIONS TRADING

RGGI Releases Auction 42 Notice.

The states participating in the Regional Greenhouse Gas Initiative (RGGI) released the *Auction Notice* and *application materials* for their 42nd quarterly CO_2 allowance auction, to be held December 5, 2018. The Auction Notice provides potential participants with the information needed to indicate their intent to bid on Auction 42. As indicated in the Auction Notice, Auction 42 will offer for sale 13,360,649 CO_2 allowances at a minimum reserve price of $2.20. In addition, there will also be a 10 million CO_2 allowance cost containment reserve (CCR) made available for the auction, which will be accessed if the interim clearing price exceeds the CCR trigger price of $10.25. From *RGGI News Release* on October 9, 2019.

Hexindai to Support Emissions Reduction.

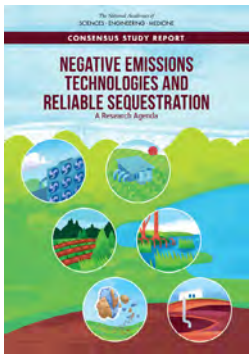
Hexindai Inc., based in Beijing, China, reached an agreement with Shell Energy (China) Limited to support China's national emissions trading scheme (ETS). Under the agreement, Hexindai will provide price hedging of National Carbon Allowances (NCAs) for three years, to begin when the cement sector is enrolled in China's ETS and the Chinese carbon offsets can be used for compliance purposes. An NCA unit is equal to one ton of CO_2 equivalent. From *Hexindai Press Release* on October 16, 2018.

New Carbon Investment Fund to Be Launched.

A New Zealand investment company announced plans to launch a carbon fund that will be listed on the New Zealand Stock Exchange (NZX). Salt Funds Management will manage the fund, with the intent to purchase carbon credits in emissions trading schemes from New Zealand and offshore. According to Salt Fund officials, the fund would provide individuals and organizations an opportunity to invest in or offset carbon. From *NZ Herald* on October 15, 2018.

CLIMATE and SCIENCE NEWS

New Report on Negative Emissions Technologies and Carbon Storage.



A new report from the National Academies of Sciences, Engineering, and Medicine provides a research agenda for technologies that capture and store atmospheric CO_2. The report, titled "*Negative Emissions Technologies and Reliable Sequestration*," discusses the role negative emissions technologies (NETs) can have on achieving goals and reducing emissions. NETs remove CO_2 directly from the atmosphere and enhance natural carbon sinks. The report concluded that the NETs available today could be scaled up, but that a research effort is needed to address potential constraints. From *The National Academies of Sciences, Engineering, and Medicine Press Release* on October 24, 2018.

Article Analyzes Impact of CCS on Marine Ecosystems.

Implementing CCS at the point of CO_2 generation is a possible solution to reduce GHGs and their impact on marine ecosystems, according to a recently published article, titled "*Ocean Solutions to Address Climate Change and Its Effects on Marine Ecosystems*." Researchers assessed 13 ocean-based measures to reduce potential climate change and its impacts on marine ecosystems and ecosystem services. Other possible solutions include shifting from fossil fuels to renewable energy, improving energy efficiency, and protecting and enhancing natural carbon sinks. From *International Institute for Sustainable Development* on October 16, 2018.

JOURNAL ARTICLES

Enhanced safety of geologic CO_2 storage with nanoparticles.

The following is the Abstract of this article: "Some methods have been developed to detect leakage of CO_2 from its desired storage domain, but that is not sufficient to prevent and mitigate a leak. Two techniques have been proposed to prevent the migration of buoyant CO_2 from the storage domain by expediting mixing of CO_2 with the brine and mitigate risk of its leakage risk. These two methods are injection of CO_2 pre-mixed with brine, and injection of CO_2 with nanoparticles (NPs). The former has been studied to some extent, however, understanding of the latter is very limited. Unlike the application of NPs in hydrocarbon recovery, its use to enhance safety of CO_2 storage is a fairly unexplored topic that can have important benefits for the safety of the storage process. Also, the use of NPs for subsurface application in general is compromised for its cost. [The authors] investigate how NPs produced from low-level nuclear waste can be added with injected CO_2 to enhance the mixing of CO_2 with brine, which can mitigate leakage risk of CO_2. [The authors] numerically investigate the effect of adding NPs from nuclear waste with the CO_2 and show that it enhances the mixing of CO_2 with in-situ brine in saline aquifers that mitigates the risk related to buoyancy and high mobility of CO_2. Additionally, [the authors] examine the effect of reservoir heterogeneity on mixing of CO_2 in reservoir brine when it is injected with NPs. The results show that: (i) addition of NPs to CO_2 leads to higher mixing, (ii) the discrete shape of CO_2 concentration in brine tends to diffuse and become smooth as the heterogeneity of the medium increases, and (iii) the impact of heterogeneity is more pronounced than the fraction of NPs on mixing." **Harpreet Singh and Akand Islam,** *International Journal of Heat and Mass Transfer.* (Subscription may be required.)

Pricing forest carbon: Implications of asymmetry in climate policy.

The following is the Abstract of this article: "Using an integrated assessment model, [the authors] examine the implications of climate policies that do not fully recognize forest carbon. Specifically, [the authors] first investigate the impact of an asymmetric policy that recognizes carbon emissions from fossil fuels while fully ignoring forest carbon. Next, [the authors] investigate the relative importance of not recognizing emissions from a reduction in the stock of forest biomass compared to not recognizing sequestration from the growth of forest biomass. [The authors] show that asymmetric carbon policies lead to lower levels of welfare, as well as higher emissions and carbon prices. This occurs because the forest resource will be allocated inefficiently under these carbon policies. Broadly, [the authors] find that when the social planner does not account for emissions or sequestration from the forest, the planner will set bioenergy levels that are too high and afforestation and avoided deforestation levels that are too low. [The authors'] results further reveal that not recognizing forest emissions leads to larger welfare losses than not recognizing sequestration." **Mathilda Eriksson, Runar Brännlund, and Tommy Lundgren,** *Journal of Forest Economics.* (Subscription may be required.)

The impact of gradational contact at the reservoir-seal interface on geological CO_2 storage capacity and security.

The following is the Abstract of this article: "The implementation of CO_2 storage in sub-surface sedimentary formations can involve decision making using relevant numerical modelling. These models are often represented by 2D or 3D grids that show an abrupt boundary between the reservoir and the seal lithologies. However, in an actual geological formation, an abrupt contact does not always exist at the interface between distinct clastic lithologies such as sandstone and shale. This article presents a numerical investigation of the effect of sediment-size variation on CO_2 transport processes in saline aquifers. Using the Triassic Bunter Sandstone Formation (BSF) of the Southern North Sea (SNS), this study investigates the impact a gradation change at the reservoir-seal interface on CO_2 sequestration. This is of great interest due to the importance of enhanced geological detail in reservoir models used to predict CO_2 plume migration and the integrity of trapping mechanisms within the storage formation. The simplified strategy was to apply the Van Genutchen formulation to establish constitutive relationships for pore geometric properties, which include capillary pressure (Pc) and relative permeability (kr), as a function of brine saturation in the porous media. The results show that the existence of sediment gradation at the reservoir-seal interface and within the reservoir has an important effect on CO_2 migration and pressure diffusion in the formation. The modelling exercise shows that these features can lead to an increase in residual gas trapping in the reservoir and [localized] pore pressures at the caprock's injection point." **Michael U. Onoja and Seyed M. Shariatipour,** *International Journal of Greenhouse Gas Control.* (Subscription may be required.)

[Decarbonization] of the Industrial Sector by means of Fuel Switching, Electrification and CCS.

The following is the Abstract of this article: "The industrial sector will have to undergo major changes in order to reduce its emissions with the goal of climate change mitigation. In this context, the iron and steel subsector accounts for the highest CO_2 emissions share. This work uses a simulation model of the global energy system and quantifies the impacts of different measures for CO_2 reduction (such as fuel switching, electrification and Carbon Capture and Storage - CCS) on investment and operation decisions. The reported scenarios consider the implementation of a CO_2 price as a policy instrument to [decarbonize] the industrial sector. The selected case study covers steel production in the USA up to the year 2050. The results show that single measures such as fuel switching, electrification and CCS adoption alone have a limited impact on the [decarbonization] of the iron and steel sector and should be rather implemented all together in an integrated approach towards climate change mitigation." **Sandro Luh, Sara Budinis, Thomas J. Schmidt, and Adam Hawkes,** *Computer Aided Chemical Engineering.* (Subscription may be required.)

JOURNAL ARTICLES *(cont.)*

A meta-frontier DEA approach to efficiency comparison of carbon reduction technologies on project level.

The following is the Abstract of this article: "Carbon reduction technologies such as renewable energy, nuclear energy and CCS technology for the power industry play a significant role in achieving low-carbon development goals. This research employed a meta-frontier DEA approach to evaluate carbon reduction efficiency of technologies on project level. The sample consists of several groups of projects such as nuclear energy, hydro-electric energy, wind energy, solar energy and biomass energy and CCS technology in power plants. The comparison study takes consideration the carbon reduction efficiency gap and management level of different technologies for the power industry. The results reveal that 1) Biomass energy power plants and conventional power plants installed with CCS have the highest efficiency in carbon reduction efficiency, with potential improvement in management. 2) Nuclear power plants show a high efficiency in carbon reduction while facing some constraints from safety and stability issues. 3) Although wind power, hydro-electric power and solar power have been exploited in power generation for a long time, they still have low efficiency in reducing carbon emission from the power industry. Suggestions are provided for policy makers to choose appropriate low-carbon development route of the power industry." **Nannan Wang, Ji Chen, Shengnan Yao, and Yen-Chiang Chang,** *Renewable and Sustainable Energy Reviews.* (Subscriptions may be required.)

An integrated measurement of household carbon emissions from a trading-oriented perspective: A case study of urban families in Xuzhou, China.

The following is the Abstract of this article: "The measurement of household carbon emissions from a trading-oriented perspective has become increasingly important and urgently required due to the growing attention to personal carbon trading. From a trading-oriented perspective, this study established an integrated measurement system of household carbon emissions that consists of four modules: direct carbon emissions produced by energy use and private transport, and indirect carbon emissions produced by the consumption of a portion of non-energy goods and services and waste disposal. The emissions coefficient method and input–output model were then adopted to systematically calculate the carbon emissions coefficients of 31 items related to household activities. Furthermore, this study developed an integrated measurement scale of household carbon emissions that includes 23 questions based on the integrated measurement system. Additionally, the carbon emissions of three urban families in Xuzhou were measured and analyzed using the integrated measurement scale, which exhibits the simple, clear, and calculable characteristics of the integrated measurement system and integrated measurement scale. This study provides new perspectives for the measurement of household carbon emissions and valuable references for the research and implementation of personal carbon trading scheme, and then contributes to the reduction of households' carbon emissions." **Daoyan Guo, Hong Chen, Ruyin Long, and Yingzhe Ni,** *Journal of Cleaner Production.* (Subscription may be required.)

A general equilibrium analysis on the impacts of regional and sectoral emission allowance allocation at carbon trading market.

The following is the Abstract of this article: "It is critical to adapt to climate change and reduce the overall carbon emissions. China announced its Nationally Determined Contributions (NDC) at the Paris climate conference in 2015. The carbon cap-and-trade scheme, which plays a key role in carbon emissions abatement, is an effective policy for China to achieve its NDC. This study focuses on the allocation of regional and sectoral initial carbon emission allowances in Shanghai. An impact evaluation on the macro-economy, carbon trading markets and participating sectors for the year 2030 was conducted by applying a computable general equilibrium (CGE) model. The results show that the carbon cap-and-trade scheme would cause a 3.4% GDP loss and an 8.9% welfare loss in 2030. The carbon price would be 161.2 USD/t and 147.2 USD/t under the two representative scenarios. The allocation of initial allowances would have a significant impact on both carbon market scale and sectoral trading behaviors. The power generation sector and the petrol oil sector would undertake the greatest output loss, while the metal smelting sector would become the main seller. Furthermore, the initial allowances allocation under a certain abatement target would hardly affect sectoral production but remarkably affect trade behaviors at the carbon trading markets." **Zhongjue Yu, Yong Geng, Hancheng Dai, Rui Wu, Zhiqing Liu, Xu Tian, and Raimund Bleischwitz,** *Journal of Cleaner Production.* (Subscription may be required.)

REPORTS and OTHER PUBLICATIONS

A Multisensor Plume Monitoring Schema for Carbon Sequestration Sites in Subsurface Engineered-Natural Systems.

The following is from the Introduction of this NETL document: "The National Carbon Sequestration (NATCARB) Monitoring, Verification, and Accounting (MVA) program is tasked with monitoring CO_2 storage sites for compliance with the U.S. Environmental Protection Agency's (EPA) Underground Injection Control (UIC) Program to ensure that potable groundwater sources and sensitive ecosystems are protected. The major monitoring technology areas are atmospheric, remote sensing and near surface, subsurface, and intelligent monitoring networks and protocols. The primary objective of the NETL-led National Risk Assessment Partnership (NRAP) is to develop simulation-based risk assessment tools needed for safe, permanent geologic CO_2 storage, as well as monitoring and mitigation protocols to reduce uncertainty in the predicted long-term behavior of a storage site. This multi-sensor monitoring assessment project addresses three technology focus areas within the NATCARB MVA program: [1]. Remote sensing and near surface - (surface deformation, near surface electric resistivity structure) using ground and satellite interferometric radar, airborne transient electromagnetic (TEM), ground-based audiofrequency/radiofrequency natural and controlled source audio magnetotelluric/radiofrequency magnetotelluric(CSAMT/RFMT) methods [2] Subsurface - (surface deformation, electrical resistivity structure from 100–15,000 ft below ground level) using ground and satellite interferometric radar, audiofrequency magnetotelluric (AMT) and controlled source electromagnetic (CSEM) methods [3] Intelligent monitoring networks and protocols - (the optimized multi-sensor deployment and data acquisition schema), as well as the monitoring protocols focus area of the NRAP program "

Reducing UK emissions: 2018 Progress Report to Parliament.

The following is from the Executive Summary of this UK Committee on Climate Change document: "This is the Committee on Climate Change's (CCC) tenth statutory Progress Report to Parliament – an important moment to reflect on the UK's achievements in tackling climate change to date. 2018 also marks the tenth year since the Climate Change Act came into force and, with it, the creation of the CCC as an independent statutory adviser. [Decarbonizing] electricity generation is the clear achievement of the last decade - a notable success, in line with the Committee's early recommendations, which will underpin a strategy of shifting progressively from fossil fuels to low-carbon electricity. But progress in the power sector masks a marked failure to [decarbonize] other sectors. In the last five years, this failure has become more acute, as emissions reductions in these sectors have stalled. Offshore wind deployment exemplifies how clear goals, an ambitious strategy and well-designed mechanisms, can encourage and enable the market to reduce cost and help to build wider economic co-benefits. These lessons should be applied more broadly - to meet the challenges [the authors] highlight in this report in transport, industry, buildings and agriculture. It is in the consumer interest to act early and avoid the need for more costly interventions later. There is also potential for economic advantage, in line with the Government's aim to develop industrial and commercial advantage from emissions reduction. [The UK] now [enters] a new decade of action to address climate change. So far, the governance framework under the Climate Change Act has worked to deliver overall UK emissions reduction, but a much tougher challenge is presented by the fourth and fifth carbon budgets. The formal request from the UK Government to provide advice on the implications of the Paris Agreement on the UK's long-term emissions targets, announced for later this year, will mark the next phase of the UK's climate leadership."

ABOUT DOE'S CARBON STORAGE PROGRAM

The **Carbon Storage Program** advances the development and validation of technologies that enable safe, cost-effective, permanent geologic storage of CO_2. The Carbon Storage Program also supports the development of best practices for CCS that will benefit projects implementing CCS at a commercial scale, such as those being performed under NETL's Clean Coal Power Initiative and Industrial Carbon Capture and Storage Programs. The technologies being developed and the small- and large-scale injection projects conducted through this program will be used to benefit the existing and future fleet of fossil fuel power-generating facilities by developing tools to increase our understanding of the behavior of CO_2 in the subsurface and identifying the geologic reservoirs appropriate for 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 are available via the *Carbon Storage Program Publications webpage*.

Get answers to your carbon capture and storage questions at NETL's *Frequently Asked Questions webpage*.

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.

National Energy Technology Laboratory

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